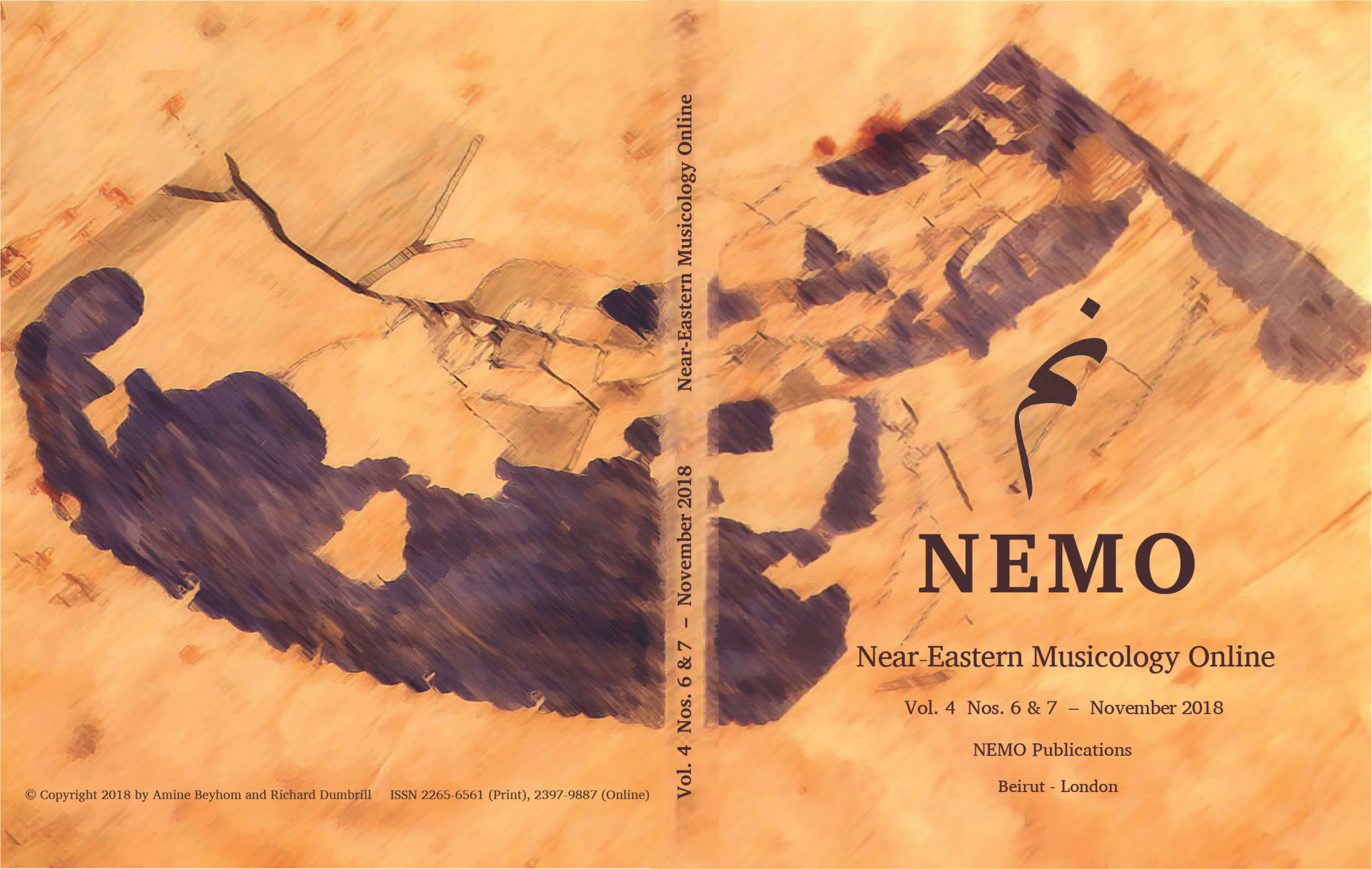


NEMO

Near-Eastern Musicology Online

Vol. 4 Nos. 6 & 7 – November 2018

NEMO Publications

Beirut - London

Vol. 4 Nos. 6 & 7 – November 2018 Near-Eastern Musicology Online

© Copyright 2018 by Amine Beyhom and Richard Dumbrill ISSN 2265-6561 (Print), 2397-9887 (Online)

NEMO

Near-Eastern Musicology Online

NEMO-Online (Near-Eastern Musicology Online, http://nemo-online.org/) is the brainchild of research groups ICONEA, in the UK, and CERMAA, in the Lebanon. These groups affiliated in 2011 and launched NEMO-Online. PLM in France, another research group (now integrated in IReMus), became an associate member of NEMO-Online in January 2012:

- ICONEA (*International Conference of Near-Eastern Archaeomusicology*) is a research group of The Institute of Musical Research, School of Advanced Study of the University of London, and specialises in Near and Middle-eastern archaeomusicology.

- CERMAA (*Centre de Recherche sur les Musiques Arabes et Apparentées*) is part of FOREDOFICO, the Foundation for Research, Documentation and Field Collection for Oriental and Arabian Traditional and Folk Music and Arts. Both promote Arts and Music in the Lebanon and are dedicated to researches on *maqām* music and modality.

- IreMus (*Institut de Recherche en Musicologie*, UMR 8223) is a research unit under the authority of the CNRS (Centre National de la Recherche Scientifique), of the université Paris-Sorbonne, the Bibliothèque nationale de France and the ministry of Culture of France: it integrates the previous PLM (*Patrimoines et Langages Musicaux*), a professional research group of musicologists, most of them being also musicians, working at Sorbonne University in the realm of history of music, ethnomusicology, music analysis and/or theory of music.

The Academic and Editorial Boards of NEMO-Online can be found at http://nemo-online.org/academic-board. For information about current, previous or forthcoming publications, please visit http://nemo-online.org/volumes or http://nemo-online.org/articles. Layout guidelines are given at http://nemo-online.org/guidelinesnormes.

© Copyright 2018 by Amine Beyhom and Richard Dumbrill

All rights reserved under International Copyright Conventions.
No part of this volume may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopy, recording, or any information storage and retrieval system, without prior permission in writing from the publisher, NEMO-Online Near Eastern Musicology Online.
All inquiries should be addressed to NEMO-Online, 10 Tadema Road, Chelsea, London SW10 0NU-UK.

Internet: www.nemo-online.org
Email: helpdesk@nemo-online.org

ISSN 2397-9887 (Online), ISSN 2265-6561 (Print)

EDITORS' LETTER

"In order to be a perfect theoretician, whatever the science, three conditions are required:
[1] To know thoroughly all of its principles.
[2] To possess the ability to deduce the necessary consequences of these principles
in the beings (elements) which belong to that science.
[3] To have the ability to answer to flawed theories
and analyse thruth from untruths and amend errors"

Abū-n-Naṣr Muḥammad ibn Muḥammad ibn Ṭarkhān ibn Uzlagh AL-FĀRĀBĪ |9th-10th centuries|,
The Great Book of Music

EVOLUTION, PROBLEMS AND ALTERNATE PROPOSITIONS FOR MUSICOLOGY AND ETHNOMUSICOLOGY[1]

It has become more and more difficult to study a field of science with polymathic abilities of philosophers such as (al-) Fārābī (Alfarabius) or (ibn) Sīnā (Avicenna). Musicology and ethnomusicology are two – related – such fields for which the ongoing specialisation makes it virtually impossible to embrace all their subdivisions. The second and third precept of Fārābī in the epigraph to this editorial are however still valid and apply to each and every field of science.

The call for papers of the 5th issue of NEMO-Online concerned itself with musicology and ethnomusicology and focused on their evolutions and problems. As explained in the editorial of Volume 3 of NEMO-Online, "*Orientalism* by Edward Said shook-up the Academic Establishment as it reconsidered the narrative conducted by scholars studying the 'Orient'. Orientalists, according to him, have created a phantasmagorical Orient, almost illusory and able to answer ostracizational needs for the colonialization of states towards colonized or dominated populations. Tumult and polemic raised by Said's book have not settled and are still ongoing to this day to the extent that Post-Colonial researches flourished, mainly in the United States, during the last decades of the twentieth century, with a constant anti-, counter- and para- and re-Orientalism as a contradictory analytical standard of Occidental-Oriental relations. Strangely enough, and while almost all human sciences have been influenced or contested because of the bouncing-back of Said's turmoil, the science of musicology continued, unaffected, on its course until today as if the particular, and very volatile, even arbitrary status of the art studied by this field was shielded from any questioning of its seminality".

[1] Notes : 1) The multilingualism in NEMO has led its editors into harmonizing English and French typographical conventions whenever possible. As a result the reader may be surprised at times by unusual typography, consequence of this harmonization. 2) Each submission to NEMO is assessed by at least two members of the editorial board. Some papers dealing with more complex themes would be submitted to external expertise. It remains that opinions produced in any form in the present volume is the responsibility of their authors as well as the quality of the language in which the contribution is submitted, this applying particularly to the English language.

The response to this immobilism of (ethno) musicology came with two resolutely critical articles by Bruno de Florence and Amine Beyhom. But it seemed to the Editorial Board that the subject was far from exhausted, while no real alternatives were proposed in this fifth issue. This is the main reason why the theme of issue No. 5 was pursued in issues Nos. 6 & 7, which are published in this fourth volume, while stressing on alternate formulations of musicology and ethnomusicology. While the first – preliminary – stage of an effective reconstruction is always a reasoned criticism of existing structures and of obvious errors in the studied field, and while musicologists are – still – supposed to make deductions based on previous or acquired knowledge of music or of its history, and correct possible errors in the formulations of their predecessors while knowing that, eventually, their own errors would be corrected by the future generations of scientists in the field, the vast domain of alternate formulations is a necessary second step. Both the sixth and seventh issues of NEMO-Online propose such alternatives.

NEMO-Online No.6

The first article of issue No. 5 is an expanded, updated and enriched reedition of **Amine Beyhom's** article "A Hypothesis for the Elaboration of Heptatonic Scales" previously published in the proceedings of ICONEA 2008. New research since its first publication presented complementary and sometimes clarifying facts which, with the evolution of terminology (see Beyhom's "Lexicon" in NEMO-Online Vol. 2 No. 2 – in French), made it indispensable to publish this new edition. In addition to the original tables and figures, the author has complemented his paper with significant appendices which help understand the complexity of scalar systemics. Moreover, Beyhom's proposition is an unchallenged – since 2003 – alternate proposition for the process of the formation of the heptatonic scale and competes effectively with previous propositions based on Pythagorean thought or on the science of acoustics.

Follows **Richard Dumbrill's** "The Truth about Babylonian Music" where this author systematically contradicts theories written about Babylonian music theory since the nineteen sixties where, either intentionally or by ignorance, Western musicologists have rejected all forms of Oriental structures from Oriental music and force-fitted Oriental pitch systems into the Western carceral dictate. Dumbrill finds there a continuation of Occicentricism which he opposes vehemently. His article is illustrated by a music score, a tonographic reproduction of the intonations compared to the score of Hurrian song H6 with a midi reproduction of the same song including intonations and a recording of the song by Lara Jokhadar, all three illustrations by Richard Dumbrill-Amine Beyhom-Rosy Azar Beyhom.

This number ends with **Bruno Deschênes'** "A preliminary approach to the analysis of *honkyoku*, the solo repertoire of the Japanese *shakuhachi*". The article is based on the absence of modes in part of the Japanese *honkyoku* repertoire, while composition is ruled mainly by the tone-color of the sounds (we do not dare write "pitches") played by the *shakuhashu* instrumentalist, at least in Traditional composition. It is certainly truly historically informative with its account of the absence of musicology until the end of the nineteenth century in imperial Japan. The corpus of the paper resides in his analysis of the Shakuhachi repertoire, with a theoretical background which is well-provided with the various scales and manner with which they are played on this instrument. Deschênes gives a thorough analysis of two *Honkyoku* pieces with Japanese score and annotated illustrations of some phrases of *Daiwa gaku* using the MELODYNE software and concludes with a critical comment of Uehara and Koizumi's "tetrachord" theory where he attests of Western influence and its inadequacy for the *honkyoku* repertoire.

NEMO-Online No. 7

This issue features one unique dossier by **Amine Beyhom** entitled "MAT for the VIAMAP – *Maqām* Analysis Tools for the Video-Animated Music Analysis Project". Beyhom stresses that musical notation has been reputed as disqualified for the analysis of "Foreign" musics since – at least – the experiments of Charles Seeger with the Melograph and that it is nevertheless still used as the main analytic – and teaching – tool for these musics in most researches in musicology, and today in the teaching of these musics in autochthonous conservatories. While Seeger's experiments brought at his time cutting-edge solutions – and alternatives – to score notation, surprisingly enough these solutions seem to have not worked out very well in the long run.

The dossier includes three parts and relies on the pioneering works of Seeger – and other ethnomusicologists – as well as on the improvements of his method that we have witnessed in the last decades. The first part expounds the past, and on-going debates about the (mis-) use of score notation as applied to "Foreign" musics, while the second part offers a retrospective of *maqām* music notation. The third part of the dossier describes different tools of pitch and spectrum analysis which help understand – and listen better to the analyzed music while exposing, in fine, the author's work and propositions for the implementation of video-animated analyses in the teaching of ethnomusicology as one major basis for this teaching. The dossier is accompanied by a short power point show (PPS) and 41 video-animated analyses (total time = 2 h 13 m).

***

Beyond problems raised within the articles in NEMO-Online Nos. 5 to 7 was a fundamental question. Is music art or science? While issue No. 5 raised the premise of a musicological and ethnomusicological scientification, the debate continued, and some alternatives were formulated in the following, 6 & 7 issues. We hope that future issues will bring more alternate formulations for what seems to us today to be a domain of the sciences with multiple and outdated fundamental issues.

ÉDITORIAL

« Pour être un parfait théoricien, quelle que soit la science dont il s'agit ; il faut trois conditions :
[1]En bien connaître tous les principes.
[2] Avoir la faculté de déduire les conséquences nécessaires de ces principes dans les êtres (les données) qui appartiennent à cette science.
[3] Savoir répondre aux théories erronées, et analyser le vrai du faux et redresser les erreurs »

Abū-n-Naṣr Muḥammad ibn Muḥammad ibn Ṭarkhān ibn Uzlagh AL-FĀRĀBĪ *|IXe-Xe siècles|*,
Le Grand Livre de la Musique

ÉVOLUTION, PROBLÈMES ET PROPOSITIONS ALTERNATIVES POUR LA MUSICOLOGIE ET L'ETHNOMUSICOLOGIE

Il est de plus en plus difficile d'étudier un domaine des sciences et d'en maîtriser tous les aspects comme pouvaient le faire des philosophes comme (al-) Fārābī (Alfarabius) ou (ibn) Sīnā (Avicenna). La musicologie et l'ethnomusicologie sont deux domaines apparentés dont les subdivisions et les spécialisations augmentent continuellement, rendant virtuellement impossible une approche exhaustive. Les deux derniers préceptes de Fārābī dans l'épigraphe de cet éditorial sont néanmoins toujours d'actualité et s'appliquent à tous les domaines de la science.

L'appel à contributions du nº 5 de NEMO-Online concernait la musicologie et l'ethnomusicologie, se concentrant sur les problèmes minant les deux disciplines. L'éditorial du Volume 3 (nos 4&5) de NEMO-Online rappelait déjà qu'à « la fin des années 1970, un livre d'Edward Said avait secoué l'establishment académique, remettant en cause le discours orientaliste véhiculé par les chercheurs occidentaux qui, selon lui, ont créé un Orient fantasmatique et quasi-imaginaire, à même de répondre aux besoins d'ostracisation par les nations colonisatrices du XIXe et XXe siècles des populations colonisées ou dominées. Les remous et polémiques causés par le livre de Said, loin de s'être calmés, sont toujours d'actualité de nos jours, au point que des recherches 'postcoloniales' ont pris leur essor – notamment aux États-Unis – dans les deux dernières décennies du XXe siècle, dans un processus constant d'anti-orientalisme/contre-orientalisme/para-orientalisme/ré-orientalisme devenu une norme de l'analyse contradictoire, de nos jours, des relations Occident-Orient.

Très étrangement, et alors que toutes les disciplines des sciences humaines (ou presque) ont été affectées ou remises en cause par les retombées du séisme *saidien*, la 'science' musicologique a continué, imperturbable, sur sa lancée jusqu'à nos jours, comme si le statut particulier, et particulièrement volatile – ou même arbitraire – de l'art étudié par cette discipline la mettait à l'abri de tout questionnement, de toute remise en cause de ses fondements ».

La réponse à l'immobilisme de la musicologie (et de l'ethnomusicologie) est venue avec deux articles résolument critiques par Bruno de Florence et Amine Beyhom. Mais le sujet, aux yeux de la rédaction, était loin d'être épuisé et aucune réelle alternative ne fut proposée dans ce numéro 5. Ceci est la raison principale pour laquelle l'appel à contributions fut reconduit pour les deux numéros suivants de la revue – publiés dans le présent Volume 4 – augmenté, cependant, d'un appel à des formulations alternatives de pans de ces disciplines, sinon de leur totalité.

Si la première phase d'une reconstruction réussie est une critique raisonnée et argumentée de l'existant. Les musicologues sont toujours supposés – de nos jours – arriver à leurs déductions en se basant sur leurs connaissances préalables du domaine étudié et de son histoire, et supposés corriger les erreurs de leurs prédécesseurs, si elles existent – sachant, néanmoins, que leurs propres déductions seront peutêre un jour remises en cause par les générations futures de musicologues. Une deuxième phase indispensable d'une reconstruction de la musicologie et de l'ethnomusicologie devrait logiquement être constituée de formulations alternatives. Les deux numéros 6 & 7 proposent de telles alternatives.

NEMO-Online n° 6

Le premier article de ce numéro est une version revisée et augmentée de l'article d'**Amine Beyhom** "A Hypothesis for the Elaboration of Heptatonic Scales" précédemment publié dans les actes du colloque ICONEA 2008. Des recherches complémentaires depuis sa première publication et l'évolution de la terminologie (voir le « Lexique » de Beyhom dans le numéro 2) ont rendu indispensable cette réédition que l'auteur accompagne d'appendices supplémentaires destinés à clarifier certains aspects de son « Hypothèse » heptatonique. Notons ici que cette hypothèse n'a pas été contestée depuis sa première formulation en 2003 et soutient efficacement la comparaison avec les théories pythagoriciennes de l'échelle ou celles basée sur la résonance acoustique.

L'article de **Richard Dumbrill** qui suit s'intitule "The Truth about Babylonian Music". L'auteur y critique systématiquement les théories publiées depuis les années 1960 sur la théorie musicale babylonienne dans lesquelles – que ce soit un processus conscient ou le résultat d'une méconnaissance du sujet – les musicologues occidentaux ont rejeté toute forme de structures musicales des musiques de l'Orient et inséré de force des systèmes musicaux de hauteurs dans un carcan occidental. Dumbrill attribue ce genre de position à une continuation de l'occicentrisme auquel il s'oppose véhémentement. L'article est illustré par une partition ainsi que par une reproduction d'un tonogramme des intonations – comparées à la notation – du chant hourrite H6, et accompagné d'une reproduction midi du même incluant les intonations ainsi que par une interprétation par la chanteuse Lora Jokhadar, résultant tous les trois de la collaboration de l'auteur avec Amine et Rosy Beyhom.

Le n° 6 se conclut par l'article de **Bruno Deschênes** "A preliminary approach to the analysis of *honkyoku*, the solo repertoire of the Japanese *shakuhachi*" qui met en relief l'absence de modalité dans une partie du répertoire *honkyoku* du *shakuhashi* et la prééminence des variations des timbres des sons émis pour la composition – traditionnelle – dans ce répertoire. L'auteur nous informe notamment de l'absence de musicologie en tant que telle au Japon impérial jusqu'à la fin du XIXe siècle, pour analyser ensuite – et principalement – le répertoire Shakuhashi avec en arrière-plan une base théorique reproduisant les diverses échelles et les manières de les jouer sur l'instrument. L'auteur analyse également dans le détail deux pièces du répertoire *honkyoku* tout en proposant des partitions japonaises et des extraits ainsi que des analyses avec le programme MELODYNE pour chacune d'entre elles, et critique en conclusion les approches « tétracordales » de Uehara et Koizumi, qu'ils considère être influencées par l'Occident – sinon inadéquates quant à leur application à ce répertoire.

NEMO-Online n° 7

Un seul dossier pour ce numéro, par **Amine Beyhom** sous le titre “MAT for the VIAMAP – *Maqām* Analysis Tools for the Video-Animated Music Analysis Project”. Beyhom rappelle les premières expériences de Seeger avec le mélographe et s’étonne que la notation occidentale n’ait pas été disqualifiée depuis pour les musiques “autres”. Plus encore, cette notation et ses avatars (notation numérique basée sur l’échelle ditonique par exemple) est toujours utilisée comme principal outil analytique – et d’enseignement – pour ces musiques dans la plupart des recherches actuelles.

Le dossier est composé de trois parties principales dont la première est une discussion de la pertinence de la notation occidentale appliquée – notamment – à la musique du *maqām* tandis que la deuxième partie est une revue des différentes notations historiques de cette dernière. La troisième partie décrit rapidement les outils numériques actuellement disponibles pour l’analyse du son et des lignes mélodiques tout en exposant, en conclusion, les développements de la méthode de Seeger dont nous avons été témoins dans les dernières décennies ainsi que les améliorations apportées par l’auteur aux plus récentes réalisations en vidéo-analyse de la mélodie.

L’auteur conclut par un plaidoyer pour l’intégration de ces outils dans l’enseignement de base de l’ethnomusicologie, et accompagne son dossier d’un exposé power point ainsi que de 41 vidéo-analyses totalisant 2 heures et 13 minutes.

***

Au-delà des problèmes soulevés dans les numéros 5 à 7 de NEMO-Online, une question fondamentale a été posée: la musique est-elle une science, ou est-elle un art ? Les articles du n° 5 ont posé les prémisses d’une scientification de la musicologie et de l’ethnomusicologie, tandis que les deux numéros 6 et 7 ont proposé certaines formulations alternatives d’aspects de ces « sciences ». Les éditeurs avaient déjà souligné, en 2016, l’utilité d’un débat autour de ces questions fondamentales : il faut espérer que ce débat continuera avec de nouvelles propositions alternatives pour ce qui nous apparaît aujourd’hui comme un domaine de la science de la science comportant plusieurs aspects fondamentaux périmés.

كلمة الناشرين

ولمّا كان كمال الإنسان في كلّ صناعة نظريّة أن تحصُلَ له فيها أحوال ثلاث: أولاها، استيفاء معرفة أصولها، والثانية، القوّةُ على استنباط ما يلزم عن تلك الأصول من موجودات تلك الصناعة، والثالثة، القوّة على تلقّي المُغالطات الواردة عليه في ذلك العلم وعلى سِبارِ آراء مَن سواه من الناظرين فيه وتكشيف الصّواب من سوء أقاويلهم فيها وإصلاح الخلل على من اختلّ رأيُه منهم

أبو النصر محمد إبن محمد إبن طرخان إبن أزلغ الفارابي – كتاب الموسيقى الكبير

التطوّر، المشاكل والحلول البديلة لعلم الموسيقى (موسيقولوجيا) وعلم الموسيقى الإثنية (الإتنوموسيقولوجيا)

أصبح من الصعب دراسة العلوم مع السيطرة على جميع جوانبها كما كان الفلاسفة القدماء مثل الفارابي أو إبن سينا يفعلون. الموسيقولوجيا والاتنوموسيقولوجيا علمان موصولان والاختصاص بهما هو شبه مستحيل بسبب استحالة استيعاب جميع تقسيماتهما. مع ذلك، يبقى الإرشاد الثاني والثالث من اقتباس الفارابي أعلاه قائمًا ومنطبقًا في كلّ أنواع العلوم حتّى في أيامنا هذه.

تركّزت الدعوة للعدد الخامس من نيمو-أونلاين (NEMO-Online) على معالجة مشاكل وتطوّر الموسيقولوجيا وعلم الاتنوموسيقولوجيا. كنّا قد شرحنا في تقدمة العدد 3 أنّه "في نهاية العام 1970 صدر كتاب لإدوار سعيد هزّ المؤسسات الأكاديمية عبر تساؤله عن الخطاب الاستشراقي الذي يُسيّرُهُ الباحثون الغربيون. فالبنسبة لهذا الأخير، نشأ شرق خيالي عن هذا الخطاب، يستجيب لحاجات النبذ الذي نفذته الدول المُنتدِبة على الشعوب المُتسعمَرة. لم يهدأ الهيجان إثر هذا الكتب والمشاكل التي عرضها ما زالت حديثة في أيامنا هذه لدرجة أنها دفعت الباحثين في العقدين الأخيرين من القرن العشرين بالقيام بأبحاث "ما بعد الاستعمار" (Post-colonial studies) – خاصّة في الولايات المتحدة – هدفها صدّ أشكال الاستشراق من استشراق معاكس ومُضاد وشبه الاستشراق وإعادة الاستشراق لكنّ هذه المبارزة تحوّلت إلى تحليل متناقض للعلاقة بين الغرب والشرق".

أتى الجواب على جمود الموسيقولوجيا والاتنوموسيقولوجيا في مقالتين نقديّتين، الأولى كتبها برونو دي فلورانس (Bruno de Florence) والثانية أمين بيهم (Amine Beyhom) إنّما يبدو للناشرين أنّ الموضوع ما زال بعيدًا عن الاستنفاد خاصّة أنّه لم تُقَدّم أيّة حلول بديلة في هذا العدد الخامس. هذا الأمر دفعنا إلى متابعة معالجة الموضوع نفسه في العددين 6 و7 المنشورين في هذا المجلّد الرابع الذي دعا

بشـدّة إلى تقديم المقاربات البديلة لبعض نواحي علم الموسـيقولوجيا والاتنوموسـيقولوجيا. كانت المرحلة الأولى من هذه العمليّة قد اقتصـرت على نقد بنّاء للأسـاسـات الموجودة وإشـارة واضـحة إلى الأخطاء الحالية في الميدان المدروس. من المُفترض أنّ علماء الموسيقولوجيا يصلون إلى استنتاجاتهم إنطلاقً من معطيات مبنيّة على معرفة مُكتسبة حول الموسيقى وتاريخها، كما يضبطون أخطاء يلاحظونها في كتابات من سـبقهم وهم على يقين أنّ أخطائهم سـتُصـحَّح من قبل الأجيال القادمة؛ لذلك ارتأينا أنّ المرحلة الثانية يجب أن تكون حول المقاربات البديلة. يحمل العددين 6 و7 خيارات من هذا النوع.

نيمو-أونلاين عدد 6

المقالة الأولى من العدد الخامس هي طبعة مُحدّثة، ومزيدة لمقال **أمين بيهم** (Amine Beyhom) : "نظرية حول تشكيل السلم السباعي" المنشور سابقًا ضمن محاضر إيكونيا ICONEA 2008. ساهمت الأبحاث الجديدة منذ النشـر الاوّل للمقال في تقديم وتوضـيح أمور عدّة – بالإضـافة إلى التطوّر في مجال المصـطلحات (أنظر مقال بيهم "المصـطلحات" في نيمو-أونلاين المجلّد 2 العدد 2 باللغة الفرنسية) – إلى لزوم إصـدار هذه النسـخة الجديدة. ذيّل المؤلف مقاله بملحقات غزيرة تسـاهم في فهم التركيب النظامي المعقدّ للسلالم وذلك بالإضافة إلى الجداول والصور الأساسية. يجدر التذكير أنّ نظرية أمين بيهم ما زالت غير مُنازَعة منذ 2003 وهي تمثّل اقتراح بديل لتكوين السـلم السـباعي كما وتنافس بجدارة الاقتراحات السابقة القائمة على الفكر البيثاغوري أو على علم الأكوستياء.

أمّا المقال الثاني فهو لـــــــــ**ـريشارد دمبريل** (Richard Dumbrill) وعنوانه "الحقيقة حول الموسيقى البابلية" حيث يقوم المؤلف بمعارضـة نظامية للنظريات حول الموسـيقى البابلية منذ السـتينات من القرن التاسـع عشـر، عندما قام علماء الموسـيقولوجيا الغربيون – عن قصـد أو جهل – برفض جميع أشـكال التركيبات الموسيقية الشـرقية بينما لجؤوا إلى قولبة الأبعاد الشـرقية في نظام موسـيقي غربي جامد. رأى دمبريل في هذا الواقع تتابع لمشـكلة التمركز الغربي التي يعارضـها بشـدّة. يتضـمّن هذا المقال تنويط موسيقي، تمثيل تونوغرافي للأبعاد يقارِن مع التنويط الموسيقي للأغنية Hurrian Song H6 كما يحوي تمثيل من نمط ميدي Midi للأغنية فيه النغمات بالإضـافة إلى تسجيل للأغنية بصوت لارا جوخادار. إن التصويرات الثلاث هي من عمل ريشارد دمبريل – أمين بيهم – روزي عازار بيهم.

يختم **برونو ديشـان** (Bruno Deschênes) هذا العدد بمقـالتـه "مقـاربـة أوليّـة لتحليـل *الهونكيوكو* honkyoku، المخزون المنفرد لآلة *الشـاكوهاشـي* shakuhachi اليابانية". يشـرح هذا المقال مسـألة غياب المقامية عن جزء من مخزون *الهونكيوكو* الياباني حيث تكون المؤلفات تحت هيمنة نبرة الأصوات (لا نجرؤ على كتابة "الدرجات") التي تنتج من عزف *الشـاكوهاشـي*، أقلّه في المؤلفات التقليدية. يُعلِمنا المؤلف أن علم الموسيقولوجيا كان غائبًا تمامًا حتى نهاية القرن التاسع عشر عن إمبراطورية اليابان. يجد القارئ في خضم هذا المقال تحليل للأسس النظرية لمخزون *الشاكوهاشي* حيث يعرض المؤلف بوضوح السـلالم المختلفة والطرائق المتعددة لتأديتها على الآلـة. ثمّ يتعمّق ديشـان في تحليل مقطوعتين من *الهونكيوكو* المكتوبتين بحسـب التقليد الياباني ويسـتخدم تنويط برنامج ميلودين MELODYNE، ويعلّق

على المقطوعات المُحلّلة. أخيرًا ينهي مقاله بملاحظة نقدية حول نظرية "الفاصل الرباعي" (tetrachord) التي يروّج لها أويهارا Uehara وكويزومي Koizumi إذ يبدو جليًا للمؤلف هنا أثر الغرب وعدم تناسبه مع مخزون الهونكيوكو.

نيمو-أونلاين عدد 7

يحمل هذا العدد ملفّ واحد لـــــ**أمين بيهم** (Amine Beyhom) عنوانه "أدوات تحليل المقام من أجل مشروع تحليل الموسيقى المتحرّكة بالفيديو" (MAT for the VIAMAP). تشدّد هذه الدراسة على أنّ التنويط الموسيقي نال حصّته من عدم ملائمته لتحليل الموسيقات "الأخرى" خاصّة أنّ تجارب شارل سيجر (Charles Seeger) بواسطة الميلوغراف قدّمت خيارات جديدة. هذا الأمر لم يمنع من بقاء التنويط وسيلة أساسية لتحليل وتعليم هذه الموسيقات في أكثرية الأبحاث في إطار الموسيقولوجيا ولم يمنع وجود التنويط لتدريس هذه الموسيقات في المعاهد في بلادها.

يحتوي هذا الملفّ على ثلاثة فصول ويعتمد على الأعمال الرائدة لسيجر – وغيره من علماء الاتنوموسيقولوجيا – كما يعتمد على تحسينات طرأت على أساليب سيجر كالتي شهدناها في العقود الأخيرة. يتوسّع الفصل الأول في مناقشة حول سوء استخدام التنويط كما هو مطبّق الآن على الموسيقات "الأخرى" وبخاصة موسيقى المقام. أمّا الفصل الثاني فيعرض استعمالات التنويط لموسيقى المقام عبر التاريخ. يقدّم الفصل الثالث أدوات رقميّة مختلفة لقياس الدرجات ولتحليل الطيف الموسيقي، ممّا يساهم في فهم واستماع أفضل للموسيقى قيد التحليل. في نهاية هذا الملفّ يقترح المؤلف تطبيق أداة التحليل الموسيقي بواسطة الفيديو في التعليم الأساسي للاتنوموسيقولوجيا. هذا الملفّ مُلحق بعرض بوير بوينت (Power Point) وبـ41 فيديو لتحليلات موسيقية (مجموع وقت الفيديو: 2 ساعة و13 دقيقة).

***

يبقى سؤال أساسي مطروح في نطاق أبعد من الإشكاليات المتباحث بها في مقالات نيمو-أونلاين العدد 5 إلى7. هل الموسيقى فنّ أم علم؟ طرح العدد الخامس فرضية علميّة للموسيقولوجيا والاتنوموسيقولوجيا ولكن الجدال تتابع وبعض البدائل طُرحت في الأعداد رقم 6 و7. نأمل أن تحمل الأعداد القادمة المزيد من الطروحات والبدائل للمسائل الأساسية التي تحتاج إلى تجديد بالكامل في هذه العلوم الموسيقية.

NEMO

Near-Eastern Musicology Online

NEMO-Online Vol. 4 Nos. 6 & 7 – November 2017-November 2018

Contents / Sommaire / ملخّص

A Hypothesis for the Elaboration of Heptatonic Scales

Amine Beyhom[*]

”ولم يستعمل الذي بالكل مرتين مفعولاً إلى أكثر من أربعة عشر بعدًا، والذي بالكل مفعولاً إلى أكثر من سبعة أبعاد، والذي بالخمسة إلى أكثر من أربعة أبعاد تحيط بها خمس نغم، والذي بالأربعة إلى أكثر من ثلاثة أبعاد تحيط بها أربع نغم، والطنيني أكثر من بعدين. وإنما دعا إلى ذلك حسن اختيار لا ضرورة [...]“

"The double octave will not comprise, in practice, more than fourteen intervals; the octave, more than seven; the fifth, more than four intervals and five degrees; the fourth, more than three intervals and four notes; the tone, more than two intervals. It is experience and not the theoretical need which dictates it [...]"

[Ibn Sīnā (Avicenna) – *Kitāb-a-sh-Shifā'*][1]

Foreword[2]

As I pinpointed in 2003,[3] the reason for having eight notes in one octave is an arbitrary concept. There are diverging explanations of this common fact but none is satisfactory. This article gives an alternative explanation of this phenomenon. It is divided in two main parts:

- Part I, entitled "Differentiation, combination, selection and classification of intervals in scale systems: basic Modal systematics", offers another view based on the theory of Modal Systematics, where basic principles are explained together with interval classification in the scale.
- Part II, entitled "Combining intervals in a system: Statistical analysis", is a statistical analysis on the

[*] Amine Beyhom is currently the editor in chief of NEMO-Online and director of the CERMAA (Centre de Recherches sur les Musiques Arabes et Apparentées), a research center affiliated to the FOREDOFICO foundation in Lebanon – he was at the time of the reading of the original paper (2008), and until the publication of the first version of this article (in 2010) an independent researcher associated to the PLM Research group at the University of Sorbonne – Paris IV.

[1] End of 10th, early 11th centuries AD; in Arabic [Sīnā (Ibn) ou Avicenne (0980?-1037), 1956], p. 40-44; and in French [Fārābī (al-) et al., 1935], p. 138.

[2] This article is an emendated, updated and enriched version of the paper entitled "A new Hypothesis for the Elaboration of Heptatonic Scales and their Origins" [Beyhom, 2010a] published in the proceedings of the ICONEA 2008 Conference. New research since its first publication presented complementary and sometimes clarifying facts (some of them exposed in the authors publications [Beyhom, 2012 ; Beyhom, 2014]) which, with the evolution of terminology (see [Beyhom, 2013] – in French), makes it indispensable to publish this new edition. Most of the tables and figures have been reintegrated in the body text, and a dedicated appendix (Appendix G) has been added concerning Octavial scales with limited transposition. To comply with NEMO-Online publishing policy, and as with all articles of the review since Volume 3, the pdf version includes bookmarks corresponding to the titles, sub-titles, tables and figures, which should help the reader navigate between the different parts of the article; additionally, one Power Point show illustrating (mainly) Appendix G with audio examples, is proposed as a complement at http://nemo-online.org/articles. A few complementary remarks: the 'hypothesis' is no longer new, and has never been challenged, to my knowledge, since its first publication in the Ph.D. thesis *Systématique modale* at the University of Sorbonne – Paris IV in 2003. It is published in this version as a complement to the dossier on Orientalism and Hellenism [Beyhom, 2016] and to the "Lexicon of modality" [Beyhom, 2013]. A copy of the original thesis [Beyhom, 2003c] can be obtained from http://www.diffusiontheses.fr/ (id.: 03PA040073; Réf ANRT : 41905) in printed form (B&W), and the emendated full version, together with most of my other musicological writings, are now downloadable free of charge at http://foredofico.org/CERMAA/publications/publications-on-the-site/publications-amine-beyhom as well as at https://hal.archives-ouvertes.fr. Finally: my heartfelt thanks go to Richard Dumbrill who invited me to participate in ICONEA 2008 (and who has read the article at my place, as various constraints prevented my attendance), translated the first version from the original French, then helped emendate the English text for the present version. This was even more welcomed as the original article (in French) was proposed beginning 2004 to musicological French speaking reviews, which did not accept it for publication.

[3] In my thesis [Beyhom, 2003c].

combination of intervals within the span of the just fourth, the fifth and the octave. It explores the systematic combination of intervals in scale elements,[4] and their filtering according to criteria inspired from traditional musics.

- The Synthesis that follows allows for the hypotheses on the formation of scale elements from the fourth to the octave and the elaboration of the heptatonic scale, and proposes clues in the search for the origins of heptatonism.

It is followed by a series of appendices:[5]

- Appendix A: "Scale elements in eights of the tone, within the containing interval of the fourth (=20 eights of the tone)",
- Appendix B: "Tables of the combination process for a just fifth",
- Appendix C: "Complete results of the semi-tone generation within a Containing interval of fifth",
- Appendix D: "Hyper-systems of the semi-tone octave complete alphabet generation",
- Appendix E: "Additional graphs for octave generations, with the extended alphabet",
- Appendix F: "Synoptic results for the quarter-tone generation",
- Appendix G: "Octavial scales with limited transposition".
- Appendix H: "Permutation processes for the combination of intervals".
- Appendix L:[6] "Core glossary".

Whenever Parts I and II are based on a learning process and explanations going from the simpler to the more complex (semi-tone generation to quarter-tone generations,[7] in the frame of the fourth, then the fifth and octave containing intervals), understanding the Synthesis, while based on the results of the analysis, requires no special insight in mathematics or statistical knowledge.

Prefatory remarks

The reasons given as to why the modern scale is made up of eight notes are unconvincing. Some suggest numerical relationships and their properties and others acoustic resonance.[8] There are also propositions stating the obvious: it is as it is because it cannot be different.

The first reason is based on the properties of numbers. It offers two alternatives, firstly the magical properties of numbers, and secondly the ratios between them. The first alternative is dismissed because it does not relate to musical perception.[9] Since Greek Antiquity, the second alternative has been the source of an ongoing dispute between the Pythagorean and the Aristoxenian schools.

The tetrad which was used by the Pythagoreans and their European followers provides the ratios of the predominant notes of the scale, as the Greeks perceived them.[10] However, it does not give any clues, and no other theory does, as to why the cycle of fifths, based on ratio 2:3, should end after its seventh recurrence.[11]

Later developments led to scales with twelve intervals, as in the modern European model, and seventeen with the Arabian,[12] Persian and Turkish paradigms.

[4] Be they included in a fourth, fifth or octave Containing interval: a Containing interval (see Part I for the complete definition) is one of the Acoustical structuring intervals in the scale (the Fourth, the Fifth and the Octave), with no melodic role.

[5] Former Appendix G in the 2010 version (complete database – quarter-tone model with reduced alphabet of intervals – now Appendix I), and new appendices J (generation of systems with the extended alphabet from 2 to 24 quarter-tones – raw results from the program Modes V. 5) and K (17[ths] of the octave full alphabet heptatonic generations of systems) are too voluminous to be included in the printed version: these can be downloaded from http://nemo-online.org/articles.

[6] See previous footnote.

[7] With one incursion in the eights of the tone model.

[8] These theories are explored at length, and refuted, in [Beyhom, 2016], Chapter III.

[9] Numbers 3, 4, 5, and 7, may play a role in the outcome of interval combinations, as shown in Part II of this article.

[10] [Crocker, 1963] and [Crocker, 1964]. The ratios 1:2 and 2:4 give the octave; the ratio 1:4, the double octave; 1:3 the octave + the fifth; 2:3, the fifth and 3:4, the fourth. These intervals were the principle consonant intervals in Pythagorean and Aristoxenian theories. In order of their consonant quality, first comes the octave, then the fifth and lastly, the fourth – more detailed explanations are available in Chapter III of [Beyhom, 2016].

[11] Or twelfth, or more: see Chapter III in [Beyhom, 2016] for more details.

[12] I use the terms "Arabian music" as a generic concept applying to *maqām* practice, although Farmer, in his "Greek theorists of Music in Arabic Translation" [1930], writes that the use of "Arab" is well attested, notably in note 1, p. 325: "I use the term 'Arab' advisedly, just as I would use the word 'English', at the same time implying the Scots, Irish, & Welsh. 'Islamic' or 'Muslim' will not serve, because Magians, Jews & Christians, contributed to this 'Arabian culture'." We shall include in this wide definition Turkish and Persian music, as well as other *maqām* music with, mainly, heptatonic scales and "neutral" (this term is defined below) intervals used in the latter.

There are no reasons either for the fourth[13] to be made up of three, or for the fifth to be made up of four intervals.

Then the Aristoxenian school raised a point of particular importance when it pointed out that the practice of performance and the perception of intervals are the keys to theory.[14]

The Pythagorean construction of intervals, which in part is based on superparticular intervals,[15] misled many theoreticians[16] into believing that acoustic resonance might explain the construction of the scale, on the basis of its similarities with it. However, this is inconsistent with the predominance of the fourth in Greek theory and, for example, in Arabian theory and practice today. Acoustic resonance shows that the fourth is not the consequence of a direct process.[17]

There are strong arguments in favor of the consonance with the just fourth.[18] However, acoustic resonance fails in that neither can it generate modal scales,[19] nor can it give satisfactory answers as to the number of eight pitches in the octave, or four in a fourth.[20]

Part I. Differentiation, combination, selection and classification of intervals in scale systems: basic Modal systematics

The study of interval combination within a fourth or a fifth would have entertained scholars since music and mathematics were found to suit each other. Aristoxenos had limited combination techniques for his understanding of what is commonly named *genera*,[21] but should be

[13] Additionally, the (Neo-)Pythagorean cycle of fifths does not generate a fourth. The scale is the consequence of an ascending cycle of fifths, bringing notes placed above the first octave back into it, hence F G A B c d e. The fourth, ascending from starting F, is F-B which is a Pythagorean tritone; see also Chapter III in [Beyhom, 2016].

[14] [Aristoxenos and Macran, 1902], p. 193-198, notably (p. 193-194): "For the apprehension of music depends on these two faculties, sense-perception and memory"; or p. 197: "That no instrument is self-tuned, and that the harmonizing of it is the prerogative of the sense perception is obvious."

[15] Intervals with string/frequency ratios of the type $(n+1)/n$ when n is a positive integer.

[16] See [Chailley, 1959] and [Chailley, 1985], p. 64-65.

[17] Acoustic resonance is not a generative process as such, but it is the consequence of the physical (and dimensional) properties of matter set to vibration. The integration of acoustic resonance within a generative theory is subjective as it admits that vertical relationships cannot be unidirectional, *i.e.*, ascending; for the particular case of the fourth, a computer program has been used to test this hypothesis, up to the 1500th harmonic, and gave no exact matches for the just fourth. A first approximation is found at the 341st harmonic, with about 496 cents, then 499 cents with the 683rd harmonic. The closest is the 1365th harmonic with 498 cents. The calculations were based on the formula: $i = 1200\times\ln(R)/\ln(2)$, where 'i' is the interval in cents, 'R' the ratio of frequencies (the ratios of frequencies are 341, 683 and 1365, respectively), and then extracting modulo of (i/1200). In analytical terms, the problem consists in finding an integer J, which multiplies N, the frequency of the fundamental tone, and the ratio of which, to the nearest and lower octave (octaves of the sound with frequency N have the form $2^k\times N$, where k is an integer number) is equal to 4:3, or $[(J\times N)/(2^k\times N) = (4/3)]$ (k is the power indicator of 2, with 2^k x N being simply an even multiple of N), which is not possible because in this case $[J=(2^k\times 4)/3]$, and neither 4 nor a power of 2 (2^k) can divide 3 – more about the Acoustic resonance theory in [Beyhom, 2016].

[18] [Helmholtz, 1895], p. 192-194 (figs 60A and 60B, p. 193). The consonance of the fourth is explained in that two simultaneous notes at a fourth apart have some theoretical harmonics in common, as for example for two notes at (1) 300Hz and (2) at 400Hz, which have common harmonics with frequencies equal to 1200, 2400, 3600Hz (etc.), *i.e.*, for every common multiple of 300 and 400 – more in [Beyhom, 2016].

[19] In [Beyhom, 2016], Chapter III, I explain how the only conceivable (melodic) scale in the Acoustic resonance theory is the zalzalian (*i.e.* of the *maqāmic* type – see footnote no. 44) Ptolemaic suite 8:9:10:11:12 which results in the "equal diatonic" pentachord (expanded from the corresponding tetrachord with ratios 9:10:11:12). See also next footnote.

[20] In order to assemble a very approximate octave made up of the degrees of the ditonic (for "containing two tones in a Just Fourth", *i.e.* the so-called "diatonic" – in fact "tense diatonic" as reminded in [Beyhom, 2016]) scale in Western theories of the scale, various resonance theories (mostly notations) generally end up at the fifteenth harmonic (sometimes the sixteenth), which is a '*b*' if the fundamental is '*c*' or, '*e*' if the fundamental is an '*f*'. This is an arbitrary proposition since no reason is given for having chosen the fifteenth harmonic as a last pitch while this would require extraordinary hearing powers, since this fifteenth harmonic placed right below the fourth octave has generally little intensity. Therefore preceding pitches from the 7th, 11th and 14th harmonics, theoretically, should be heard much louder than the 15th harmonic.

[21] This process is plainly explained in [Barbera, 1984], especially p. 231-232: "Aristoxenos has described the enharmonic *genus* in such a way that there can exist only three species of fourth. This is so because he has allowed only two different intervals, the enharmonic diesis or quarter-tone and the ditone, to enter his discussion. Thus, we can arrange two quarter-tones and one ditone in at most three different ways. Had Aristoxenos considered a chromatic *genus* containing three different intervals, for example, 1/3 tone, 2/3 tone, and 1 ½ tones, what would have been the result? Later writers make clear that the six possible arrangements of these three intervals were not all possible musically. In fact, only the first, second, and third species were musical possibilities, *i.e.*, those species that are arrived at by making the highest interval the lowest or vice

considered as plain tetrachords as very few indications on Music practice exist in Ancient Greek manuscripts.[22] (Al-) Fārābī[23] saw them as systematic combinations.[24]

The combination of intervals must obey rules. Thus heptatonism is made up of a small number of consecutive intervals which we shall call conceptual. They are placed in larger containing[25] intervals, such as the fourth, the fifth or the octave. Aristoxenos used the quarter-tone as the smallest interval in his scales and tetrachords. With Cleonidēs the twelfth of the tone was a common denominator for all intervals.[26] Fārābī divided the octave in 144 equal parts.[27] This is twice the amount as in Cleonidēs. This shows that Fārābī was influenced by the Harmonists, as Aristoxenos had them labeled. These scholars were focused on tonometry and generally used a small common denominator for a maximum of accuracy in their quantification[28] of intervals.[29] However, the Aristoxenian school[30] favored the largest possible common denominator, *i.e.,* an interval which can also be used as a conceptual interval (a second among intervals building up to larger containing intervals such as the fourth, the fifth or the octave).

Let us take a tetrachord[31] with a semi-tone or a quarter-tone as largest common denominator, within a fourth. To find out how many semi-tones make up a fourth, add semi-tones, one after the other until the fourth is filled up (Table 1). These intervals make a form of alphabet the letters of which being multiples of semi-tones.

$1 = 1$ semi-tone

$1 + 1 = 2$ semi-tones, or one tone

$1 + 1 + 1 = 3$ semi-tones, or one-and-a-half-tones

$1 + 1 + 1 + 1 = 4$ semi-tones or a ditone

$1 + 1 + 1 + 1 + 1 = 5$ semi-tones or the approximate fourth

Table 1 Interval alphabet in an approximate fourth (in semi-tones).

In Table 1, the intervals labeled 1, 2, etc., are integers. They are multiples of the largest common denominator which is the semi-tone. If we place three intervals in a fourth, other intervals may not fit in any longer.

For example, if we place two of the smallest semi-tone intervals, the largest interval to fill up the fourth is one-tone-and-a-half, that is three semi-tones. When a

versa, leaving the rest of the sequence un-changed. The three arrangements that are not considered are neglected, I believe, because they are not species of a musical *genus*. A *genus* is, after all, a tuning, or more precisely, infinitely many tunings within firmly established boundaries. Such tunings presume a musical scale or system as background – a first note or string, a second note, third, and so forth. One can focus attention on any four consecutive notes of the scale and, depending upon the segment of the scale that is chosen, one can discern a variety of species. At no point, however, can one alter the sequence of notes of the scale. For instance, the third note of the system never becomes the second note. Therefore, because a system – the Greek musical scale – is assumed, and because species must be species of a *genus*, there can exist only three, not six, species of any specific tuning of a musical fourth" – this is further explained in this article in relation to intervals combination.

[22] See previous footnote; Greek manuscripts exist only as late copies as pinpointed in Chapter I of [Beyhom, 2016].

[23] There are two major theoreticians of Arabian music from old, Abū-n-Naṣr Muḥammad ibn Muḥammad ibn Tarkhān al-Fārābī (9th-10th centuries) and Ṣafiyy-a-d-Dīn ʿAbd-al-Muʾmin ibn Yūsuf ibn (ab-ī-l-Ma)Fākhir al-Urmawī (d. 1294). Urmawī's theoretical concept of the scale is a Pythagorean adaptation of the 17-intervals scale found in all theoretical and practical writings on Arabian music since Yaʿqūb ibn Isḥāq Abū Yūsuf al-Kindī (0801?-0867?), the "Philosopher of the Arabs" who was the first to use Ancient Greek theories to (try) describe Arabian music at his time – see [Beyhom, 2010b].

[24] [Fārābī (al-), 1930], p. 127: "Should a consonant interval be repeated within a group, the small intervals could be situated at different places in that group. Thus the fifth having been placed within a group with a certain arrangement of its small intervals, one can, within the same group have other fifths having their small intervals arranged in another way. For instance, the first interval in the first arrangement might be the last in another. In the case an interval is seen often in a group with its small intervals differently arranged, each of these arrangements of small intervals form a *genus*, a species, of a group. Within an interval, the arrangement of small intervals it contains can be classified as first, second, etc., until the various arrangements in this group are exhausted."

[25] Or "container", or "delineating".

[26] [Cleonidēs, 1884], *L'introduction harmonique*, (ed. and tr. Ruelle, Ch.), notably §71: "Differences are produced numerically in the following manner. Having agreed that the tone is divided in twelve small parts each of which called a twelfth of a tone, all the other intervals have a proportional part in relation to the tone."

[27] [Fārābī (al-), 1930], p. 59 *sq*.

[28] Metrologic accuracy is essential to mathematical precision. However, Fārābī himself acknowledges that music performance dismisses very small intervals in the scale – see [Fārābī (al-), 1930], p. 174-176.

[29] The "Harmonists" are supposed to have used the (exact) quarter-tone as a common denominator for their scales: this may be short of the truth (see Appendix 2 of [Beyhom, 2016]), as the Harmonists had 28 (and not 24) "quarter-tones" in their scales.

[30] Not Aristoxenos as he had a more complex understanding of intervals (a fact that has been overseen by most followers and critics), and used Pythagorean mathematics imbedded in his explanations of typical tetrachords – see Appendix 3 of [Beyhom, 2016].

[31] The term *genus* will only be used for the melodic expression of a tetrachordal polychord (= "made of multiple conjunct intervals of second"); the same applies, as pinpointed in [Beyhom, 2013; 2016], to the terms "mode" and "scale".

fourth is made up of three intervals, the alphabet is reduced and has only intervals equating to one, two or three semi-tones.

The tetrachords made from the systematic combination of the intervals in the alphabet constitute the well-known six tetrachords of semi-tone scales (Table 2), among which the first[32] and the fourth[33], are mentioned by Aristoxenos.

1 1 3 (semi-tone, semi-tone, one-and-a-half-tones) – “tonic chromatic” of Aristoxenos
1 3 1 (semi-tone, one-and-a-half-tones, semi-tone)
3 1 1 (one-and-a-half-tones, semi-tone, semi-tone)
1 2 2 (semi-tone, tone, tone) – “tense diatonic” of Aristoxenos
2 1 2 (tone, semi-tone, tone)
2 2 1 (tone, tone, semi-tone)

Table 2 Species of tetrachords made from multiples of the semi-tone.

The first three *species*[34] have two classes of intervals: the semi-tone class, 1, and the one-and-a-half-tones class, 3. This also applies to the three other ditonic[35] tetrachords, but in this case with intervals of one semi-tone, 1 and one-tone, 2. Interval classes can be expressed as capacity vectors, according to the number of intervals of each size they have (Table 3).

Another approach to the problem would devise a literal expression for the size of intervals expressed as multiples of the semi-tone, and then, arbitrarily, assigning the system amounting to the least integer number, as indicator of capacity.

A good example is the tetrachords with two one-semi-tones and one one-and-a-half-tones additional interval (Table 4). The digits of the intervals are concatenated in a single integer. The lowest number in the series of three is 113. If we assign the smallest number in the series as a capacity vector, we need only count the number of occurrences of each interval. We start with the smallest one to find out what is the capacity of the corresponding scale systems. This is known as a hyper-system.

Int. size:→	1	2	3	Vectors
Tetrachords:↓	Number of intervals of this size contained in the *tetrachord*			
1 1 3	2	0	1	(2,0,1)
1 3 1	2	0	1	
3 1 1	2	0	1	
1 2 2	1	2	0	(1,2,0)
2 1 2	1	2	0	
2 2 1	1	2	0	

Table 3 Capacity vectors for tetrachords on a semi-tonal basis.

From scalar systems to integer numbers			Capacity vector	Hyper-system
Sub-systems	concatenated number	Read		
1 1 3	**113**	one hundred and thirteen	(2,0,1)	113
1 3 1	131	one hundred and thirty-one		
3 1 1	311	three hundred and eleven		

Table 4 Expressing the scale systems “1 1 3”, “1 3 1” and “3 1 1” as integer numbers and deriving the capacity vector and hyper-system (sub-system resulting in the smallest integer number).

Taking, for example, vectors (2,0,1) and (1,2,0), with corresponding hyper-systems 113 and 122 as basis for generating remaining combinations, the intervals in each hyper-system can be combined differently in three sub-systems, or unique arrangements of intervals contained in the hyper-system (Table 4).

The reason for this is that each model contains a semi-tone which is repeated, in the first hyper-system and two one-tone intervals for the second. The outcome of the combination of intervals in a hyper-system containing three different intervals would be different. However, this configuration does not exist for semi-tone integer multiples.

[32] ‘1 1 3’ (two adjacent semi-tones followed by one one-and-a-half-tones interval): [Aristoxenos and Macran, 1902], p. 202-203.
[33] ‘1 2 2’ (semi-tone, tone, tone): [Aristoxenos and Macran, 1902], p. 204.
[34] These are defined as sub-systems in Modal systematics.
[35] Understand as *tense diatonic* (or Western diatonic), as many other shades of diatonic tetrachords exist as explained in [Beyhom, 2016], Chapter I, and in [Beyhom, 2010b ; 2015b].

Conceptual, quantification, and elementary intervals: Understanding theory and practice

In the Western equal-temperament scale,[36] also known as the 12-ET system (equal temperament with 12 intervals in the octave), both conceptual and quantification intervals may have the same value. The semi-tone is half of a tone. It is the smallest interval and therefore divides the fourth into five semi-tones. The fifth, is made of seven semi-tones: three tones and one half-tone. The octave has twelve semi-tones, that is six tones. The cent being equal to one hundredth of a semi-tone, appears to be more accurate. However, it has little purpose with the 12-ET since the semi-tone is the exact divider for all larger intervals.

With other systems,[37] the smallest interval used, in theory, may neither be a divider of other intervals, nor a conceptual interval, or an interval which is used in the scales and melodies of a particular type of music. An example of it is the systematic scale defined in the first half of the 13th century by Ṣafiyy-a-d-Dīn al-Urmawī, in his *Book of cycles*.[38] There, the smallest conceptual interval[39] is the *leimma*. The tone, is made up of two *leimmata* and one *comma*, both Pythagorean.[40] The *leimma* is equated[41] to the semi-tone. Therefore, a typical tone may take the form L + L + C, where ‘L’ stands for the *leimma*, and ‘C’ for the *comma*. Therefore, a pitch can be placed in a scale on the boundaries of these intervals.[42]

In this case, the *leimma*, and the *comma* play the role of elementary intervals (they are used to make up other intervals in the scale). However, the *comma* is not a conceptual interval because it is never used as such between neighboring pitches of a scale[43] but only as part of another and larger conceptual interval.

The *comma* and the *leimma*, make up conceptual intervals used in the composition of other intervals such as the “neutral[44] – or *zalzalian* – second, called *mujannab*

[36] More than two thousand years ago, Ancient Greek *theory* included the semi-tone equal temperament which is in use in most Western music today (classical, to some extent, and pop music in general), together with modern Arabian quarter-tone divisions of the octave. Aristoxenos’ theory is reportedly based on an equal-temperament division. He defines the fourth as composed of five semi-tones (see [Aristoxenos and Macran, 1902] p. 208); in both Ancient Greek theory and practice, however, equal-temperament was never used, because exact computation of the intervals of equal-temperaments was not possible. Moreover, and as reminded in [Beyhom, 2016] – Chapter I, Aristoxenos’ concept of the scale was never based on equal-temperament. This is one of the reasons why intervals functions must be differentiated from their measurements.

[37] Such as many types of unequal temperaments.

[38] Urmawī’s *Book of cycles* is extensively analyzed by Owen Wright in *The Modal System of Arab and Persian Music A.D.1250-1300*, [Wright, 1969]. There appears to be no translation in English. There is a translation in French by Erlanger (1938) but there he refers to a commentary (the *Sharḥ Mawlānā Mubārak Shāh bar Adwār*) which he attributed to Ṣafiyy-a-d-Dīn al-Urmawī, under the title of *Kitāb al-Adwār* [“*Livre des cycles musicaux*”], in *La Musique Arabe*, Vol.3, [Urmawī (d. 1294) and [Jurjānī (al-)], 1938]. In the same volume, Farmer (p. XIII of Erlanger’s translation) ascribes it to ʿAlī ibn Muḥammad a-s-Sayyid a-sh-Sharīf al-Jurjānī.

[39] Reminder: a stand-alone interval in the scale.

[40] The Pythagorean *comma* amounts (notably) to six Pythagorean tones (8:9) from the sum of which one octave is taken away. The *comma* has the ratio of 524288:531441, which is about 23 cents. This discrepancy can be described as the consequence of the Pythagorean tone, about 204 cents being slightly larger than the equal temperament tone at 200 cents. Therefore, the octave is made up of five tones and two *leimmata*. The Pythagorean fifth is made up of three tones and one *leimma* (about 702 cents), and the fourth, of two tones and one *leimma* (498 cents). The *leimma* is the ‘left over’ quantity between two Pythagorean tones away from a fourth. This amounts to a ratio of 243:256, about 90 cents.

[41] The *leimma* is (see previous note) the complement of the Pythagorean ditone within the just fourth of ratio 3:4.

[42] One of Urmawī’s (intervallic) octave representations runs as: L L C, L L C, L, L L C, L L C, L L C, L. Placing notes at Pythagorean boundaries, we have *c* (L L C) *d* (L L C) *e* (L) *f* (L L C) *g* (L L C) *a’* (L L C) *b’* (L) *c’*. In the *maqām Rāst* of Arabian music, as defined by Urmawī, the boundaries stand differently: *c* (L L C) *d* (L L) *e*$^{-}$ (C L) *f* (L L C) *g* (L L C) *a’* (L L) *b*$^{\flat-}$ (C L) *c’*. The intervals between *d* and *e*$^{-}$ (or for the latter a pitch which stands between *e* flat and *e* sharp) and between *e*$^{-}$ and *f* are the *mujannab*, or *zalzalian* seconds of Urmawī. The same applies to the intervals between *a’* and *b*$^{\flat-}$ and *c’*. Their value is (L + L) or (L + C), but both hold the same name of *mujannab*, whilst intervals such as the *leimma* ‘L’ or the tone, have one single interval capacity, that is one *leimma* for the semi-tone (with Urmawī), and two *leimmata* and one *comma* for the tone.

[43] Or in a melody.

[44] Because this term, used by Orientalists, is biased and gives the ditonic system the priority on other music systems (and compels me to use double quotes for “neutral” all over the text of this article), I shall use exclusively the term *zalzalian* from this point on to characterize such intervals. As explained in [Beyhom, 2016], Zalzalian divisions of the scale are generally deduced from the existence, in a containing (or delineating) interval (*i.e.* a fourth, a fifth, an octave), of small(er) structuring intervals the values of which are frequently expressed as odd multiples of the (approximate) quarter-tone. The term “Zalzalian” {from Manṣūr Zalzal a-ḍ-Ḍārib, an 8th-9th-centuries *ʿūdist* who was – supposedly – the first to introduce the fingerings of the *mujannab*(s) – *i.e.* the so-called zalzalian seconds and thirds – on the neck of the *ʿūd*} refers more generally to intervals (or musical systems which use them) using other subdivisions as the semi- (or “half-”) tone, noticeably all the varieties of *mujannab* seconds spreading from the exact half-tone to the disjunctive (Pythagorean) tone – see Fig. 5: 14 (references to figures and tables have page

which, according to Urmawī, can be made up of two *leimmata* (*i.e.,* L + L) or with one *leimma* plus one *comma* (*i.e.,* L + C or C + L).

The difference between the two zalzalian seconds, *i.e.,* the difference between two *leimmata* and one *leimma* plus one *comma* (Fig. 1), or [(L+L) - (L+C) = (L - C)], is about 67 cents, almost three Pythagorean *commata.*

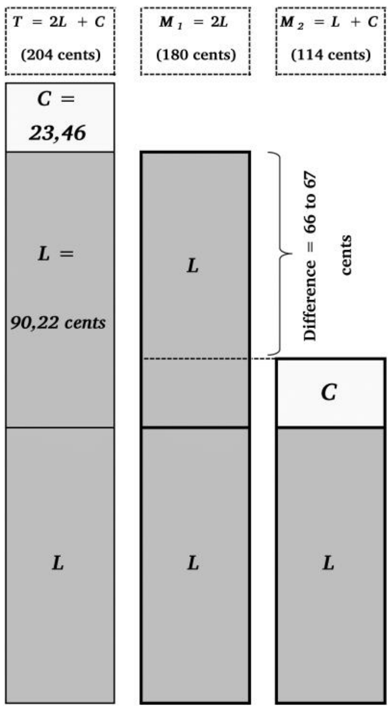


Fig. 1 Urmawī's tone (left) and two expressions of the *mujannab* (center and right): T = tone, M = *mujannab*, L = *leimma* and C = *comma.*

Conceptually, however, the two possible forms of zalzalian seconds, with Urmawī, are equal (Fig. 2). Both are called *mujannab* and considered as intermediate intervals placed between the *leimma* and the tone.

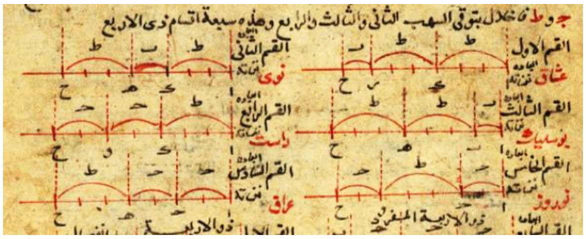


Fig. 2 Excerpt from an autograph[45] by Urmawī of the *Book of Cycles* which illustrates the conceptual equality of the two forms of the *mujannab* (and of the use of elementary intervals as conceptually equal).[46]

Arabian theory has hardly changed since Urmawī.[47] Modern scholars give two principal representations of a scale with all possible locations of pitches. The first is an approximation of the general scale with Holderian commas,[48] HC, henceforth, and the second uses the quarter-tone for quantification.

A HC equates to 1/53rd of an octave, about 23 cents (22.6415)[49]. Therefore one *leimma* equates to four HC, about 91 cents. This is close enough to the Pythagorean *leimma*. The tone is 9 HC, or 204 cents, matching the Pythagorean tone. Typically, a tense diatonic (or ditonic) tetrachord[50] is modeled as a succession of two Pythagorean tones of 9 HC each, plus a *leimma* with 4 HC. The *mujannab* of Urmawī, which amounts to a zalzalian second, has two possible values in Modern Arabian theories of the scale, 6 HC or 7 HC, but they are considered as identical conceptual intervals (Fig. 3).[51]

The first division of the octave, the 53-ET giving the Holderian comma as a common divisor of all conceptual intervals, follows, in Modern Arabian theory, complex rules.[52] The second division of the octave, in 24 theoretically equal quarter-tones, will demonstrate a privileged example of interval relationship.

numbers, when needed, after a colon); the same applies to intermediate intervals between the (exact or Pythagorean) tone and the one-tone-and-a-half interval (either equal-tempered or Pythagorean "augmented" second), etc.

45 According to Owen Wright (Personal communication).

46 [Urmawī (al-), 2001, p. 6].

47 The concept remains the same throughout history, and is based on the division of the tone into three small intervals and on the division of the zalzalian second in two other, even smaller ones – see [Beyhom, 2007c ; 2010b].

48 The modern concept of divisive commas is different from the Ancient Greek concept based on ratios; therefore, the Pythagorean *comma* is written in italics in this article, which is not the case with the Holderian comma.

49 Accuracy to the 4th decimal is needed only for computational purposes as in practice anything under two cents is hardly noticeable – more in [Beyhom, 2016].

50 The tense diatonic [ditonic] *genus* is the Western paradigm as explained above.

51 For example in [Ṣabbāgh (a-ṣ-), 1950].

52 Ṣabbāgh uses (p. 29 for example in the aforementioned book of this author), the terms 'flat plus one quarter' for the note e^{-} in the scale of the mode *Rāst*, although the intervals that surround it are different in size (6 HC and 7 HC). Much in Arabian theories of the scale relies on prior knowledge of *maqām* rules and on former theorizations – see also next footnote.

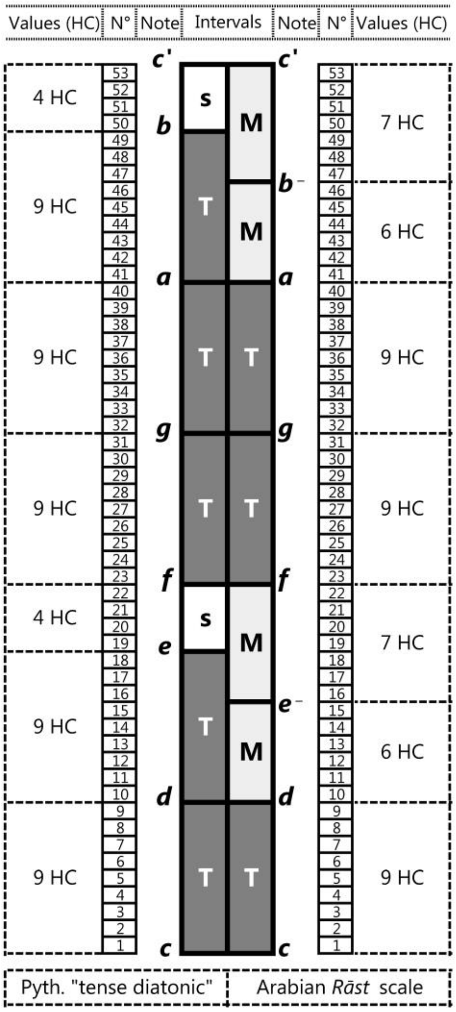


Fig. 3 Comparison between the modeling of the Pythagorean tense diatonic scale (left) and of the Arabian *Rāst* scale (right) with Holderian commas.

At this point, it may be useful to explain how two intervals, which are different in size, can, according to Urmawī, be considered as identical conceptual intervals.[53]

The best example is with the *maqām Bayāt* (Fig. 4). It is based on the same scale as the *maqām Rāst*. The *Rāst* scale is composed of approximate three 'one-tone' and of four 'three-quarter-tones' intervals.

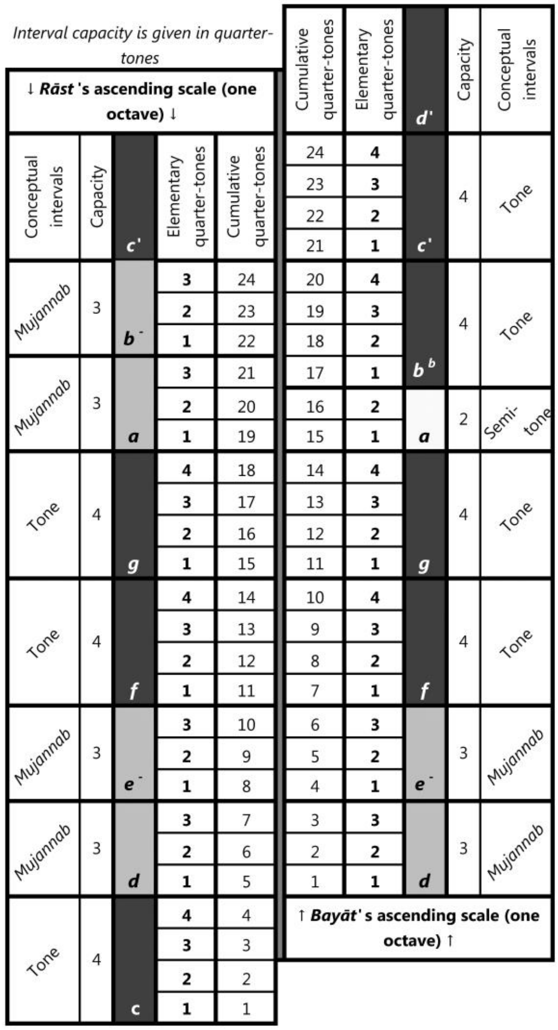


Fig. 4 *Maqām Rāst* and *Bayāt* scales in the Modern quarter-tone theory.

[53] Conceptual intervals represent qualities of intervals when used in a melody or a scale. Compared one to another, each has a unique and identifying quality which relies on its relative size. These compose the fourth, the fifth or the octave, and play a distinct role in performance, bearing in mind fluctuations and regional preferences which will be stressed for the degree *SĪKĀ* in Arabian music for example, (Fig. 5, p. 14) and identified by the performer as a semi-tone, a *mujannab*, or a one-tone interval, and so forth. The Arabian usage of the HC agrees with the adepts of Pythagoras who insisted in the Pythagorean approximation of the Arabian scale, instead of an equal temperament. The reason is that the odd number of HC in one tone (nine) and its distribution among the Pythagorean *leimma* (4 HC – sometimes called 'minor' semi-tone) and the Pythagorean *apotome* (5 HC – sometimes called 'major' semi-tone) are good enough approximations and represent two different intervals whenever the *mujannab* intervals in Arabian music, conceptually equivalent to one and single interval, may also be approximated to two intervals of slightly different sizes, *i.e.*, 6 HC and 7 HC, which, when added, equate to the augmented second of the Western scales. While Urmawī's *mujannab* intervals could better be approximated with 8 HC (for the two-*leimmata mujannab*) and 5 HC (for the *apotome-mujannab* = *leimma* + *comma*), modern Arabian theoreticians need to differentiate the latter interval from the semi-tone, and stay close to the quarter-tone theory: this fact explains most of the inconsistencies and problems with the HC notation found in the literature.

It could be notated as *c d* e^- *f g a* b^- *c'*, with e^- and b^- being approximately one quarter-tone lower than their western equivalents. The scale of the *Bayāt* is close to the general structure of *maqām Rāst*, but begins with *d* and has a (generally descending)[54] b^{flat}. This gives *d* e^- *f g a* b^b *c' d'*.[55]

The note e^- which has the same name in all theories of the *maqām*,[56] is placed differently according to the context of the performance, or depending on the local repertoire (Fig. 5).[57]

In this *maqām*, the position of the degree *SĪKĀ*[58] (e^- in Western equivalence) has a lower pitch in Lebanese folk music than it has in Classical Arabian music in the Near-East. Should we decide to use a quarter-tone approximation for the intervals in Arabian music, as most modern theoreticians do, then the two zalzalian intervals between *d* and e^- and between e^- and *f* are conceptualized as two three-quarter-tones intervals (Fig. 4). However, with the *Dalʿūna*, in *maqām Bayāt*, Near-Eastern folk music has a lower e^-, which, regardless, is considered as a *SĪKĀ*, but the lower interval between *d* and e^-, the lower *mujannab*, is smaller than an exact three-quarter-tone (Fig. 5), and the higher interval between e^- and *f* is larger.[59]

Furthermore, the positioning of the *SĪKĀ* depends on which *maqām* is played as well as region and repertoire. A good example is in the difference between the position of the *SĪKĀ* in the *maqām Bayāt* and the position of the same note in the *maqām Rāst* which in this case is higher in pitch, but lies approximately around the three-quarter-tone boundary.

In the *maqām Sīkā*,[60] or one of its frequent variants, the *maqām Sīkā-Huzām*,[61] the position of *SĪKĀ* is still higher and could sometimes reach the upper value of Urmawī's greater *mujannab*. This is the position assigned to this note in modern Turkish theory.[62]

The boundaries for these different positions for *SĪKĀ* are not established in practice, and the study of its variations would require another paper. This pitch is perceived as a *SĪKĀ* anywhere the player may perform. The difference is quantitative. However, the relative positioning of the note which is placed between e^b and *e*, will always be perceived as a *SĪKĀ*.

Therefore, the conceptual understanding of the zalzalian second is not simply quantitative, but also relative and qualitative.[63] Importantly, the *mujannab* is perceived as an intermediate interval between the one 'half-tone' and the 'one-tone' intervals.

This applies for all other intervals such as the semi-tone which is an interval smaller than the *mujannab*, and to the 'one-tone' interval which is larger than the latter.

[54] *Maqām Bayāt* ascending scale is often represented with the same structure as *maqām Rāst*, but beginning with *d*: the "normalizing" influence of the semi-tonal temperament (see [Beyhom, 2016]) has most probably precipitated an exclusive semi-tonal ascending and descending b^{flat} found in recent theoretical literature (Fig. 4) – see [Beyhom, 2003c], Vol. 1, Part I.

[55] As noted above, elsewhere, b^- may be used for b^b.

[56] Depending on the transliteration and, or, on local pronunciations: *SĪKĀ*, *SEGAH*, *SEH-GĀH*, etc.

[57] The positions of the notes in the *maqām*, including the fundamental, may vary slightly during performance. See [Beyhom, 2006, p. 18–24], [2007a, p. 181–235] and [2016].

[58] I write note names fully capitalized, mode names with an initial capital letter and polychord (or *genus*) names with no capital letters, to differentiate for example the note *SĪKĀ* from the mode *Sīkā* and from the trichord *sīkā* in Arabian music.

[59] This and the following explanations are based on the author's own experience while practicing Lebanese folk tunes, as well as on interval measurements of performance examples in various modes including the degree *SĪKĀ*; on thorough discussions with teachers of Arabian music (mainly on the *ʿūd*), and also on an extensive and systematical study of contemporary *maqām* theories in the Near- and Middle-East. For the latter see for instance [Beyhom, 2003c].

[60] The mode *Sīkā* traditionally begins with the note *SĪKĀ*.

[61] The two are commonly used both with Classical and Folk Arabian music in the Near-East.

[62] [Signell, 2002]. Turkish (classical) modern theory uses the HC approximation for its intervals. In practice, however, as Signell stresses (p. 37-47) and the way in which many contemporary Turkish musicians perform (as underlined for Kudsi Erguner on *Nāy* or for Fikret Karakaya on the *Lyra* in [Beyhom, 2006 ; 2016]), the note *SĪKĀ* tends to be played lower than its assigned value (that is *e* minus one *comma* in Turkish theory), notably in *maqām Rāst*, *Ṣabā* and *Bayāt*.

[63] The difference between the mobile notes of Ancient Greek theory and the variable position of the single note *SĪKĀ* lies in the fact that mobile notes may move from one position to another in the general scale, whilst the variability of the degree *SĪKĀ*, for example, involves only one position in the general scale, which varies. An example of mobility is a change from pitch *e* to pitch e^b, when a minor tetrachord *d e f g* modulates into a *Kurd* tetrachord (or also as the introductory tetrachord in the flamenco scale, starting with *d*: *d* e^b *f g*), while the position of *SĪKĀ* may vary depending on a certain number of factors, but its relative positioning in the scale remains the same (it is still considered as the same intermediate – and identified – pitch between e^b and *e*, or e^-), and the intervals it delimitates are identified, in the *maqām Rāst, Sīkā and Bayāt* scales, as *mujannab* intervals.

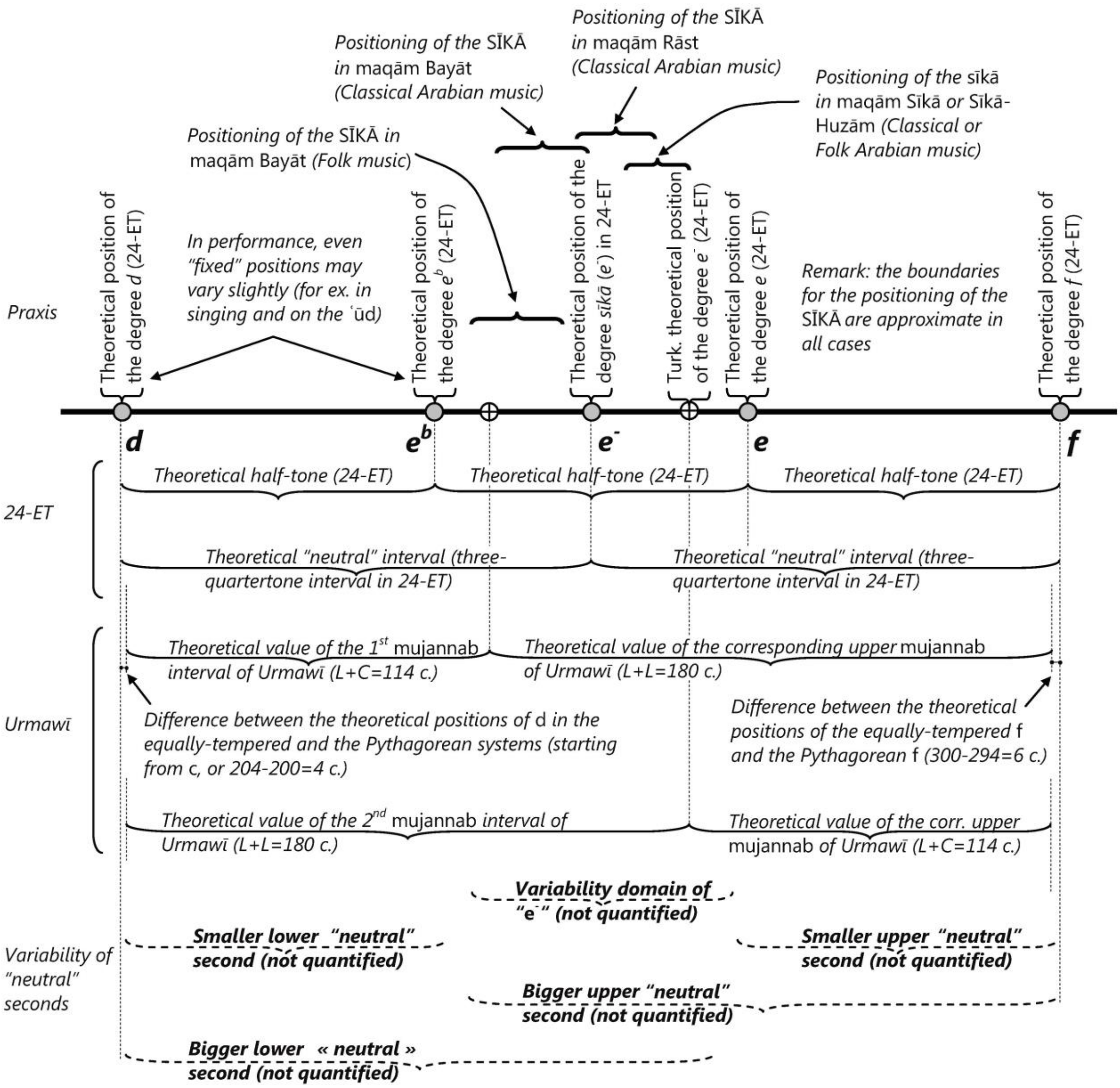


Fig. 5 Repertoire or regional variations of *SĪKĀ* and of the zalzalian seconds – this emendated figure is taken from [Beyhom, 2016].

The tonometric value of *mujannab* may vary,[64] but it is the relative position of the interval in the scale and its qualitative and relative size, compared to other conceptual intervals, which gives it its full value in the repertoire.

To conclude on the nature of intervals in a scale, they are of three types[65]:

1. An interval of measurement is an exact (or nearly exact) divider of other intervals. As a general rule, any musical system based on the equal division of the octave, as in an equal temperament, gives an interval of measurement, such as the semi-tone in the 12-ET, and with the quarter-tone in the 24-ET or the HC in the 53-ET divisions of the octave.
2. Conceptual interval. This is one of the consecutive intervals of the second forming a musical system. For example, three seconds in a just fourth, four seconds in a just fifth, or seven seconds in an octave. Conceptual intervals can be measured either exactly or approximately with smaller intervals, usually of measurement, as in approximations using the quarter-tone or the HC.

[64] For example "the *SĪKĀ* in Lebanese Folk music is lower than the *SĪKĀ* in…".

[65] To which we can add the Container (or Containing) intervals.

3. Elementary intervals are used in combination to build up to consecutive conceptual intervals of seconds within a system. They can combine either with a similar elementary interval, such as with the two *leimmata* in Urmawī's general scale, which combine into a *mujannab* interval, or with another elementary interval, such as the *leimma* + *comma*, for the second form of the *mujannab*, with Urmawī.[66]

These three types of intervals are not mutually exclusive. When the smallest conceptual interval is also the smallest common denominator of all conceptual intervals, as with the semi-tone in the 12-ET, then it becomes an interval of measurement, but it is also an elementary interval, although it remains conceptual when used as an interval of second within a musical system. The need to differentiate these three types of intervals arises within unequal temperaments, for example with Urmawī.[67]

This distinction will provide with a better understanding of the combination processes applied to music intervals.

Applying the concept of qualitative differentiation of intervals on Urmawī's scale

Urmawī's explanations about his scale show that the ("major", Pythagorean) tone is composed of three elementary intervals and that no interval within the fourth may contain either three successive *leimmata* or any two successive *commata* (Fig. 6).

The *comma* is neither a quantifying interval as it does not divide exactly other intervals such as the *mujannab* or the tone,[68] nor is it a conceptual interval, as it is never used as a melodic interval between two pitches in a modal scale.[69] Furthermore, a *comma* is never used as the first interval of a combination, with a notable exception for the *mujannab* which can hold the form 'C+L'.

A conceptual interval generally starts with itself or with another conceptual interval. The *leimma*, for example, is used both as a conceptual interval, the smallest interval used in any of Urmawī's modal scales and as an elementary interval used in the composition of other, relatively larger, conceptual intervals.

With Urmawī, both the *comma* and the *leimma*, are elementary intervals. However and additionally, the *leimma* is also a conceptual interval.

In modal construction, and with an appropriate choice of pitches within the scale, with Urmawī, there are other conditions to be met. These include, for example, the inclusion of the fourth and of the fifth. They must be complementary in the octave. With such limitations, we can conceptualize the intervals of adjacent seconds in Urmawī's modes in the following way (Fig. 6):

1. A conceptual interval of one semi-tone is composed of a single interval, part of the scale. Since the smallest conceptual interval is the *leimma*, we may conclude that the semi-tone is equivalent to a *leimma*.
2. The *mujannab*, or zalzalian second conceptual interval is composed of two elementary intervals of the scale: the *mujannab* can be either composed of one *leimma* + one *comma*, L+C, or of two consecutive *leimmata*, L+L. It is the only interval with Urmawī, listed among intervals smaller than the fourth which may have two different sizes.
   - As a corollary to this, two *mujannab* may follow each other, but only if they have a different composition such as when one is L+C and the other is L+L (or L+L then C+L).[70]

[66] Additionally, the Pythagorean *comma* is an *auxiliary interval*, *i.e.* an interval which is neither a *measuring interval*, nor *conceptual*.

[67] The urge for such a concept is even more evident with music not responding, partially or completely, to temperament, such as we have with traditional *a capella* singing worldwide.

[68] At least in Urmawī's concept of the scale: it is much later in the history of music theory that some theoreticians began using the Holderian comma as a measuring interval for approximating Pythagorean intervals, but this cannot apply to theoreticians of the Western "Middle Ages" who dealt mainly with Pythagorean frequency (or string) ratios for interval handling – see [Beyhom, 2016].

[69] This means that a melody would not, in the modal or *maqām* music described in Urmawī's theories, move directly from one pitch to another, one *comma* apart, unless this process is used in performance as an intonation variation within the original melody (in which case the size of the *comma* is approximate). This is still the case with Arabian music, but where the quarter-tone is the elementary interval of the 24-ET – see the example of *maqām Awj-Āra* in Part II and footnote 147.

[70] The explanation of the (theoretical) role of two consecutive *mujannab* lies possibly in the perception of this interval as being the result of the division of the one-and-a-half-tones interval in two smaller intervals (more information about this process can be found in [Beyhom, 2005]), in which case, any two *mujannab* in a row must add up, at least in theory, to the greater tone shown in Fig. 6, *i.e.*, composed of 3 *leimmata* and one *comma*: the only possibility for this is that the two *mujannab* be of different sizes.

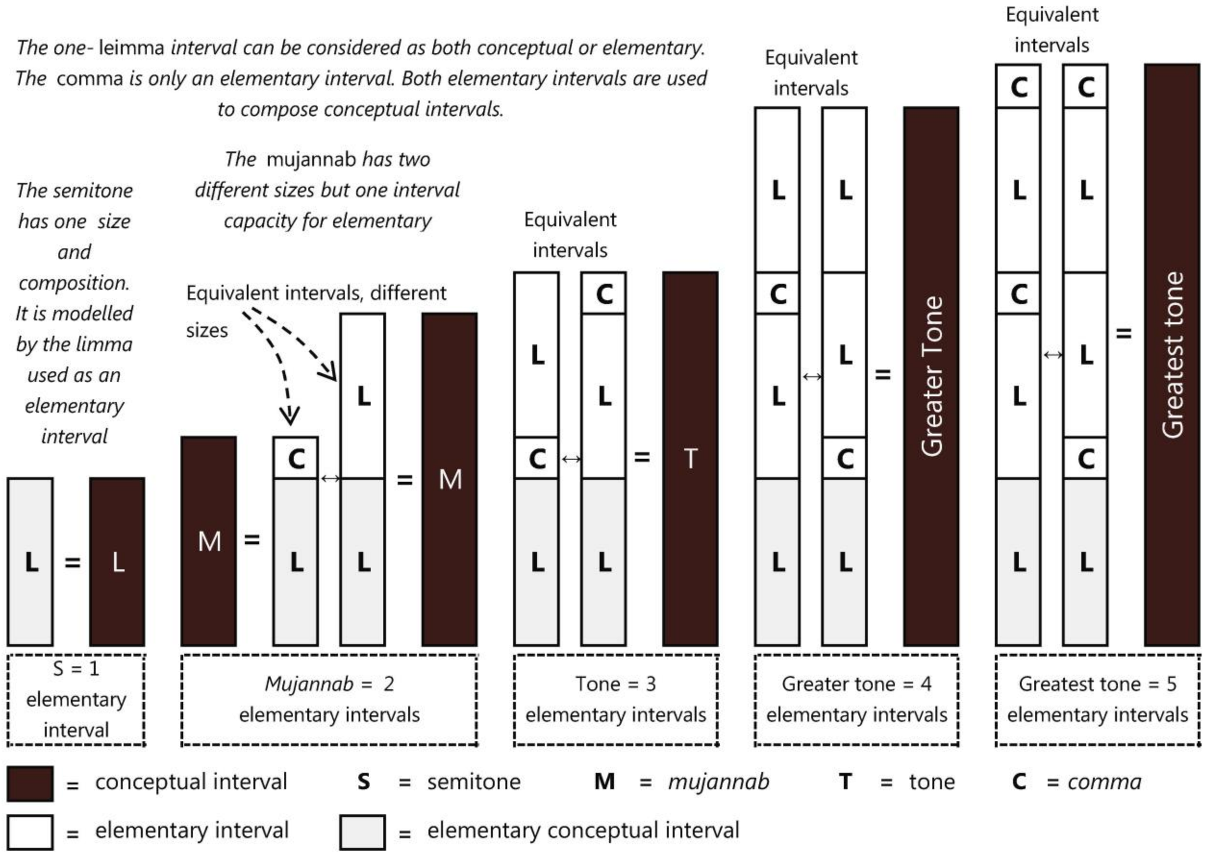


Fig. 6 Obtaining the 5 qualities of seconds in Urmawī's theory: the semi-tone is the smallest conceptual interval, and is modeled with a *leimma*. Other intervals within the fourth are modeled from a first *leimma*, augmented with a combination of *commata* and *leimmata*, bearing in mind that no more than two *leimmata* in a row, and no successive *commata*, may be used. The *mujannab* has two possible sizes, but contains in both cases two elementary intervals. All intervals larger than the semi-tone have two different possibilities for combinations of elementary intervals.

3. The tone is composed of three elementary intervals. However, a) three *leimmata* must not follow each other,[71] and b) the *comma* must always be preceded or followed by a *leimma*. In this case, the tone can only include two *leimmata* and one *comma*, with two possible arrangements: L + L + C, or L + C + L.
4. The greater, or augmented conceptual interval of the tone is composed of four elementary intervals. It can only be made up of three *leimmata* and one *comma*. They can only be arranged in this manner: L + L + C + L or L + C + L + L. This interval is not mentioned in the *Book of Cycles*. It is only assumed as part of Urmawī's seconds.
5. The greatest conceptual interval of the second is made up of 5 elementary intervals because the fourth can only be composed of a maximum of seven elementary intervals, within the systematic[72] general scale. However, two other intervals of second (conceptual interval) are needed for its completion. Since the smallest second is the semi-tone, the *leimma*, the greatest conceptual interval is equal to the remainder coming from the subtraction of two *leimmata* from the fourth. The fourth is composed of two tones and one semi-tone, *i.e.*, [2 × (2L + C)] + L, or 5L + 2C. Taking away two *leimmata*, the resulting capacity of the greatest conceptual interval in a fourth is 3L + 2C. Applying the rules of construction of the intervals, such

[71] Because three small intervals are necessarily bigger than a *mujannab*, which means that their sum must necessarily be equal to the one-tone Pythagorean interval, which stands next in the row of conceptual intervals.

[72] The "Systematist scale" is the name given to Urmawī's scale by Western musicologists, and his followers are known as the "Systematists".

as no more than two *leimmata* in a row, etc., the possible forms of the greatest second, or tone, in Urmawī-type scales are L+L+C+L+C, or L+C+L+L+C. This interval is not mentioned as such in the *Book of Cycles* but is also assumed.

The fourth needs a combination of smaller intervals so that their sum can add up to its capacity in terms of elementary intervals. In order to simplify the process, I shall use a simple handling of numbers equating to the conceptual intervals of the second with Urmawī:[73]

1. The semi-tone equals number 1, as one elementary interval is needed to compose this conceptual interval.
2. The *mujannab* is given the value of 2 since two elementary intervals are needed to build it up to a conceptual interval.
3. The tone interval is given the value of 3 since it needs three elementary intervals.
4. The Greater tone has the value of 4 since it requires four elementary intervals.
5. The greatest interval of the second within a fourth has the value of 5 because it needs five elementary intervals.

Although having a quantitative function in terms of numbers of elementary intervals which make up a conceptual interval, numbers 1 to 5 express the intrinsic quality of the interval: its (theoretical) identification as a different conceptual interval from those represented with another number. As a common rule, the fourth is made up of three conceptual intervals. In order to comply with Urmawī, they must add up to seven elementary intervals.

Reduced to their hyper-systems, we have the following:

1. 115, with $1+1+5=7$ (not in Urmawī's *Book of cycles*)
2. 124, with $1+2+4=7$ (not in Urmawī's *Book of cycles*)
3. 133, with $1+3+3=7$
4. 223, with $2+2+3=7$

Therefore, in this case, a fourth may contain, either 1) two semi-tones, '1', and one greatest interval of second, '5', or 2) one semi-tone, one *mujannab*, or zalzalian tone, '2', and one augmented, or greater tone, '4', or 3) one semi-tone and two intervals of one tone, '3', or 4) two *mujannab*, or zalzalian tones and one one-tone interval.

The algorithm for these hyper-systems is straight forward (Fig. 7):

1. To find the first hyper-system, (Fig. 7, first step) take the smallest conceptual interval, 1 twice in this case, and then deduce the value of the third interval by subtracting the quantitative value of the first two, which adds up to 2 elementary intervals, from the value of a fourth, or 7 elementary intervals, which gives 5.
2. The second hyper-system, the 124 hyper-system above, is obtained by decrementing the value of the last digit interval in the preceding first hyper-system, (Fig. 7, second step) and by incrementing accordingly the value of the interval standing just before in the series: the last digit in the first hyper-system is 5, which is decremented to 4, and the interval which precedes it, which is the central 1 in the 115 hyper-system, is incremented, accordingly, to 2.
3. The simultaneous decreasing of one interval value by one unit, or its decrementation, with the increasing of one other interval value by the same unit of one, or accordingly incrementing it, insures that the sum of the numbers in the series remains unchanged. Here it is equal to 7.
4. Applying the same process to the resulting hyper-system 124, (Fig. 7, second step — repeated) the third hyper-system is now 133.
5. Applying the same process to this last hyper-system would result in 142.

The capacity of the last series is, however, the same as for 124. The reason is that in the preceding 133, the last two intervals were equal but with the continuation of the process in the same way, interval values for the central '3' are the same as the preceding values for the last '3', *i.e.,* 4 and 5, and reciprocally, which would result in the same composition of intervals, in terms of quantity, within the fourth.[74]

[73] One could also use corresponding letters, for example S, M, T, etc., for the combination process: numbers have the same discriminating power, but have the advantage of allowing a quick check of the sum of the elementary intervals in the series.

[74] Intervals do change with this algorithm, but they have a fixed sum, here 7 elementary intervals. This condition limits drastically interval variation.

At this point, we need to improve the algorithm in order to find the remaining hyper-systems. This is done by decreasing the rank of the intervals to be modified by applying the same process to the interval the rank of which is immediately below the rank of the interval to which the decrementing process was last applied, *i.e.,* 133. The latter is the third interval in the series and now we must decrement the second interval in the series, and increment, accordingly, the preceding one, the first interval in the same series.

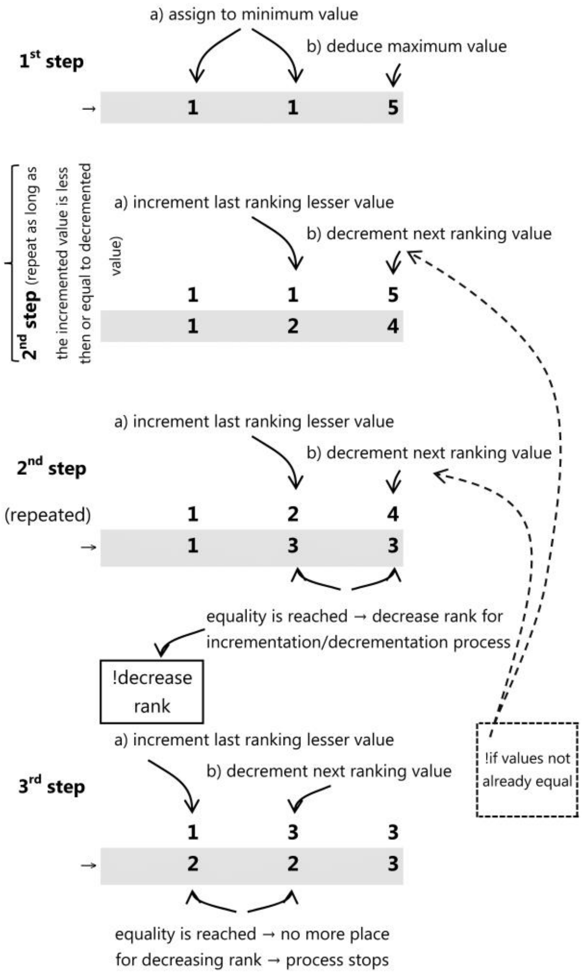


Fig. 7 An algorithm for hyper-systems.

Applying this process to 133 which we found in the preceding step, the second interval, central 3 (Fig. 7, 3rd step) is decremented to 2, and the first interval, 1, is incremented to 2 (as well), whilst the third interval, which is the last 3, remains unchanged. This gives the new figure of 223. This is where the generation process ends since the two first intervals have now similar values. Any further step would generate a redundant hyper-system.[75]

Now that we have determined the hyper-systems agreeing with Urmawī, we need extract all possible tetrachords and shades to give the full range of intervals in the fourth. The next section will review combination processes of intervals, for any hyper-system.

Various forms of interval combination

There are different methods for combining intervals. One is the rotation and the other the permutation process.[76] These are the most common. Rotation was used, notably, by Aristoxenos in his Elements of Harmonics,[77] and permutations were often used throughout history, and most probably by Fārābī in his tetrachords, adding to Aristoxenos' range of tetrachords.[78] Both processes are deficient since they do not give, in their simplest expression, a full account of all the possible combinations. The tree process given below has the whole range of results. However, this is more related to statistical and probabilistic analyses.

There are other procedures, such as de-ranking, which can be considered as a general case of the Byzantine-wheel method. Modal systematics uses them all for the purpose of arranging and classification, with special recourse of the de-ranking process.

ROTATION OF INTERVALS

Rotation (Fig. 8) is a straight forward process by which intervals may be combined, placing the first after

[75] This simple algorithm is used for computer combination processing and is very efficient for larger interval series as, for example, a heptatonic scale: it is applied in a more elaborate formulation in the generative procedures used by the theory of Modal systematics, which allow a complete survey of hyper-systems, systems and subsystems as they shall be defined below.

[76] The permutation process(es) are explored in Appendix H.

[77] English translation in [Aristoxenos and Macran, 1902 ; Barbera, 1984], aforementioned.

[78] The additional tetrachords of Fārābī are what I call the zalzalian tones tetrachord (which is equivalent to the Arabian *bayāt*), and the original equal-tones tetrachord: expressed in multiples of quarter-tones, the first genus can be represented by 3 3 4, or three-quarter-tones, three-quarter-tones, and one one-tone, intervals. In its essence, it is equivalent to the equal diatonic (ascending) tetrachord of Ptolemaos with successive string ratios of 11/12, 10/11 and 9/10. For a general survey of Greek genera, see [Barbera, 1977], notably p. 296, 298, 302, 303, 307, and [Mathiesen, 1999], p. 468-75. The second addition of Fārābī, the equal-division tetrachord (or equal-tone division of the tetrachord), is composed of three identical intervals each of which has a size of 5/6 tone (see [Fārābī (al-), 1930, v. 1, p. 58–59], and Appendix 3 in [Beyhom, 2016]).

the last one, or inversely, the last before the first, leaving the other intervals in their position.

The first method is a clockwise process which continues as long as the first interval does not come back to its initial position, obviously. Fig. 8 shows that this process generates intervals in three different ways (the first does not rotate since it places the interval system in its original and basic position).

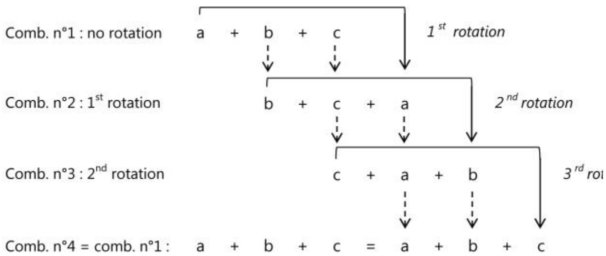


Fig. 8 Rotation of three distinct intervals a, b and c with the three resulting combinations.

However, the rotation process is defective, as it always gives three possible combinations of three intervals, whenever the combination possibilities for these three intervals allows for six different combinations.[79] For the purpose of his explanation, Aristoxenos used intervals of the enharmonic tetrachord which are made up of two quarter-tones and one ditone, that is two equal intervals out of three.

Fig. 9 shows intervals with subscript numbers so that they retain their initial rank in the basic configuration, that is a_1 as the first interval of the basic configuration, a_2 as the second and b_3, as the third.

Even then, the rotation process gives three distinct combinations. If the three intervals are equal to Fārābī's equal-tone distribution where each is 5/6 of a tone, a combination process, whatever it may be, will always give the same result as combining the three intervals a a a. Other processes are more effective but Aristoxenos' use of this limited process might have been a consequence that he considered interval combination as a deranking process.

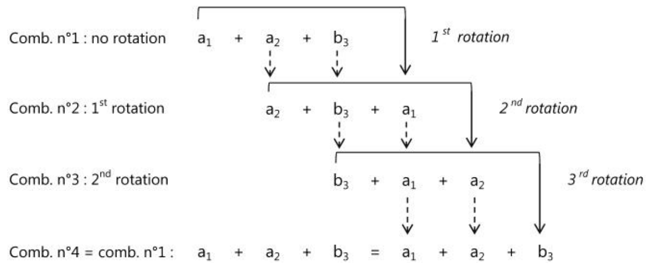


Fig. 9 Rotation of three intervals out of which two (the 'a' intervals) can be considered as equivalent (the subscript numbers identify the initial rank of each interval in the original – basic – combination): the outcome is still three distinct combinations.

Tree processing[80]

In the tree processing the combinations are based on an initial choice of intervals, rank by rank (Fig. 10).

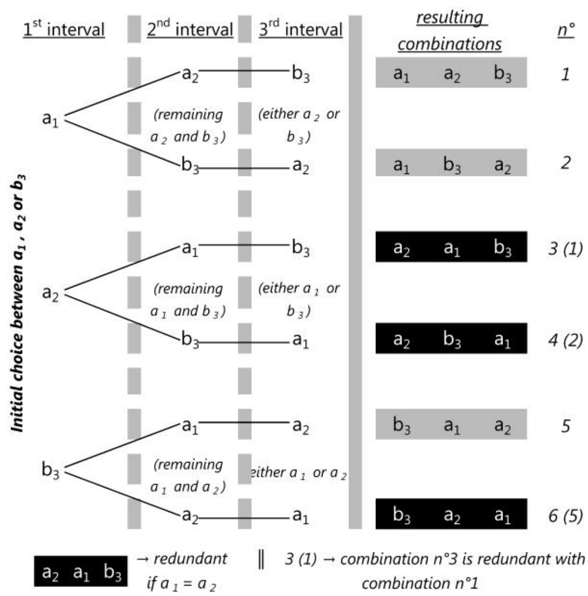


Fig. 10 Tree processing for three intervals.[81]

With the first rank, we may choose between the three intervals a_1, a_2, or b_3 (the subscript plays here more the role of identifier for each interval, than the role of an initial rank number).

Having completed this first step, we still have two intervals of which one must be assigned to the second

[79] The total number of combinations is obtained through the formula N! (or N factorial), in which N is the number of intervals to combine. Here, we have 3! (or three factorial) which is equal to 3 x 2 x 1 = 6. On the other hand, any rotation (or, here, combination of three identical intervals would give the same redundant combination, like in a a a, for example.

[80] This process is used in statistical and probability algorithmic, which is historically a recent domain in science. Reminder: the permutation processes, combined with rotations, are explained in Appendix H.

[81] See previous figure: the outcome is 6 distinct combinations as in the rotation/permutation procedure (see Appendix H), but the result is straight forward; however, if 'a_1' and 'a_2' be considered as identical, there would remain only three distinct combinations out of six possibilities.

position in the series. The third step leaves us with one possibility since two out of three intervals have already been used.

The process is straightforward as it gives directly the six distinct combinations seen above. There are no redundancies although intervals a_1 and a_2 could be taken as equal. In this case, again, we only have three distinct combinations.

The tree processing method is rarely used for combination of intervals and this is one of the reasons why we have to explore further the de-ranking process which is of crucial importance in Modal systematics[82] as it is a practical way for arranging and classifying large numbers of interval combinations, such as in the heptatonic scales.

The de-ranking process, or picking intervals 'N' in a row out of repeated series of 'M' conjunct intervals – Hyper-systems, systems, and sub-systems

De-ranking is closely related to rotation. It is very useful and in the study of musical systems applies mostly to the double octave. In a reduced form, the de-ranking process takes it that a series of conjunct intervals is repeated a certain number of times, for example for in the series a_1 a_2 b_3 a_1 a_2 b_3 a_1 a_2 b_3…[83]

By de-ranking the first interval, we start the series of intervals by the first interval a_2 instead of the first interval a_1. We may consider this process as a rotation of intervals where the first a_1 goes to the end of the extended series. If we choose N intervals out of a repeated pattern of N intervals, this process is a repeated rotation[84] where N = M = 3. (Fig. 11)

In a more general application of this process, N intervals in a row are taken out of a series of M, repeated at least once, with both N and M being integer numbers. In the case of five intervals **a b c d e** repeated once in a row, for example (Fig. 12), we can pick up any series of three conjunct intervals to form a combination. The first ranking combination is **a b c**, the second **b c d**, the third **c d e**, etc.

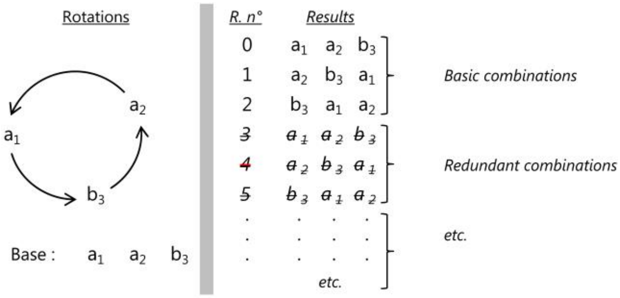


Fig. 11 Endless rotations of intervals as a particular case of the de-ranking procedure.[85]

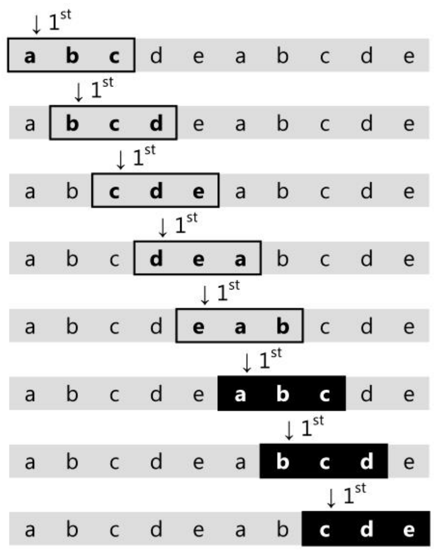


Fig. 12 De-ranking procedure applied to three successive intervals picked out from a double row of five intervals.[86]

If we apply this process to a double heptatonic tense diatonic (ditonic) scale,[87] and in turn select seven conjunct intervals among the fourteen of the series (Fig. 13), beginning with the first interval, the second, the third, etc., and until the seventh, we obtain the seven different species of the scale[88].

In Fig. 13 the basic scale is 1 2 2 1 2 2 2, in which intervals are expressed as multiples of the semi-tone.

This corresponds to the ditonic, and here also, the equal temperament Western scale beginning with *B* or

[82] And for music theory as a whole.

[83] This process is called the Wheel by Byzantine chant theoreticians. It is applied to intervals composing a fifth repeated in a row. See [Giannelos, 1996, p. 89], "Le système de la roue", and [Beyhom, 2015a].

[84] In which case the procedure is called "calibrated de-ranking".

[85] By picking three (N) conjunct intervals, out of three ('M=N') endlessly repeated intervals, beginning with the first, then the second, etc., we end up applying a rotational procedure with, as a result, an endless series of redundant combinations.

[86] There are five distinct combinations out of eight, the last three being redundant with the first three.

[87] Starting here with *B*, for reasons explained farther.

[88] Which are named sub-systems in the theory of Modal systematics.

its equivalents (*b*, *b'*, etc.), or *B* 1 (semi-tone) *c* 2 *d* 2 *e* 1 *f* 2 *g* 2 *a* 2 (*b*). Of all possible species of the double ditonic octave, this scale corresponds to the lowest value when expressing the concatenated intervals as an integer number.

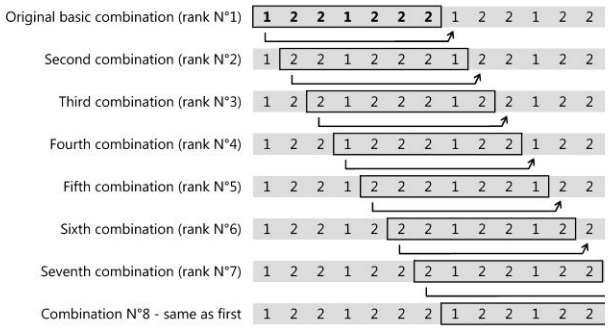


Fig. 13 Calibrate[89] de-ranking procedure applied to two identically composed octaves in a row.[90]

With modal systematics, the first in a series of de-ranked combinations is considered as the basic system.[91] The others, in this example, are sub-systems of system 1 2 2 1 2 2 2 (Fig. 14).

(Hyper-system is ***1 1 2 2 2 2 2****)*	**Rank of the sub-system**	**Beginning note (West.)**	**Intervals in multiples of the semi-tone**						
(Basic system has rank N°1)	**1.**	*B*	**1**	**2**	**2**	**1**	**2**	**2**	**2**
The seven sub-systems (including the basic system) extracted (by a de-ranking process) from basic system 1221222	**2.**	*c*	2	2	1	2	2	2	1
	3.	*d*	2	1	2	2	2	1	2
	4.	*e*	1	2	2	2	1	2	2
	5.	*f*	2	2	2	1	2	2	1
	6.	*g*	2	2	1	2	2	1	2
	7.	*a*	2	1	2	2	1	2	2

Fig. 14 Results of the de-ranking procedure as applied in Modal systematics to the Western ditonic scale.[92]

The hyper-system is the interval capacity indicator that we find in arranging all intervals in a combination from the smallest to the largest. For example, in the hyper-system 1 1 2 2 2 2 2, from which we get that the capacity of all corresponding systems and sub-systems is equivalent to two one-semi-tone intervals and five one-tone intervals, there are other systems which are distinct from 1 2 2 1 2 2 2. They have the same capacity, within the same hyper-system.

In order to find all systems and sub-systems originating from a hyper-system, one needs apply, for example, a combined process of rotations/permutations to its intervals.[93] This has been explained above.[94] If we eliminate the redundant systems or sub-systems, we find (Fig. 15) two other systems for hyper-system 1 1 2 2 2 2 2.

The first of these two distinct systems is the hyper-system itself, as it expresses an arrangement of intervals 1 1 2 2 2 2 2, where the two semi-tones in the first combination are placed in a row, and which is different from 1 2 2 1 2 2 2. This system has in turn seven sub-systems. In this case, they are species.

The remaining system which has the same interval capacity as the precedent ones but whose intervals are arranged following a different pattern where two semi-tones are separated alternately by one, then four, one-tone intervals, is 1 2 1 2 2 2 2, and has, accordingly, seven distinct sub-systems. Fig. 15 shows how hyper-system 1 1 2 2 2 2 2 has intervals that can be combined in three distinct systems which in turn, give each seven different combinations or sub-systems obtained from de-ranking.

This hyper-system is peculiar in that it is the only one composed exclusively of one 'semi-tone' or one 'tone' intervals. If to our alphabet of intervals, we add the 'one-and-a-half-tones' interval class in our model, we find two other hyper-systems, 1 1 1 1 2 3 3 and 1 1 1 2 2 2 3.

[89] I use "calibrated" to characterize de-ranking when it is similar to rotation – see footnote no. 84.

[90] Seven species (or sub-systems in the theory of Modal systematics) may be extracted through the procedure – see also footnote no. 87. Calibrated de-ranking only will be used through the remaining part of the article, and shall simply be called "de-ranking process" or "de-ranking".

[91] Together as the first sub-system of the series.

[92] The sub-system having the smallest figure as a whole number (as an integer concatenated form), is sub-system 1 2 2 1 2 2 2 (in concatenated form 1221222, or 'one million two hundred and twenty-one thousands and two hundred twenty-two'). All other sub-systems have a corresponding integer value which, if their intervals be concatenated to form an integer number, is larger than the former. Consequently, in modal systematics, the combination 1 2 2 1 2 2 2 holds the head rank among these 7 sub-systems and is considered as being the basic system from which the six others are deduced by the de-ranking procedure (the basic system is, besides being the head or base system, the first sub-system in the group of seven). The capacity indicator of these sub-systems is hyper-system 1 1 2 2 2 2 2 (two one-semi-tone and five one-tone intervals).

[93] See Appendix H; there are other more sophisticated algorithms for interval combinations in computer mathematics but my main purpose is to remain as close as possible to an intuitive handling of intervals – see also the introduction ("Impromptu") of Part II in this article.

[94] The hyper-systems, systems and sub-systems are, in the general case of statistical research on scales (in Modal systematics), generated with the help of a computer program based on an extended version of the algorithm shown in Fig. 7, p. 18.

Hyper-system: 1 1 2 2 2 2 2

System	Rank of the sub-system	Beginning note (West.)	Intervals in multiples of the semi-tone						
System N°1: 1 1 2 2 2 2 2	1.	No corresponding "regular" Western scale	**1**	**1**	**2**	**2**	**2**	**2**	**2**
	2.		1	2	2	2	2	2	1
	3.		2	2	2	2	2	1	1
	4.		2	2	2	2	1	1	2
	5.		2	2	2	1	1	2	2
	6.		2	2	1	1	2	2	2
	7.		2	1	1	2	2	2	2
System N°2: 1 2 1 2 2 2 2	1.	No corresponding "regular" Western scale	**1**	**2**	**1**	**2**	**2**	**2**	**2**
	2.		2	1	2	2	2	2	1
	3.		1	2	2	2	2	1	2
	4.		2	2	2	2	1	2	1
	5.		2	2	2	1	2	1	2
	6.		2	2	1	2	1	2	2
	7.		2	1	2	1	2	2	2
System N°3: 1 2 2 1 2 2 2	1.	*B*	**1**	**2**	**2**	**1**	**2**	**2**	**2**
	2.	*c*	2	2	1	2	2	2	1
	3.	*d*	2	1	2	2	2	1	2
	4.	*e*	1	2	2	2	1	2	2
	5.	*f*	2	2	2	1	2	2	1
	6.	*g*	2	2	1	2	2	1	2
	7.	*a*	2	1	2	2	1	2	2

Fig. 15 Complete listing of the systems and sub-systems related to hyper-system 1 1 2 2 2 2 2 (in multiples of the half-tone).[95]

These generate 15 and 20 distinct systems, respectively, or 105 and 140 distinct sub-systems. They are too numerous to be listed here, but an example of sub-system from the first hyper-system is the (Modern)[96] scale of the well-known *Ḥijāz-Kār* Arabian mode, with two *ḥijāz* tetrachords (1 3 1),[97] separated by a one-tone interval: 1 3 1 [2] 1 3 1.[98]

Another example, related to the second hyper-system, is the scale of the contemporary Arabian *maqām Ḥijāz*, which commonly follows the scale 1 3 1 2 1 2 2 when reduced to a semi-tone scale without zalzalian intervals.

Now if we wanted to express the intervals of these hyper-systems in the equal-quarter-tones distribution of modern Arabian theory, then this would give:

1. 2 2 4 4 4 4 4[99]
2. 2 2 2 4 4 4 6
3. 2 2 2 2 4 6 6

If arranged in agreement with modal systematics classification, with the lesser values of hyper-systems holding the lower rank, their places would be reversed as:

1. 2 2 2 2 4 6 6
2. 2 2 2 4 4 4 6
3. 2 2 4 4 4 4 4

Let us now take in consideration the two zalzalian intervals used in modern Arabian theory. These are the three-quarter-tone '3' and the five-quarter-tone '5' intervals, which are conceptually differentiated from the one-semi-tone, one-tone, and one-tone-and-a-half. Combining the five intervals 2, 3, 4, 5, and 6 in seven possible positions, with the condition that the sum of the intervals must be equal to 24 quarter-tones, we end up having 19 hyper-systems (Table 4: 23) with a possible number of 4795 sub-systems or scales. Among them, there are very few in usage.

Scales used in semi-tone hyper-systems such as hyper-systems nos. 1, 6 and 12 in the table, are limited to the ditonic and to the ("Modern", *i.e.* westernized) *Ḥijāz-Kār* or *Ḥijāz* type scales.

For the remaining hyper-systems, scales used in the performance, practice and theory of Arabian, Persian and Turkish[100] music are remarkably few.

[95] Three systems are generated, one of which applies to the western regular scale (semi-tonal ditonic – or simply "ditonic"). The other two scale systems (or seven sub-systems for each system) are rarely used but are found in the specialized literature and used in contemporary music (see [Beyhom, 2003b, p. 48–50] for more details). See Slide no. 20 in the accompanying Power Point show to listen to the scales.

[96] *i.e.* semi-tonal following the influence of the semi-tonal piano.

[97] Or one semi-tone, one tone and a half, one semi-tone: this tetrachord is equivalent to the tonic chromatic tetrachord of Aristoxenos, with the semi-tones placed on both sides of the one-and-a-half-tones interval.

[98] This mode is also frequently assigned to European gypsy music, and also used with film music, notably the score by Maurice Jarre for *Lawrence of Arabia* (dir. David Lean, 1962 – see [Anon. "*Lawrence of Arabia* (film)", 2016]); more about *ḥijāz*-type tetrachords can be found in [Beyhom, 2014].

[99] This is the most homogeneous system among the three, with only two different classes of intervals used.

[100] In the case of the latter music, scales are notated differently but are conceived as being the same as Arabian corresponding scales. This is too lengthy a subject to be treated here, but the reader can have more information in [Beyhom, 2006 ; 2014 ; 2016].

H.	Value	NS	NSS	NSS4	FF	Remarks
1	**2 2 2 2 4 6 6**	**15**	**105**	**58**	**21**	***Ḥijāz-Kār*, "Arabian", "Gipsy" or "chromatic" scales**
2	*2 2 2 2 5 5 6*	*15*	*105*	*23*	*6*	*Very rare: existence not confirmed as (5 2 2 6 2 5 2)*
3	*2 2 2 3 3 6 6*	*30*	*210*	*54*	*0*	*Rare: existence confirmed as (3 3 2 6 2 6 2)*
4	2 2 2 3 4 5 6	120	840	208	60	Variants of N°1
5	*2 2 2 3 5 5 5*	*20*	*140*	*56*	*12*	*Existence not confirmed to this day*
6	**2 2 2 4 4 4 6**	**20**	**140**	**80**	**46**	**Frequent: generates *Ḥijāz* (2 6 2 4 2 4 4)**
7	*2 2 2 4 4 5 5*	*30*	*210*	*40*	*14*	*Existence not confirmed to this day*
8	*2 2 3 3 3 5 6*	*60*	*420*	*120*	*0*	*Existence not confirmed to this day*
9	**2 2 3 3 4 4 6**	**90**	**630**	**168**	**54**	**"Regular" *Ṣabā* (3 3 2 6 2 4 4) and other modes**
10	2 2 3 3 4 5 5	90	630	210	54	Variants of N°1
11	2 2 3 4 4 4 5	60	420	96	36	Variants of N°6
<u>12</u>	**<u>2 2 4 4 4 4 4</u>**	**<u>3</u>**	**<u>21</u>**	**<u>12</u>**	**<u>9</u>**	**<u>Semi-tonal "diatonism" and derivatives</u>**
13	*2 3 3 3 3 4 6*	*30*	*210*	*46*	*0*	*Existence not confirmed to this day*
14	*2 3 3 3 3 5 5*	*15*	*105*	*29*	*0*	*Existence not confirmed to this day*
15	2 3 3 3 4 4 5	60	420	120	36	Scales are close to those of N°6
<u>16</u>	**<u>2 3 3 4 4 4 4</u>**	**<u>15</u>**	**<u>105</u>**	**<u>30</u>**	**<u>18</u>**	**<u>Frequent: Arabian *Bayāt* and other modes</u>**
17	*3 3 3 3 3 3 6*	*1*	*7*	*0*	*0*	*Existence not confirmed to this day*
18	*3 3 3 3 3 4 5*	*6*	*42*	*12*	*0*	*Existence not confirmed to this day*
<u>19</u>	**<u>3 3 3 3 4 4 4</u>**	**<u>5</u>**	**<u>35</u>**	**<u>18</u>**	**<u>9</u>**	**<u>Frequent: Arabian *Rāst* and other modes</u>**
<u>Total</u>	**<u>19</u>**	**<u>685</u>**	**<u>4795</u>**	**<u>1380</u>**	**<u>385</u>**	

Table 5 19 hyper-systems generated within the quarter-tone model with the limited alphabet of intervals with "2", "3", "4", "5", and "6" quarter-tones. Columns to the right of the "Value" column express numbers of systems or sub-systems with or without conditions (fourth or fifth); rows with green background underline hyper-systems that generate most of the scales described in specialized literature, while a gray background stresses the existence of original *Ḥijāz* and *Ḥijāz-Kār* systems, today mostly considered as outdated variants by Arabian (but not Persian, for example) musicians and theoreticians (see [Beyhom, 2014]); H: Hyper-system (numbers in this column correspond to the rank of the hyper-system); NS: Number of Systems in current H; NSS: Number of Sub-Systems in current H; NSS4: NSS in just fourth from tonic; FF: NSS with a just Fourth in a just Fifth from tonic – all these are further explained in the text.

These are no more than 150 to 200 which, when compared to the possible number of 4975, or out of more than eight thousand possible sub-systems with the extended alphabet[101], as we shall see in Part II, raises questions about the criteria differentiating these scales from others.[102]

Some preliminary remarks on the systems and sub-systems of the quarter-tone generative model can already here be expressed:

- Homogeneity of interval composition within a hyper-system results in a lesser number of systems because of the redundancy factor. The less the interval contains different classes of intervals (for example with hyper-system no. 12, which contains only two classes of intervals, the 2 and the 4), the less it generates systems and, consequently, sub-systems.[103] Two relatively homogeneous hyper-systems, nos. 16 = 2334444 and 19 = 3333444, generate scales which are mostly used in Arabian music. Hyper-system no. 17, although very homogeneous, 3333336, is not in use (notably) because its intervals can add up neither to a just fourth (sum = 10) nor to a just fifth (sum = 14).
- Hyper-systems nos. 1, 6 and 12, share with hyper-system no. 19 an important feature: more than half of their sub-systems have a fourth or a fifth beginning with the first interval.
- System 2 4 4 2 4 4 4 in hyper-system no. 12 (this is the ditonic system that we have noted before) maximizes the number of fourths or fifths since six out of seven of its sub-systems contain a direct fourth and a direct fifth in relation to the tonic. Seven out of seven have either of them. This is the only system, among those generated with this model, with such qualities.
- Hyper-systems which have the augmented seconds of Western music in a *ḥijāz* tetrachordal combination (*i.e.*, containing at least one interval of one-and-a-half-tones – or 6 – and two intervals of one-semi-tone – or 2 – in the form 2 6 2) generate large numbers of systems and sub-systems; these are hyper-systems nos. 1, 6 and 9. This is an indication that these scales are a reservoir for modulation from and to ditonic scales. Along with hyper-systems nos. 12, 16 and 19, these generate about one hundred sub-systems that are the most frequently used, or mentioned in specialized literature.

As shown in Table 5, Hyper-systems 12 and 19 are main containers, respectively, for the Western and Arabian scales; Fig. 16 shows the de-ranking process for the scale of *maqām Rāst* and the resulting scales in suites of quarter-tones. The rank of (the scale of) *maqām Rāst* in the quarter-tone database is, however, "3" as the scale of *maqām ʿUshayrān* (3344334) is the scale that minimizes the integer value of the system (Fig. 17).

[101] *i.e.* with intervals greater than the one-and-a-half-tones – see Appendix J (downloadable at http://nemo-online.org/articles) with reproduces the raw results for *systems*: sub-systems can be deduced by de-ranking.

[102] The main question arising here is why, out of this great number of potential scales, traditional music around the world would use only a few? A first answer to this question was given in [Beyhom, 2003c], in which some of the criteria suitable to scale systems in order to verify if they correspond to musical practice as we know it are identified, such as the presence of a fourth or fifth from the tonic, and/or the absence of particular scale combinations (such as combining two large intervals in a row, or more than two semi-tones in a row, etc.). Applying these conditions, as well as others, to the scales of the quarter-tone generation which can be made up, we can get close enough to the configuration of scales used today, particularly in Arabian music. Exceptions to the main hyper-systems can be dealt with separately, and will give valuable information about this particular music, and, of others, and the additional criteria applying to it. Note that traditional pre-*Congrès du Caire* of 1932 (see [Anon. "Cairo Congress of Arab Music", 2016]) Arabian music used other scales still (mainly in connection with the Old *ḥijāz* and *ḥijāz-kār* tetrachords – see [Beyhom, 2014]) that today are mostly lost, notably because of the influence of Western music and theory.

[103] There is a relatively simple empirical formula for the calculation of the number of systems which can be generated by a hyper-system provided that the total Number of Intervals in one hyper-system is NI intervals, and that different classes of intervals contained in the hyper-system have a capacity Oi (each interval i is reproduced Oi times in the hyper-system), the number of distinct permutations of intervals within the hyper-system is equal to (NI!)/(O1! x O2! x O3! etc.). In the case of hyper-system no. 12, interval 2 occurs five times, and interval 4 twice, by replacing in the formula we obtain the number of distinct sub-systems or [(7!)/(5! x 2!)] = [5040/(120 x 2)] = 21. The structure of the formula explains why homogeneity of the conceptual intervals composing a hyper-system, is a factor that lessens the number of resulting (non-redundant) sub-systems.

Reintegrating these scales in the general database of the quarter-tone model and arranging them in ascending order we get the scales issued from the de-ranking process on Fig. 18. This allows for a permanent and unambiguous identification of the 4795 scales of the Octavial database.

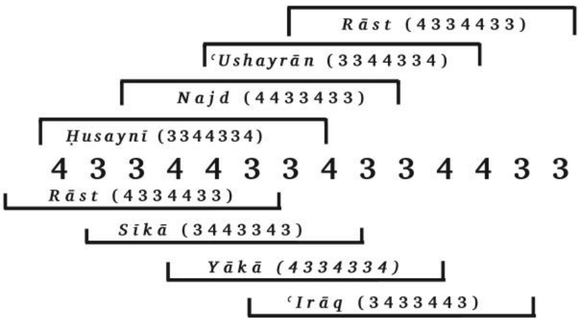


Fig. 16 De-ranking the scale of Arabian *maqām Rāst*.

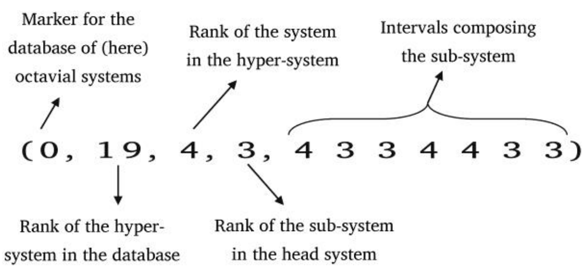


Fig. 17 Classifying the scale of *maqām Rāst* within the octavial[104] database in the quarter-tone model (reduced alphabet with '2, 3, 4, 5, 6' quarter-tones).

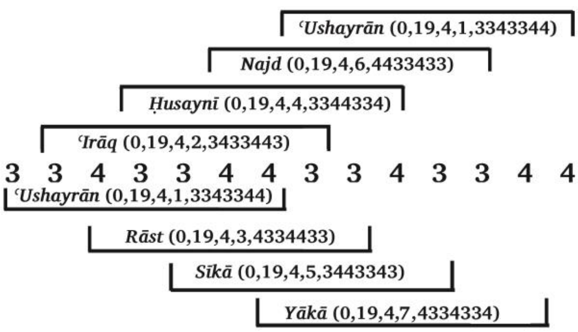


Fig. 18 De-ranking the scale of *maqām ʿUshayrān* within the general database of the quarter-tone model (with reduced alphabet '2, 3, 4, 5, 6' with quarter-tones) and corresponding classification of the resulting scales.

Useful to know, the scales of hyper-systems nos. 12, 16 and 19, although stemming from hyper-systems with a reduced generative capacity, with about 22% of the total of sub-systems, form from two thirds to three quarters of the reservoir of scales used, or attested in Arabian music.[105]

Their ratio of sub-systems with a double fourth and fifth from the tonic is close to 39% with most of the other sub-systems in usage (see rows with variants or "close to" in the column of remarks of Table 5, *i.e.,* hyper-systems nos. 4, 10, 11 and 15 – the number of sub-systems marked FF for these represents a ratio of more than 46% of the total) contained in hyper-systems related to them.

- In the "Remarks" column with Table 5, variants are mainly scales containing an alternative *ḥijāz (-kār)* tetrachord made up of intervals of 2, 3 and 5 quarter-tones. This is a possible indication that this tetrachord evolved from earlier forms such as 2 5 3 or 3 5 2, to our standardized form of 2 6 2, because of the pressure induced by the existence of the semi-tone equal temperament.[106]

These remarks, made on the basis of the quarter-tone generative model of modal systematics, suggest already some criteria which may be applied in statistical studies of systems and sub-systems as we shall apply in Part II of the present article. These criteria will help answer the question why out of 12 possible intervals in a semi-tone distribution, or out of almost 24 intervals in a quarter-tone distribution, only seven are combined, in most music, to form an octave? And why are there three intervals in a fourth and four in a fifth, generally.

Before answering these questions, we must return to Urmawī's tetrachords, in order to have a better understanding of how, by applying the qualitative interval differentiation concept, uneven divisions of the octave can amount to even ones.

[104] As explained further in the text, Modal systematics also applies for non-octavial scales, a subject explored in [Beyhom, 2003c] but too voluminous to be explained here.

[105] Some of the scales found in the literature are questionable: a review of Arabian scales is given in [Beyhom, 2003b] (for example p. 15-50).

[106] This is discussed in [Beyhom, 2007b], and further in the dossier [Beyhom, 2014].

Applying modal systematics to Urmawī's tetrachords

In Urmawī's model, we have distinguished intervals of the second by means of the capacity of integers, from 1 to 5 (Fig. 6: 16). If we combine these intervals in the frame of a fourth, the sum of which must be equal to seven elementary intervals, we obtain the following hyper-systems:

- 1 1 5
- 1 3 3
- 1 2 4
- 2 2 3[107]

Hyper-systems within the fourth as a containing interval, with two identical intervals generate one single system equivalent to the generative hyper-system. They amount to three: 1 1 5, 1 3 3 and 2 2 3. Among them, the last two agree with Urmawī in the *Book of cycles*, with intervals not greater than the tone. By de-ranking, possible combinations of the intervals contained in the three aforementioned hyper-systems are, for the first, combinations 1 1 5, 1 5 1 and 5 1 1. For the second, combinations 1 3 3, 3 3 1 and 3 1 3. For the third, combinations 2 2 3, 2 3 2 and 3 2 2. The remaining hyper-system, 1 2 4, generates two systems resulting in six distinct combinations which stem from 1 2 4: 1 2 4, 2 4 1 and 4 1 2, and stemming from system 1 4 2: 1 4 2, 4 2 1 and 2 1 4 (Fig. 19, left).

All tetrachords in hyper-systems 2 2 3 and 1 3 3 are known both to Urmawī's *Book of cycles* and to modern *maqām* theory of the quarter-tone division of the octave (Fig. 19, right).

The possible but missing tetrachords in the treatises have in common peculiar features: each of them contains two small intervals in a row, either two consecutive conceptual semi-tones or *leimmata*, or a *leimma* and a *mujannab* in a row, similar to the 1 and 2 intervals in Urmawī's qualitative model (Fig. 19, left), and the 2 and 3 quarter-tones intervals in the quarter-tone model (Fig. 19, right). This is another criterion which will be applied in the statistical study which follows.

At this point, we may also note that the connection between the quarter-tone model and the model in Urmawī's qualitative interval equivalents is straight forward: in order to shift from Urmawī's model to the quarter-tone model, add one unit to each interval in the first (Table 6).

All the scales of the quarter-tone model connect directly with Urmawī's qualitative representation, through a unitary vector subtracted from the interval values in the former. For example, the *maqām Ḥijāz* scale, 2 6 2 [4] 2 4 4 (sum = 24) in modern *maqām* theory (the square brackets identify the disjunctive tone between two tetrachords), becomes 1 5 1 [3] 1 3 3 (sum = 17) in Urmawī's model, and the *maqām Rāst* 4 3 3 [4] 4 3 3, in quarter-tones becomes 3 2 2 [3] 3 2 2, or two similar tetrachords composed of, successively, one 'one-tone' and two *mujannab* intervals, with a disjunctive one-tone [3] interval.

Urmawī	Transition	Quartertones	Transition	Urmawī
1	+ 1	2	-1	1
2	+ 1	3	-1	2
3	+ 1	4	-1	3
4	+ 1	5	-1	4
5	+ 1	6	-1	5

Table 6 Transition from Urmawī's conceptual intervallic representation to the quarter-tone model, and reciprocally.

In the model applied to Urmawī's intervals which consist in a division of the octave in 17 equal parts, the total sum of the intervals must amount to 17 elementary intervals in one octave.

The transition to the quarter-tone interval is straightforward, as by subtracting one unit in each conceptual interval of a heptatonic scale in the quarter-tone model, we end up subtracting seven units from the total of 24 quarter-tones, which gives the sum of 17.

All the scales of the quarter-tone model, arising from the hyper-systems in Table 5: 23 have equivalent counterparts in Urmawī's model.[108] This proves that the two models are, in essence, conceptually equivalent.[109]

[107] These intervals can be considered, for the sake of simplification, as multiples of the 17th of an octave. The 17-ET model is a simplification of the 17 unequal intervals scheme(s) and is conceptually equivalent to the latter. This applies equally to the 24-ET model used in the statistical study in Part II of this article with a limitation of the smallest conceptual interval to the semi-tone.

[108] And reciprocally – see Appendix J for systems in Urmawī's model.

[109] Complementary research (see [Beyhom, 2007c] and [Beyhom, 2010b] showed a continuity of the 17 unequal intervals per octave model (or seven elementary intervals in a just fourth and three in a one-tone interval), throughout the history of Arabian theory, beginning with Kindī (9th century).

Hyper-system	System	Rank of the sub-system	Intervals in qualitative numbers					Equivalents in quarter-tones		
Hyper-system N°1: **1 1 5**	System N°1: **1 1 5**	**1.**	**1**	**1**	**5**	?	Extended tetrachords	**2**	**2**	**6**
		2.	1	5	1	exists		2	6	2
		3.	5	1	1	?		6	2	2
Hyper-system N°2: **1 2 4**	System N°1: **1 2 4**	**1.**	**1**	**2**	**4**	?		**2**	**3**	**5**
		2.	2	4	1	exists		3	5	2
		3.	4	1	2			5	2	3
	System N°2: **1 4 2**	**1.**	**1**	**4**	**2**	exists		**2**	**5**	**3**
		2.	4	2	1	? (rare)		5	3	2
		3.	2	1	4	?		3	2	5
Hyper-system N°3: **1 3 3**	System N°1: **1 3 3**	**1.**	**1**	**3**	**3**	exists	*Urmawīs' tetrachords*	**2**	**4**	**4**
		2.	3	3	1	exists		4	4	2
		3.	3	1	3	exists		4	2	4
Hyper-system N°4: **2 2 3**	System N°1: **2 2 3**	**1.**	**2**	**2**	**3**	exists		**3**	**3**	**4**
		2.	2	3	2	exists		3	4	3
		3.	3	2	2	exists		4	3	3

Fig. 19 Urmawī's tetrachords (the two hyper-systems below) and additional potential tetrachords, in both conceptual (qualitative) interval modeling (left) and quarter-tone approximation model (right). The tetrachords of Urmawī represent the full potential of the related hyper-systems; additional tetrachords (and hyper-systems) exist only partly in literature (and practice) of traditional Arabian music.

As a further consequence, all the results from the statistical analysis, resulting from generations with the limited alphabet, from 2 to 6 quarter-tones, may be applied to Pythagorean equivalents in Urmawī's model.[110]

Another conclusion may be drawn at this stage. Urmawī's concept of the scale, regardless of Pythagorean procedures used to explain, or legitimize his ideas about music, is profoundly Aristoxenian and based on a combination model. Moreover, Urmawī's concept is, as with Modern Arabian theories of the scale, additive (see Fig. 21), and not divisive (*i.e.* Pythagorean-based – see Fig. 20).

In modern terms, altering an interval[111] is different from altering a note of the scale. Whenever altering an interval means adding or removing a measuring (or small conceptual) interval from it, altering a note in western (Pythagorean based – Fig. 20) theories is a divisive concept,[112] from which we deduce that d^{flat} is one comma lower than $c^{\#}$, whenever an "augmented" *b_c* interval (or its equivalent) with Urmawī will always be below the "diminished" *c_d* interval.[113]

[110] The internal structure of the fourth or of the fifth may differ within the 17 intervals to an octave model and the quarter-tone model, when considering possibilities other than the three intervals to the fourth and four intervals to the fifth. Furthermore, the 17th of octave model allows a differentiation between the chromatic tetrachords, based on hyper-system 1 2 4 in the 17th of octave model, and the enharmonic tetrachord which may be represented by system 1 1 5.

[111] A common characteristic in "Oriental" theories of the scale, including Byzantine chant – see [Azar Beyhom, 2012] for the explanations of Mīkhāʾīl Mashāqa (who compares the "Arabian scale", according to him, with Chrysanthos Madytos' scale) about Arabian modes in the first half of the 19th century, and [Beyhom, 2015a] for more explanations on the alterations in Byzantine theories of the scale (19th to 21st centuries).

[112] Intervals *c_c#* and d_d^{b} intersect – see Fig. 20.

[113] Consecutive action of the alterations: intervals $c\_c^{\#}$ and d_d^{b} are independent from one another, and separated by $c^{\#}\_d^{b}$ which is one *leimma* – see Fig. 21.

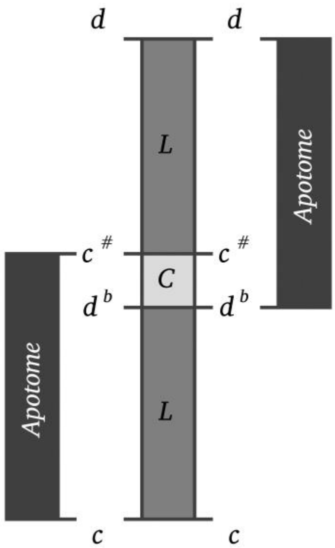


Fig. 20 Alterations in Pythagorean theories adapted to the Common practice scale of western music are divisive: intervals $c\_c^{\#}$ and d_d^{b} intersect.[114]

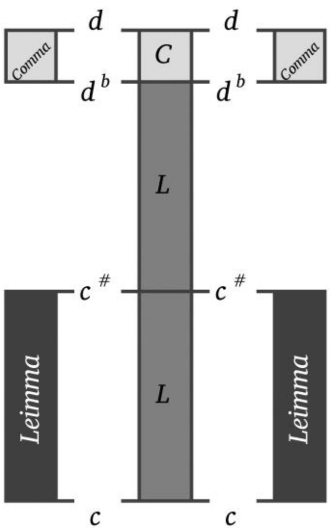


Fig. 21 Conjunct intervals and consecutive action of the alterations with Urmawī: intervals $c\_c^{\#}$ and d_d^{b} are independent from one another, and separated by $c^{\#}\_d^{b}$ which is one *leimma* – adapted from Fig. 17, p. 115 in [Beyhom, 2014].

This applies as a rule to the composition of conceptual intervals using elementary intervals. The intervals within a fourth are derived from a combinatory process where the fourth and the fifth add up to an octave, a concept we can find throughout by Urmawī, with similar additive constructions of the tone, the fourth and the octave (Fig. 22).[115]

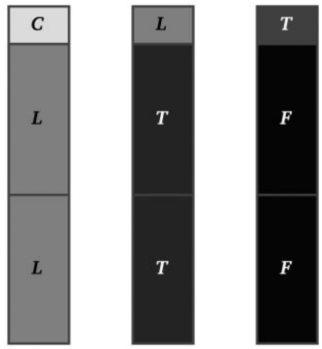


Fig. 22 Similar concepts by Urmawī for the construction of the tone (left), the fourth (center) and the octave (right).[116]

Conclusion for Part I

A quantitative model based on the equal division of the octave can be a qualitative model, taking in account the size of the intervals of which the scale is composed. They express the number of elementary intervals which build up each of the conceptual intervals.

In the case of the quarter-tone model, the smallest elementary interval is the approximate quarter-tone (the measuring interval), the smallest conceptual interval is composed of two elementary intervals, or two approximate quarter-tones, etc. Combining the resulting conceptual intervals, we combine qualities of intervals that are differentiated by their capacity to contain elementary small intervals (Fig. 23).

Urmawī's concept is that there are two elementary intervals: the *comma* and the *leimma*. In modern Arabian quarter-tone theory, these would be the quarter-tone and the semi-tone, respectively.

This means that the scales which result from that type of generative model have intervals of seconds which, if measured exactly, would differ from one another even when having the same interval capacity; for example, a one-tone interval in one scale may be slightly different from a one-tone interval in another scale, as

[114] Adapted and translated from Fig. 16, p. 115 in [Beyhom, 2014]; *L* stands for *leimma*, *C* for *comma*, both Pythagorean.

[115] In his *Book of cycles*, Urmawī takes the fifth (as was the case in Ancient Greek theory which inspired him) as a fourth to which a one-tone interval is added. With this concept of the scale, a fourth plus a fifth amounts to the same as combining two tetrachords (in fourth) and a one-tone interval in the frame of one octave, which, in Modal systematics, is equivalent to the combination of three intervals (among which two are equal) with a fixed sum.

[116] *L* stands for *leimma*, *C* for *comma*, *T* for one-tone interval, *F* for (Just) fourth – see also FHT 28, p. 141 in [Beyhom, 2014] which shows the three levels of structuring of the intervals in Urmawī's general scale.

differences of intonation may occur – but the interval remains conceptually the same.

However, these intervals, when taken in relation to other intervals in the scale carry a unique quality which differentiates them from the latter, which is typical of modal systematics.

Part II. Combining intervals in a system: statistical analysis

Impromptu on Modal systematics, or "Why so much computing?"

One frequent remark about Modal systematics is that its systematical generation of scale elements is huge[117], and partly "useless"; objections that came from renowned mathematical-musicologists[118] were mainly that there existed other, more economical ways of generating scales with the criteria defined in the original 2003 thesis and which were partly explained in Part I of this article.

Whenever this remark is true, these mathematicians forget two important facts: 1) a theory of traditional music[119] should never prescribe it, but only describe it; 2) the original idea of Modal systematics was not the elaboration of a "new" theory of the scale, which would prescribe, or even describe it; it was to found a series of tools based on intervallic description in order to, firstly, generate all the possible scalar elements within a particular model, then (secondly) apply supplementary tools to try to understand the mechanisms of the elaboration of the scale, through the thorough examination and comparison of the existing reservoir of polychords and scales of the so-called "Oriental" musics with the unconstrained possibilities of scalar elements generation.[120]

Within this reservoir, the Western semi-tonal scale of Common practice[121] is but a byproduct of the process of scale elaboration,[122] while the semi-tonal scalar elements are[123] explored at length, and systematically compared to the other two models[124] proposed in this article: it was most important to understand how the today predominant music in the world could fit within the process of elaboration of the heptatonic scale, which eventually disclosed itself,[125] and what characteristics[126] could differentiate it from its "Oriental" cousins.

In the process, some particularities of the structure of semi-tonal music were also uncovered,[127] and help understand, on one side, what were some of the mechanisms of the elaboration of the Western scale and, on the other side, how[128] these particularities were implemented in musics it has influenced.[129]

117 See examples in appendices I, J and K.

118 Mostly in France, from IRCAM (Institut de Recherche et Coordination Acoustique/Musique).

119 That every theory of the elaboration of the scale should be.

120 The main difference between generative theories and adaptive theories such as Modal systematics is that, although Modal systematics uses arithmetic and mathematics to model scale structures, its final goal is to adapt its axioms, and to sort the results in function of criteria stemming from existing musics in order to better understand and explain them. Other generative theories generally work independently from the existing structure of musics, and base themselves on axioms which are frequently biased or ill-adapted such as, for example, using successive thirds or fifths (either Pythagorean or in equal-temperament) as a paradigm for the formation of traditional scales (see for instance [Beyhom, 2016], Chapter III: "The cycle of fifths").

121 Because other Western scales exist, notably traditional European scales that are ignored by Western mainstream musicology; not to forget the post-Classical period and its micro-tonal explorations.

122 A fact that Western musicology overlooked for centuries, and that it still endeavors to dismiss – see [Beyhom, 2016] on this matter.

123 For obvious reasons, one of which being that not all musicologists are connoisseurs of *maqām* theories and particularities; a constant reference to the semi-tonal model could help in such case comprehend the other models explored in this article.

124 The quarter-tone and the 17th of the octave models, which can be considered as conceptually equivalent within the limits imposed to the quarter-tone generations.

125 See the Synthesis: the Hypothesis is the result of the application of the theory of Modal Systematics, the initial purposes of which were 1) understanding the reasons for the number seven of intervals in the (heptatonic) scales, and 2) understanding the mechanisms at work in modal music, for *maqām* in particular.

126 Apart from the obvious semi-tonal division of the octave.

127 Or ascertained.

128 And partly why.

129 One other particularity of the tools of Modal systematics, explored at length in the original Ph.D. thesis (in the IIIrd part of Volume 1, entitled "Systématique du *maqām*", [Beyhom, 2003a, p. 287–341]), is that determining the characteristics of traditional *maqām* music can help explore alternative scales within the frame of tradition: examples of such scales are proposed in the aforementioned thesis {see [Beyhom, 2003a, p. 333–335], with a few recorded – for three of them non-traditional – examples, namely Tracks 13 and 15-18 on the accompanying audio CD, entitled "13 - Beyhom - *Sīkā-Ḥijāz*", "15 - Saab 19, 5, 2, 3434343 sur *la*^{db}", "16 - Saab 19, 5, 2, 3434343 sur *si*^{db}", "17 - Multaka, AbuSamra 16, 13, 3, 4433424" and "18 - Multaka syst. modal 16, 7, 2433534 sur *ré*^{dd} - *mi*^{db}, *si*^{b}, *la*^{db}, *do*^{dd}, *fa*^{dd}, (*sol*)"}.

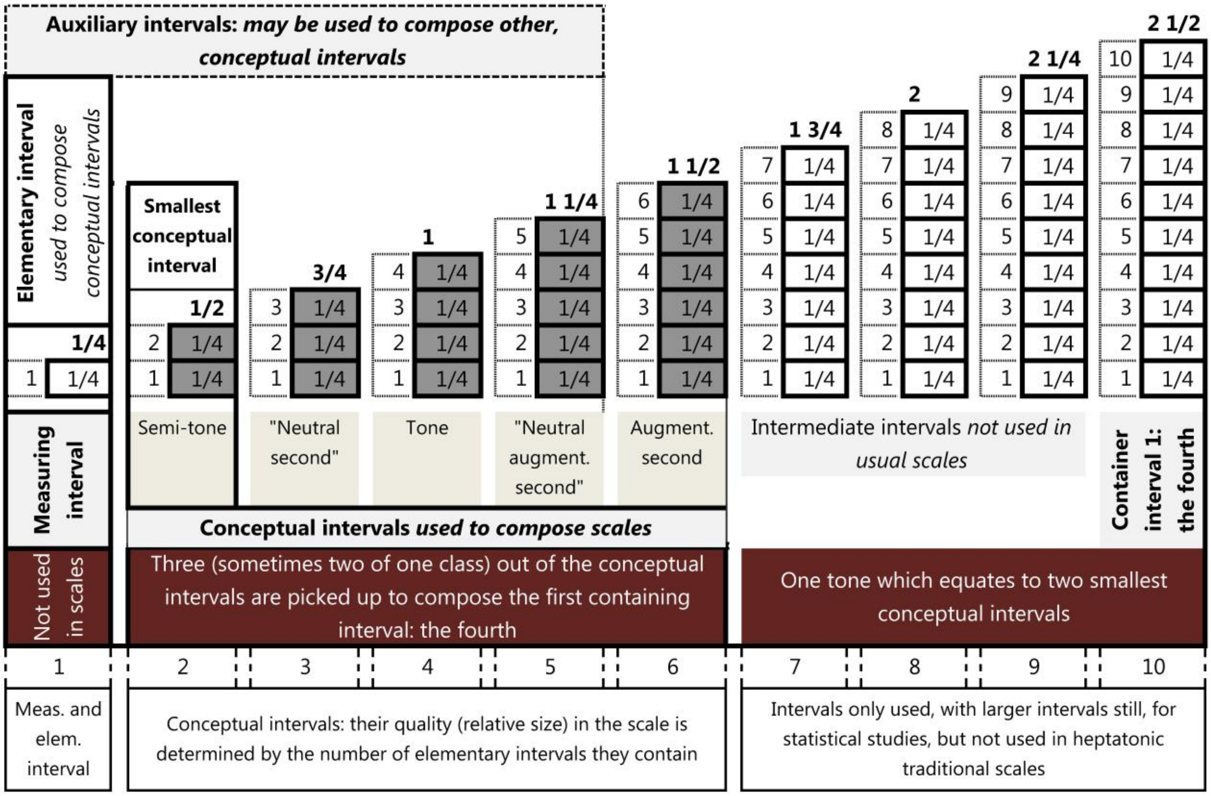


Fig. 23 Measurement, elementary, conceptual and containing intervals within the fourth in the quarter-tone model. This figure introduces the concept of auxiliary intervals, *i.e.*, smaller conceptual intervals which if combined with elementary intervals may be thought of as composing larger conceptual intervals, such as the zalzalian augmented second, which has five quarter-tones and which can be conceived as made up of a one-tone interval plus one elementary interval, that is a quarter-tone.

Reminder about the basics of Modal systematics

With modal systematics the basic process consists in combining intervals expressed as integers and then analyzing the results in relation to both music practice and theory. The elements of the scale consist in a sequence of consecutive conceptual intervals.

Conceptual intervals are stand-alone units in the scale. They are distinct in theory and in practice. They are placed between the notes of the scale. Their function is qualitative.[130] For an immediate identification of any interval in a scale series, Modal systematics determines the optimal (or the smallest, with the largest elementary interval) division of the scale, in such a way that the quantifying interval is the smallest conceptual interval and the elementary interval. In the semi-tone scale, the semi-tone is such that it fulfills the functions of quantifying, elementary and conceptual intervals.

With Arabian music,[131] the semi-tone model is ineffective because conceptual intervals, such as the zalzalian tone or zalzalian augmented second – the *mujannab* and the greater tone in Urmawī's model in Fig. 6: 16, or the three-quarter-tones and the five-quarter-tones intervals in the quarter-tone model (Fig. 23: 30), cannot be distinguished and identified as conceptual intervals. Therefore, another division of the octave is necessary to provide qualification for all types of intervals.

[130] Although some theoreticians may consider them as an exact expression of the size of the intervals, which would be the wrong conclusion to make: recent research on the scales of *maqām* music (see [Beyhom, 2010b ; 2012 ; 2015a]) suggest that equal-divisions (with unequal interval sizes) of the string on lute-type instruments is probably the first theorizing tool used by musicians. The numbers of divisions used vary from one culture to another, one lute-type (or tuning) to another, but these still show a research of an optimum between complexity and expressivity (a concept explained further in this article) and confirm the general process explored in this article.

[131] As well as for an imposing other types of music.

In this case it is the 17-ET, or the division of the octave in 17 equal intervals[132] which is needed, since this division allows for the distinction of all conceptual intervals. These small intervals have values (Fig. 6: 16) of 1 to 5.

Integers segregate the semi-tone 1, the *mujannab* or zalzalian second 2, the tone 3, the zalzalian augmented tone, or greater tone above 4 and the fully augmented tone, greatest tone above 5.[133] However, the 17-ET model has a flaw which makes it difficult to see it as a representative division of the octave (Fig. 24).

If taken strictly as a measuring interval, the 17th of an octave is 71 cents. Adding these intervals, we have 494 cents for a fourth and 706 cents for a fifth. These figures are close enough to the corrected values of the fourth and the fifth in the Pythagorean system, *i.e.,* 498 cents and 702 cents.

The problem lies with the representation of the semi-tone. If the 17th of an octave is conceptualized as a semi-tone interval, the discrepancy with an equal temperament semi-tone, in approximation is 29 cents, or $100-71=29$, which is unacceptable to most musicologists.

As a result, and although the measuring 17th of an octave interval which divides the octave in 17 equal parts is also an elementary[134] and a conceptual interval,[135] we shall take the quarter-tone model for Arabian-Persian-Turkish music bearing in mind the equivalence between the two models.[136]

The principle of economy: optimal balance between method and expression

In his first paragraph of his *Tonality of homophonic music*, Helmholtz said of the musician's liberty:

> "Music was forced first to select artistically, and then to shape for itself, the material on which it works. [...] Music alone finds an infinitely rich but totally shapeless plastic material in the tones of the human voice and artificial musical instruments, which must be shaped on purely artistic principles, unfettered by any reference to utility, as in architecture, or to the imitation of nature as in the fine arts, or to the existing symbolical meaning of sounds as in poetry. There is a greater and more absolute freedom in the use of the material for music than for any other of the arts. But certainly it is more difficult to make a proper use of absolute freedom, than to advance where external irremovable landmarks limit the width of the

132 Which may be combined in order to compose conceptual intervals.

133 The sizes of the greater and greatest tones in the 17-ET model suggest that the augmented second could be less, or greater than, the equal-temperament one-tone-and-a-half. The *ḥijāz* tetrachord (which today is usually made up of, in this order: one-semi-tone, one-tone-and-a-half, and one-semi-tone) is not mentioned in Urmawī's list of tetrachords. This is very strange since this tetrachord is a combinatory variant of the old tonic chromatic Greek *genus* and commonly used in contemporary traditional music. Comparing sizes of the greater and greatest tones in the extended model, the difference between them would be one *comma*, which is the same difference existing between the *leimma* and the smaller *mujannab* (or the equivalent of an *apotome*). However, the relative size of one *comma*, compared to one *leimma* or one *apotome*, is very different from its relative size when compared to the greater and greatest tones. The difference, which is (for untrained ears) already difficult to hear between, for example, a double-*leimma* and a Pythagorean tone (add one *comma* to the former to obtain the latter), would be even less distinguishable between the two larger intervals. On the other hand, Urmawī could not have used the *leimma* between the greater and the greatest tones in order to differentiate them, as this would not have allowed for space, in the frame of a fourth, for two additional semi-tones (or *leimmata*) in a tri-intervallic configuration (Fig. 6, p. 16 – if we add one *leimma* to the greater tone, the capacity of the greatest tone would have to be one *comma* plus four *leimmata*. The capacity of the fourth in a Pythagorean 17 intervals model, is two *commata* plus five *leimmata* – *i.e.*, a difference of one *comma* plus one *leimma*. This leaves no space for the two additional *leimmata*). This is possibly the reason why Urmawī gave up the *ḥijāz* tetrachord in its two (three) potential Pythagorean expressions, which would have been (a) M_1+Ts+S or a succession of one small *mujannab* (*leimma* + *comma*, or *apotome*) plus one greater tone (tone + *leimma*) plus one semi-tone (*leimma*), (a') $S+Ts+M_1$ or a succession of one semi-tone plus one "greater tone" plus one *mujannab*, and (b) the regular succession of one-semitone (*leimma*), greatest tone (tone + small *mujannab* – or *apotome*) and one-semi-tone (*leimma*) intervals (or L + greatest tone + L) – see also the documented article [Schulter, 2013] on *buzurg*- (and *ḥijāz*-) like tetrachords (including in the Systematist era), and [Beyhom, 2014] on the modern *ḥijāz* tetrachord (in French).

134 Used in the composition of other intervals.

135 Furthermore, that the numbers in the scale series express, before all, the quality of the intervals.

136 As a general remark on Urmawī's Pythagorean model, the sizes of zalzalian intervals, particularly in the *Book of cycles*, seem a bit far from their counterparts in music practice (and in Fārābī and Sīnā's theories). Owen Wright has explored this at length in his aforementioned *The Modal system…* I have shown, however, that Urmawī's concept of the scale is not tonometric. It is qualitative (and conceptually additive). This is why the quantitative values of the intervals should not be taken into consideration for practice. Only their qualitative values should, of which the most important being the *mujannab* which lies somewhere (in size) in-between the one-*leimma* and the one-tone intervals. Appendix K (download from http://nemo-online.org/articles) is provided for comparisons between the quarter-tone generations and the 17th of the octave generations – as explained above, it suffices to add 1 to each interval in Urmawī's scales to obtain the quarter-tone equivalents.

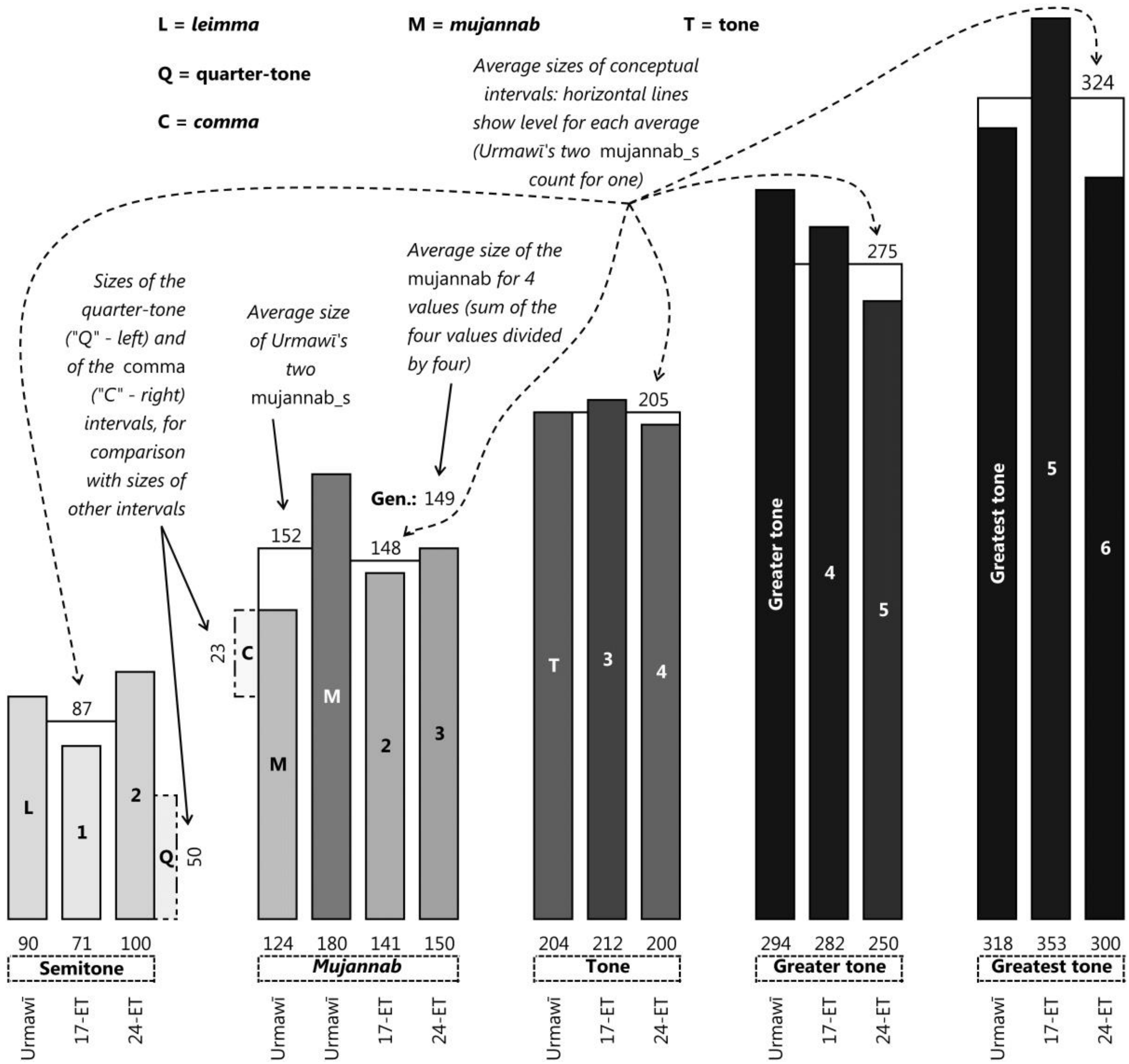


Fig. 24 Conceptual intervals from Pythagoras and Urmawī's, 17-ET and 24-ET models. Averages show that the transition from one conceptual interval to another, respectively 61, 57, 70, 49, with the average value of 59, can be modeled by either the one-seventeenth of an octave, 71 cents, or the quarter-tone interval of 50 cents. The usage of *commata* and *leimmata* in Urmawī's model accentuates the unevenness with zalzalian intervals, the *mujannab* and the greater tone – the "zalzalian augmented" second.

> path which the artist has to traverse. Hence also the cultivation of the tonal material of music has […] proceeded much more slowly than the development of the other arts. It is now our business to investigate this cultivation".[137]

For thousands of years, freedom in music has been restricted by the necessity to produce recognizable pitch patterns making up melodies.[138] To this end, most cultures use heptatonic scales. They are a paradigm for composition. In order that a melody can be recognized, the degrees of the scale must be identifiable by pitches in relation to the other degrees of the scale.

When these are expressed as intervals, they become conceptual intervals where each has its own quality so that they can be identified. Conceptual intervals must neither be too small as they would be too difficult to

[137] [Helmholtz, 1895, p. 250].

[138] Free Jazz or contemporary Western music break away from this principle and try to explore all the possibilities of sound. These attempts, although sometimes memorable, were never popular. It could be that music has an emotional power which may not exist with other forms of art, and that this emotion is induced by a process of reminiscence, the more predominant in music because of 1) its transience and 2) due to the long-term impossibility of recording it.

perceive, nor too big, as in both cases melodies may not be easily perceived.

Variations of intonation or subtle differences of intervals, especially with music which does not answer to any known temperament, are the consequence of impromptu performance, great mastery, regional variations, organology, particular tuning and so forth, all combined with the ability of the performer.[139] In a traditional process of knowledge transmission, however, these subtle variations, particularly in the domain of performance mastery and instant creativity, take place at a later stage of music understanding and perception.[140]

In order to transmit and receive,[141] a basis must be found allowing for a firm structure of the musical discourse, whilst allowing the performer the possibility to further develop his freedom of interpretation. This basis, which is the essence of the melodic repertoire, is commonly named the scale.

When confronted with an audience, a traditional musician of average talent would try to perform with utmost expression and invention, keeping in mind the need for a melodic pattern that his listeners will recognize.

This process should request the least possible energy whilst taking the least possible steps within the continuum of pitch, in the search for balance between technique (or complexity of the means used) and expression (or the effect of the musical discourse on the audience).

In order to achieve this goal, this musician would ideally need to have previously tested all possibilities, within an octave or other important containing intervals, and determine which would result in the maximum number of expressive possibilities.[142] The process for interval combination and the search for the optimal number of intervals within a "fourth", a "fifth" or an "octave"[143], will be defined as stemming from the *principle of economy*.

A semi-tone and quarter-tone model for polychords and scales

The two models in this study are the (semi-tonal) Western and the (Modern, quarter-tonal) Arabian. Whilst Common-practice western music uses the semitone, the quarter-tone is the basis of conceptual divisions with the *maqām* where subtle refinements reveal modal complexity.[144] In both cases, the smallest conceptual interval is an approximate semi-tone.

A recurrent objection to the use of the semi-tone interval as a smallest conceptual interval is that the Arabian quarter-tone is half its size. Some theoretical modern descriptions of *maqām Awj-Āra*, for example, show indeed one quarter-tone intervals in the scale.

[139] See [Beyhom, 2006 ; 2007a ; 2007b ; 2014 ; 2015a ; 2016], notably in connection with modal heterophony.

[140] Whilst most of the characteristics described in this section correspond to melodic and *maqām* music, it would have been an aberration to include in these the characteristics of the semi-tonal harmonic language, as these are historically a later exception in music worldwide. Too many Western theoreticians and "musicologists" from the 18th-21st centuries have forgotten this simple fact in their eagerness to promote the ditonic scale as the perfect paradigm for music – see [Beyhom, 2016].

[141] This is the basis of tradition, and traditional music worldwide.

[142] If intervals are too small or too large, there are no longer any scale, or any pattern for the melody.

[143] The terms fourth, fifth and octave are in double-quotes because, in the statistical study, all possible compositions of these containing intervals are considered, *i.e.*, with more than, or less than, three (or four, or seven) conceptual intervals to a just fourth (or to a just fifth, or to an octave).

[144] Turkish music and Byzantine chant follow roughly the same rules as Arabian music. They used the *maqām* as a *lingua franca*. The Turkish model is an extension of Urmawī's scale which might be better adapted to transpositions for the long necked *ṭunbūr*, and in the Chrysanthos of Madytos' version of 1818, Byzantine chant follows a 17-ET paradigm (extended to the 68th of an octave, by dividing the 17th of an octave in four parts, called *minutes* – although Chrysanthos' scale, the same as with Urmawī, is not based on equal-divisions of the octave, the relationship between the two scales is direct; see [Beyhom, 2015a] and Chapter IV in [Beyhom, 2016]). The 1881 Byzantine version of the Music Committee of Constantinople, a 24-ET model, had each quarter-tone being further divided in three equal measuring intervals (or a semi-tone equal temperament, with each of the semi-tones divided in six equal minutes, resulting in a 72-ET model – in practice, however, the divisions of the scale correspond to even multiples of the *minutes*, *i.e.* sixths of the tone). In both types, conceptual intervals remain equivalent to those in Arabian music, with the greatest conjunct tone (in the chromatic tetrachord) of Byzantine chant being equivalent to the greatest tone in Urmawī's model. On the other hand, Ancient Indian music follows the same concept of interval quality because with the principle of 22 unequal *śrutis* the conceptual intervals are the result of a theoretical concatenation of smaller intervals, which are themselves elementary and auxiliary intervals (see also the second part of [Beyhom, 2012] – for an overview of the tonal systems of Indian music, see for example [Powers and Widdess, 2001], p. 170-178). Other subdivisions of the scale, for example those of Javanese and other musics, would be explored in detail in future publications.

This *maqām* is reminiscent of Turkish music as its scale is similar to the *maqām Ḥijāz-Kār,* but with *AWJ* (=b^-)[145] as its starting note. This causes some cultural and technical problems with the organology of the *ʿūd,* because of the usage of the theoretical equal-quarter-tone in the 1920s and 1930s.[146] These problems are easily resolved with the difference between conceptual and measuring intervals I have explained.[147]

Another objection to Arabian performance is mainly with *maqām Sīkā.* It begins, as its name suggests, with *SĪKĀ*, = e^-. In the quarter-tone model, this scale equates to 3 4 4 3 3 4 3, beginning with e^- and with a b^- between the conjunct two-three-quarter-tones intervals. In the common Arabian tuning of the *ʿūd*,[148] the open strings of lower pitch are often used as drones repeating the fundamental note of the *maqām*.[149] In order to reinforce the fundamental, some contemporary lutenists tune the lowest auxiliary string to E^-. Many, however, prefer to keep the original tuning[150] and use a technique of fast alternation between e^- and a note about a third of a tone lower,[151] and quickly coming back and insisting on e^- so that the fundamental e^- is reinforced. The small interval used between e^- and the slightly lower pitch[152] is only a variation and is used intonationally. Its main function is to underline the importance of e^-, the next, the lower degree in the scale being d, which is (approximately) three quarter-tones away from e^-. This is why the performer must use a smaller interval of intonation leading to the fundamental.[153]

Now that these two main problems have been addressed and that the limitation of small intervals is taken in both models as equal to the conceptual semi-tone, two possibilities have been considered regarding the largest interval in the scale. It must be firstly limited only by the size of the octave, and by the minimum of two intervals amounting to a scale element, or secondly by the largest conceptual interval in both models, *i.e.*, the one-and-a-half-tones interval.[154] As a result, each generative process uses alternatively two alphabets. In the semi-tone generation, the first alphabet is without limitations except for the semi-tone division. The largest interval in the alphabet is the largest possible allowed in a particular generation. The second alphabet is reduced to the three conceptual intervals of one semi-tone 1, one tone 2, and one and a half-tones, 3, or augmented second. This also applies to the generation process for the quarter-tone, except that in this case, the interval increments are quarter-tones, with a limited alphabet of 2, 3, 4, 5 and 6 of them (Fig. 23: 30).

The generative process is simple. A computer program detects all the combinations of a certain number of intervals given in an initial alphabet of conceptual intervals (with a fixed sum of elementary intervals), and arranges the results as hyper-systems, systems and sub-systems. This process starts with the minimum possible number of intervals in the scale elements[155] and ends with the maximum possible number of elements in the containing interval. The minimum number of intervals

145 *Maqām Ḥijāz-Kār* traditional beginning (and reference) note is *RĀST*, commonly considered in Arabian music as equivalent to the Western note *c*.

146 This was mainly spread through the collective *Recueil des Travaux du Congrès de Musique Arabe qui s'est tenu au Caire en 1932 (Hég.1350)*, [Collectif, 1934], and Erlanger's fifth tome of *La musique arabe*, [Erlanger, 1949].

147 For a detailed study of this problem, see [Beyhom, 2003a, p. 314–317] – in French. Furthermore, in a live performance, I have heard only once an Arabian version of *maqām Awj-Āra*. This was played by Moroccan lutenist Saïd Chraibi, in 2005. In a private conversation, the musician explained that he used the scale of *Awj-Āra* as given in Erlanger because he could not get a hold on a recorded Arabian version of this *maqām*. Chraibi had already made at least two recordings [Chraibi, s.d. ; s.d.] including this *maqām*, with no references or commercial identification, which I later acquired under the titles *Souleïmane* and *Taquassim Aoud*.

148 This instrument is the main reference in both theory and practice for Arabian music and musicians. It is commonly tuned in ascending fourths with an additional (lowest) variably tuned string. This string is sometimes tuned to e^- whilst performing *maqām Sīkā* or other modes beginning on e^-.

149 The drones are sometimes used to accentuate the role of a structural note of a particular scale.

150 The tuning of the *ʿūd* is difficult and time consuming. One musician has confided to the author and other participants, during a workshop at Royaumont (France), and probably with some exaggeration, that he had probably spent half of his twenty years of professional career tuning the *ʿūd*. See [Beyhom, 2006].

151 Mostly when coming back to the fundamental as a resting note.

152 An approximate third of the tone (66 cents), which is very close to a 17th of an octave (71 cents.).

153 This whole discussion wouldn't need to take place, had the Arabs kept the 17 intervals paradigm of Urmawī: alas, Western theories of the scale have been very efficient at influencing Arabs and others, resulting in the quarter-tone notation.

154 Bearing in mind that the size of this interval may be, in performance, greater or lesser than the exact one-and-a-half-tones.

155 A scale element, here, is equivalent to a succession of conjunct intervals forming a containing interval. The minimal possible succession is made up of two intervals. The statistical study of the octave containing element (infra) shows sometimes the results for one single interval (NI = 1), to show symmetry with (NI = 12).

in combination is two, and the maximum depends on the containing capacity of the intervals in the model.

With both models this corresponds to the number of half-tones in a row which can be arranged in a containing interval, *i.e.,* five for a fourth, seven for a fifth and twelve for an octave.

Preliminary definitions and remarks

Specialized terms for scale systems will be used throughout this study, their definition follows:

1. A scale system is a sequence of numbers for different classes of conjunct (conceptual) intervals within the frame of a containing element.[156] This is defined as an interval composed of conceptual intervals with the sum of the containing element equating to the number of elementary intervals building up to it set to a certain value. Containing intervals are equal to the fourth, with an ascending frequency ratio of 4/3, and the fifth, with a frequency ratio of 3/2, and the octave.
2. A hyper-system is a capacity indicator of conceptual intervals. It is a scale element in which these intervals and the numbers composing the sequence, are re-arranged to form the least integer when numbers are concatenated. Hyper-systems are arranged, in the frame of a generative process, from the smallest (when expressed in integer concatenated form) to the largest.
3. A system is a particular arrangement of intervals in a hyper-system. Systems are also scale elements. They are arranged from the lowest corresponding integer to the highest within the hyper-system. A hyper-system is identical to the first ranking system it generates.
4. A sub-system is a particular arrangement of intervals inside a scale element which corresponds to a de-ranked system. The original system is the first sub-system, and each de-ranking produces the next ranking sub-system. The number of conceptual intervals, NI, henceforth, limits the number of sub-systems in a system, as some of the combinations resulting from the de-ranking process may be identical and therefore redundant. The number of non-redundant sub-systems may therefore be lesser than the corresponding NI. The first ranking sub-system in a system is identical to the head system.
5. NI is the number of conceptual intervals of conjunct seconds which constitute a scale element. In the statistical study below, NI is variable and extends from two conceptual intervals in a scale element, to the maximum possible number of smallest conceptual intervals in a row within the containing interval. In both models, the maximum number of conceptual intervals in a scale element is equal to the number of conjunct semi-tones – the smallest conceptual interval – required to build it up. The maximum number of conceptual intervals in a containing interval (NImax) of a fourth is equal to the number of semi-tones needed, *i.e.,* five consecutive semi-tones (NImax = 5).

A typical example of the relationship between hyper-systems, systems and sub-systems is shown in Fig. 15: 22 and Table 5: 23 where the 19 hyper-systems of the quarter-tone model generation with the limited alphabet 2, 3, 4, 5, and 6, and with seven intervals (NI = 7) to the octave, are arranged in ascending integer values. A typical hyper-system generates ditonic scales, *i.e.,* hyper-system no. 12 in the generation with the reduced alphabet (Table 5: 23). This hyper-system generates three systems (Fig. 15: 22) for the corresponding semi-tone model, when each in turn generates 7 distinct sub-systems by de-ranking intervals in each system.[157]

Table 5 is specific to the general combination process used in modal systematics. Since the containing interval is equivalent to the octave, the sum of the integers (in un-concatenated form) in each scale is 12 half-tones in the semi-tone, and 24 quarter-tones in the quarter-tone model.[158]

[156] Note that arbitrary smaller scale elements can be used, such as the eighth or the twelfth of the tone (or even the quarter-tone), but these are not conceptual intervals and would be used only for the purpose of further study of combinations with smaller divisions of the tone (or of the octave).

[157] Reminder: the full database of the hyper-systems, systems and sub-systems of the heptatonic scales in the quarter-tone model, with the limited alphabet of intervals, can be found in Appendix I (download from http://nemo-online.org/articles) and in [Beyhom, 2003b], p. 113 *sq.*

[158] Computations in Urmawi's model show that the results would be, however, similar to the results in the quartertone model, with

With the fourth, the respective sums in the two models are 5 semi-tones or 10 quarter-tones, and in a just fifth 7 and 14 respectively. The equality of the intervals of the semi-tone and the quarter-tone models is straightforward. For the transition from a semi-tone interval system to its equivalent in the quarter-tone model, simply multiply the intervals of the integers by two. To reverse the process, divide all the integers in the quarter-tone model by two. However, intervals represented by odd integers in the quarter-tone model have no equivalents in the semi-tone model. This is the reason why the ranks of the hyper-systems in the semi-tone model are corrected to their rank in the quarter-tone model, as explained in the next section.

The main question is why the generally assessed number of conceptual intervals in a modal scale is seven in an octave, or what is the optimal number of conceptual intervals in containing intervals with ratios 4/3, the fourth, 3/2, the fifth, and 2, the octave.

Combining intervals within a fourth: filters and criteria

In a combination process of conceptual intervals using the semi-tone as the smallest conceptual interval, the sum of the containing interval of the fourth[159] must be 5 in the semi-tone, and 10 in the quarter-tone models. Our first goal is to find all combinations of intervals of the alphabet that sum up to these values.

In the semi-tone generation (Fig. 25, top), the alphabet is unlimited, except by the semi-tone structure of the intervals. The smallest interval is the semitone, and the largest, for NI = 2 (two intervals in combination) can therefore only be a 4 semi-tones interval, 4 in the concatenated sequence of intervals, '[14]' in the first hyper-system of the semi-tone scale generation with NI = 2.

The sum of the two intervals in the first hyper-system is equal to 1 + 4 = 5. The other hyper-system for NI = 2 is 23, with two intervals 2 and 3 (the semi-tone value is represented by the two digits).[160] The rank of the hyper-systems (first column to the left) is given both in the semi-tone (plain numbers) and the quarter-tone models (between brackets) if the two differ.

If the hyper-system does not exist in the semi-tone model, only the rank of the corresponding quarter-tone hyper-system is given (one number between brackets). For NI = 2, the two hyper-systems 14 and 23 both generate one single system, with two sub-systems for each system. For NI = 3, we still have two (but different) hyper-systems (or capacity indicators) which generate each one single system, but with three sub-systems each (due to the three conjunct intervals in the system).

This generation corresponds to the commonly accepted number of three intervals in a fourth, and contains the tetrachord equivalent of the tense diatonic *genus*, hyper-system 122, and of the tone, or tense chromatic: 113. For each of NI = 4 and NI = 5, we obtain one single hyper-system, with four sub-systems for NI = 4, and five identical, (with four which are redundant) sub-systems for NI = 5.

The total numbers of hyper-systems, systems and sub-systems in each case figure in the row below the last sub-system.

A first, and evident remark can be made. A small number of intervals, NI, implies that larger intervals have more chances to find a place in the system, whenever a larger NI results in an increased use of smaller intervals, notably here the semi-tone. Additional rows below the grand total give the numbers of remaining sub-systems for each NI whenever some eliminating conditions are met (the number of excluded sub-systems is shown in brackets, with a minus sign):

1. The total number of non-redundant sub-systems is equal to the initial total number of sub-systems minus the number of redundant sub-systems in each case. Redundancy occurs once in the semi-tone model, for NI = 5. Here the hyper-system, system and sub-system(s) are identical, as one single interval class, the semi-tone, is used in the scale element. These redundant sub-systems, generated through the de-ranking process, are struck out in Fig. 25 and must be excluded from the generative process.

mainly differences in the composition of the lesser containing intervals, *i.e.* the fourth and the fifth: these and other particularities of Urmawī's model will be explained in a further publication.

[159] We shall use the terms fourth, fifth and octave henceforth, bearing in mind that the number of intervals in these containing intervals is variable, and represented by NI. The term "just" for each of these intervals is to be considered as an implicit quality.

[160] These two intervals are taken as a successive one-tone and a one-and-a-half-tones

Semi-tone model

Rank of HS	NI = 2			NI = 3			NI = 4			NI = 5		
	HS	S	SS	HS	S	SS	HS	S	SS	HS	S	SS
1	14	14	$\underline{14>}$, $\underline{41>}$	113	113	113*, **131**, 311*	1112	1112	1112*, 1121*, 1211*, 2111*	11111	11111	11111*
(2)												~~11111*~~
2 (3)	23	23	$\underline{23§}$, $\underline{32§}$									~~11111*~~
2 (4)				122	122	**122, 221, 212**						~~11111*~~
(5)												~~11111*~~
Total	2	2	**4**	2	2	**6**	1	1	**4**	1	1	**5**
Total non redundant (-)			(-0) 4			(-0) 6			(-0) 4			(-4) 1
Double semitone criterion (*)			(-0) 4			(-2) 4			(-4) 0			(-5) 0
Conjunct big intervals (§)			(-2) 2			(0) 6			(-0) 4			(-0) 5
Intersecting criteria 1 (OR)			**(-2) 2**			**(-2) 4**			**(-4) 0**			**(-5) 0**
Large intervals			*(-2)*			*(-0)*			*(-0)*			*(-0)*
Small conjunct different intervals			*(-0)*			*(-0)*			*(-0)*			*(-0)*
Intersecting criteria 2			**(-4) 0**			**(-0) 4**			**(-4) 0**			**(-5) 0**

Quarter-tone model

Rank of HS	NI = 2			NI = 3			NI = 4			NI = 5		
	HS	S	SS	HS	S	SS	HS	S	SS	HS	S	SS
1	$\underline{28}$	$\underline{28}$	$\underline{28}^{>}$, $\underline{82}^{>}$	226	226	226*, **262**, 622*	2224	2224	2224*, 2242*, 2422*, 4222*	22222	22222	22222*
2	37	37	$37^{>}$, $73^{>}$	235	235	235, **352**, 523	2233	2233	2233*, 2332, 3322*, 3223*			~~22222*~~
(2) 3	$\underline{46}$	$\underline{46}$	$\underline{46}^{§}$, $\underline{64}^{§}$		253	**253**, 532, 325		2323	2323, 3232, ~~*2323*~~ , ~~*3232*~~			~~22222*~~
4	55	55	$55^{§}$, ~~*55*~~ §	244	244	**244, 442, 424**						~~22222*~~
(4) 5				334	334	**334, 343, 433**						~~22222*~~
Total	4	4	**8**	4	5	**15**	2	3	**12**	1	1	**5**
Total non redundant (-)			(-1) 7			(-0) 15			(-2) 10			(-4) 1
Double semitone criterion (*)			(-0) 8			(-2) 13			(-7) 5			(-5) 0
Conjunct big intervals (§)			(-4) 4			(0) 15			(-0) 12			(-0) 5
Intersecting criteria 1 (OR)			**(-4) 4**			**(-2) 13**			**(-9) 3**			**(-5) 0**
Large intervals			*(-4)*			*(-0)*			*(-0)*			*(-0)*
Small conjunct different intervals			*(-0)*			*(-4)*			*(-8)*			*(-0)*
Intersecting criteria 2			**(-8) 0**			**(-6) 9**			**(-12) 0**			**(-5) 0**

Fig. 25 Combinations and filters in the frame of a fourth containing interval: HS = Hyper-system, S = system(s), SS = sub-systems. Multiple criteria are applied, allowing for a better modeling of tetrachords existing in traditional music practice.

2. The 'double semi-tone criterion' (an asterisk is added at the end of each sub-system which responds to this criterion) excludes (separately from other filters) sub-systems containing two semi-tones in a row (conjunct semitones).[161] This filter, which has been inspired from Arabian music, is most effective when applied to sub-systems with a large number of intervals of greater values. If two consecutive semi-tones are present in a heptatonic scale, they are commonly found at the sides of the junction between two tetrachords, or at the junction between a scale and its equivalent to the octave, lower or higher.[162]
   - For larger containing intervals such as the fifth and the octave, this criterion is applied for three conjunct semi-tones.[163]
3. The 'conjunct large intervals' filter (sub-systems marked with §) excludes scale elements containing at least two conjunct intervals larger than, or equal to, the one-tone interval, and among which one, at least, is larger than a tone. This is a general rule which is present in the heptatonic Arabian traditional scales. Examples of sub-systems with such characteristics are 46 and 55[164] for NI = 2 in the quarter-tone model (Fig. 25, bottom). The criterion is most effective with smaller values of NI.[165]
4. All these filters operate independently. If we combine them in one complex criterion, filtered sub-systems will add up or merge ('neither nor', or a Boolean inversed 'OR' operator in the theory of ensembles) with a resulting number of filtered sub-systems in the row entitled 'Intersecting criteria 1'.

The aim is to compare, excluding all filtered sub-systems, the results of the generative process for different values of NI and to determine the optimal number[166] of conceptual intervals in the containing interval. The results of the semi-tone generation, with or without filters applied to them, are shown in the two graphs of Fig. 26.

The generation with NI = 3 (or three conceptual intervals in a containing fourth interval) gives the largest number of independent, non-redundant, sub-systems, *i.e.,* 6. The filters or criteria, accentuate this optimal value.

If we exclude scale elements comprising large intervals (greater than the one-tone-and-a-half)[167] in addition to those excluded through the 'intersecting criteria 1' composed filter, the remaining two sub-systems in the case NI = 2 would be equally eliminated, leaving thus the case NI = 3 as the unique possibility concerning the ability to generate a just fourth (see 'intersecting criteria 2', Fig. 25).[168] The same applies to the quarter-tone distribution, (Fig. 27) with however some quantitative and qualitative differences in the contents of the two generations.

161 This filter is one of the aesthetic criteria deduced from contemporary Arabian music and from Urmawī's model (which forbids two consecutive conceptual semi-tones). However, they do not necessarily apply, in the case of the fourth, to all modal music.

162 See next footnote.

163 See [Powers et al., 2001], p. 775-860, sub Mode, §V, 3: Middle East and Asia: Rāga – (ii) Modal entities and the general scale, notably p. 838: "There are a few evident parallels between South Asian and West Asian orderings of modal complex and general scale. For instance, in both cases a given modal entity will use only some of whatever pitch positions an octave span of the general scale makes available – in principle seven – and normally no more than two intervals of the semi-tone class will occur in a succession in a single modal complex." For the fourth, the 2 conjunct semi-tones filter is sufficient: note that there must be no exception for the tetrachord 622 Erlanger recognizes as *Sipahr* (see [Erlanger, 1949, v. 5, p. 91] and the note to his first volume, p. 30). Erlanger says that he felt this (old tonic chromatic of Aristoxenos) tetrachord, should be included among other Arabian tetrachords. In [Fārābī (al-) et al., 1935, v. 2, p. 276], Erlanger (or Manoubi Snoussi, his secretary, see Poché's introduction to the second edition [Fārābī (al-), 2001]) explains, nevertheless, that "In *genera* theory, the most sensitive matter is the order in which the intervals (de-)composing the fourth in melodic sounds are placed, in relation to one another. With Arabian music, or at least in its urban form, that may be called classical, there is no occurrence of two consecutive semi-tones in the same tetrachord".

164 In multiples of the quarter-tone. These are hyper-systems three and four (for NI = 2) in Fig. 25, bottom.

165 Sub-systems having intervals larger than the largest conceptual second (the greatest tone – in both models taken as equal to one tone and a half) are marked with a post positioned '§' and kept 'as is', even when the conjunct large intervals filter is applied. However, their number is shown for each case (for each value of NI) in the Conjunct big intervals row.

166 The smallest NI giving the largest number of sub-systems, after eliminating sub-systems that do not comply with the aesthetic criteria listed in Fig. 25.

167 This is equivalent to a generation with the limited alphabet of 1, 2, 3 in the semi-tone generation, and to 2, 3, 4, 5, 6 in the quarter-tone model.

168 The small conjunct different intervals criterion has no effect on the results of the semi-tonal generation.

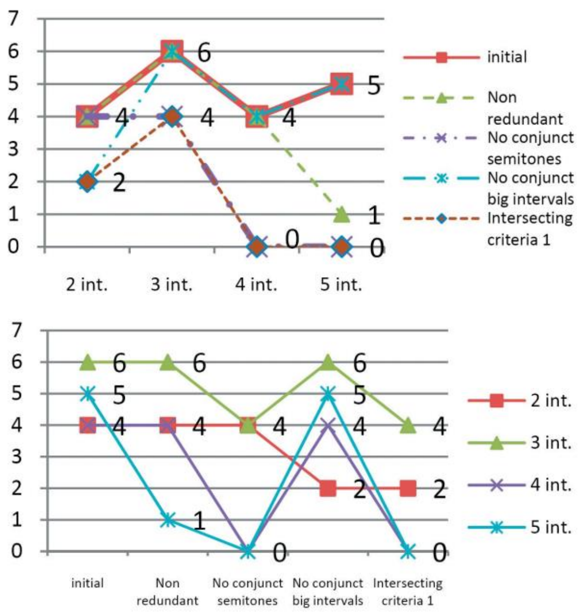


Fig. 26 Graphs of the distribution of sub-systems in a fourth, in relation with the number of intervals (conceptual conjunct intervals of second) in the scale element (above), and in relation with applied filters (below – cross-reference) for each case (NI = 2, 3, 4 and 5) – semi-tone model.[169]

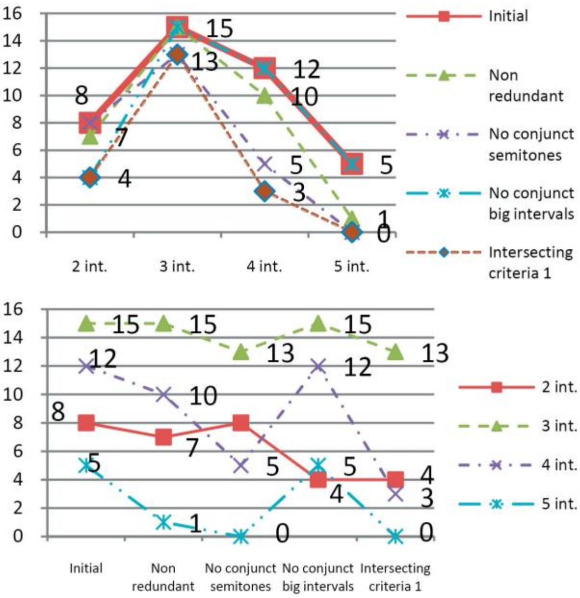


Fig. 27 Graphs of the distribution of sub-systems in a fourth, in relation with the number of conjunct conceptual intervals of second (NI) in the scale element (above), and (below) in relation with filters (cross-reference) applied in each case (NI = 2, 3, 4 and 5) – quarter-tone model (compare with Fig. 26).

A first difference is that the quarter-tone model (Fig. 25: 37, lower half and Fig. 27) generates, as expected, intermediate and additional hyper-systems containing zalzalian interval equivalents (or odd multiples of the quarter-tone) which are for example hyper-systems nos. 2 and 4 in the case of NI = 2.

Whenever the smallest and largest intervals are the same, in both semi-tone and quarter-tone generations, for the same NI (due to the limitation of the smallest conceptual interval to the semi-tone in both cases), then the intermediate hyper-systems generate additional sub-systems in the quarter-tone model. The optimal number of intervals (the most economic choice) is still three.

All the filters accentuate the optimal value by giving the two neighboring sections of the line a smaller angle (in Fig. 27, top, 'intersecting criteria 1' give the most acute angle around value 13 for NI = 3).

Fig. 25: 37 shows, however, that the new possibilities in the quarter-tone model are not fully integrated, for NI = 3, in Arabian music, although this case comprises no redundant sub-systems.[170] The new sub-systems 235, 532, 523 and 325 are seldom or never used in this music, as the only configuration for hyper-system 235, with its two systems 235 and 253, seems to be the one which places the largest interval in the middle (*i.e.,* sub-systems 253 and 352).

If we were to add this criterion (*i.e.,* if we dismiss sub-systems containing suites of very small intervals such as 23 or 32, in the quarter-tone model) to the filters already used for the semi-tone model of the fourth, we would end up having NI = 3 as the unique possibility for this containing interval, because the remaining sub-systems for NI = 4 are excluded by this criterion (see the row 'intersecting criteria 2' for the quarter-tone model in Fig. 25: 37).

169 Results for filtered sub-systems should be compared to the values of the non-redundant line on the top-most graph, and to the corresponding values on the bottom one.

170 This is because in order to generate redundant sub-systems, a system must contain a repetitive pattern, for example 112 (in the semi-tone multiples) in the 112112112 scale (an octave scale for which NI = 9, and the sum of the conjunct intervals S = 12) in the semi-tone model – other considerations allow for a better understanding of the redundancy phenomenon: see Appendix G which further explores this problematic (notably the final Addendum concerning generations in the fourth and the fifth Containing intervals), and the accompanying Power Point show with audio examples for redundant scales, in both semi-tonal and quarter-tonal models.

The reverse *pycnon* rule

All the filters and criteria used with the fourth correspond to common practice and theory and their application provides with complementary information on the aesthetics of modal music, especially with the *maqām* and modal diatonic[171] music. It would be interesting however to try to find one single criterion which would have the same effect as the four criteria explained above.[172] Taking a closer look at the composition of the sub-systems commonly in use in the ditonic and Arabian music (Fig. 25: 37; quarter-tone model, in bold), and comparing the sums for any two conjunct intervals within them, we come up with a very interesting conclusion. All these sums are comprised between 6 and 8 quarter-tones.

Fig. 28 shows pairs of conjunct intervals in ascending values from the top and the left, beginning with a first interval of 2, and conjunct intervals (from top to bottom), beginning also with a 2, incremented until the maximum which is 8 quarter-tones, in order to complete the sum for the fourth. The next column shows the same process, starting with interval 3 and a conjunct interval 2, with the conjunct interval incremented by one unit downwards. The largest interval for this column is 7, since the sum of the two intervals may not exceed 10, which is the value of the fourth in multiples of the quarter-tone.

The process continues for the other columns until all possibilities are given. Common bi-interval combinations are written in bold on grey background for combinations commonly used in Arabian music, or on black background for ditonic tetrachords. Sums are given on the top right or bottom left corners of each bi-interval element. Equality of the sums follows oblique parallel lines, from bottom left to top right (or reciprocally). All series with two conjunct intervals found in the commonly used tetrachords are concentrated in the three oblique rows with sums of 6, 7 or 8. Other combinations have sum values below or above.

This is a very strong indicator for homogeneous interval distribution of the intervals within the scale. If we add to all these bi-interval combinations other intervals, to the left or to the right and check those which follow the rules of homogeneity (Fig. 29), we end up having only common tetrachords listed in Fig. 25: 37.

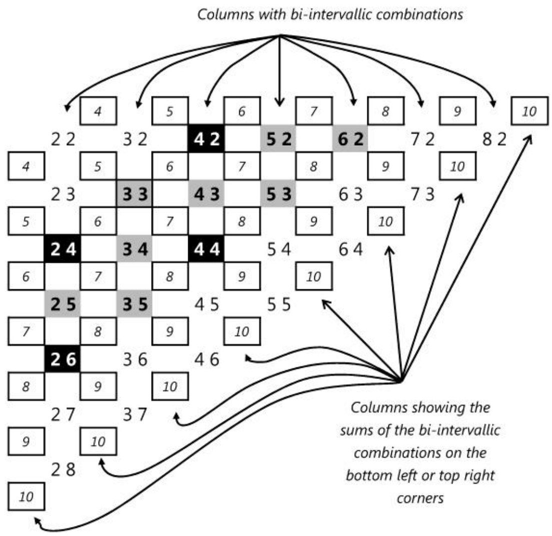


Fig. 28 Bi-interval elements of the generation for a containing interval of fourth in the quarter-tone model.[173]

With a single criterion applied to the intervals of the sub-systems within the fourth, there is a model which is the closest possible to common practice and theory. Furthermore, this rule of homogeneity is the reciprocal of Aristoxenos' *pycnon* rule (see Fig. 30).

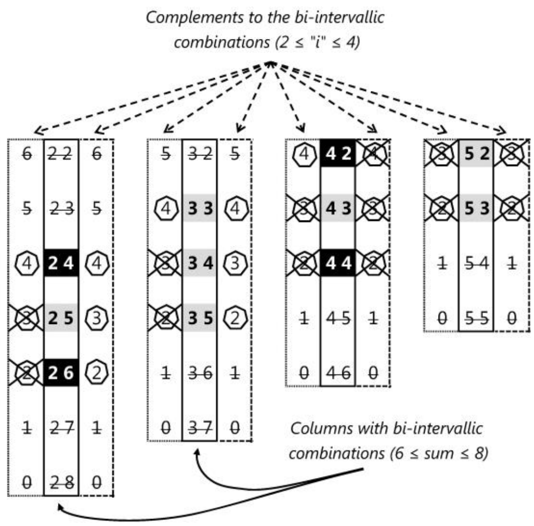


Fig. 29 Complements to the bi-interval elements of common use (black or grey background) on both sides of the elements, in order to obtain one tetrachord on each side.[174]

[171] Here in the general meaning of the word, *i.e.* not having a *pycnon* – see "The reverse *pycnon* rule" below).

[172] I do not count here the non-redundancy criterion, as this filter is self-evident.

[173] Commonly used combinations are concentrated in (and occupy completely) the sector where sum values are comprised between 6 and 8 (both values included) – on black background: ditonic combinations; on black or grey background: Arabian combinations.

[174] After redundant combinations (crossed intervals) are excluded, and by eliminating all combinations that do not comply with the homogeneity rule (which states that the sum of any two conjunct

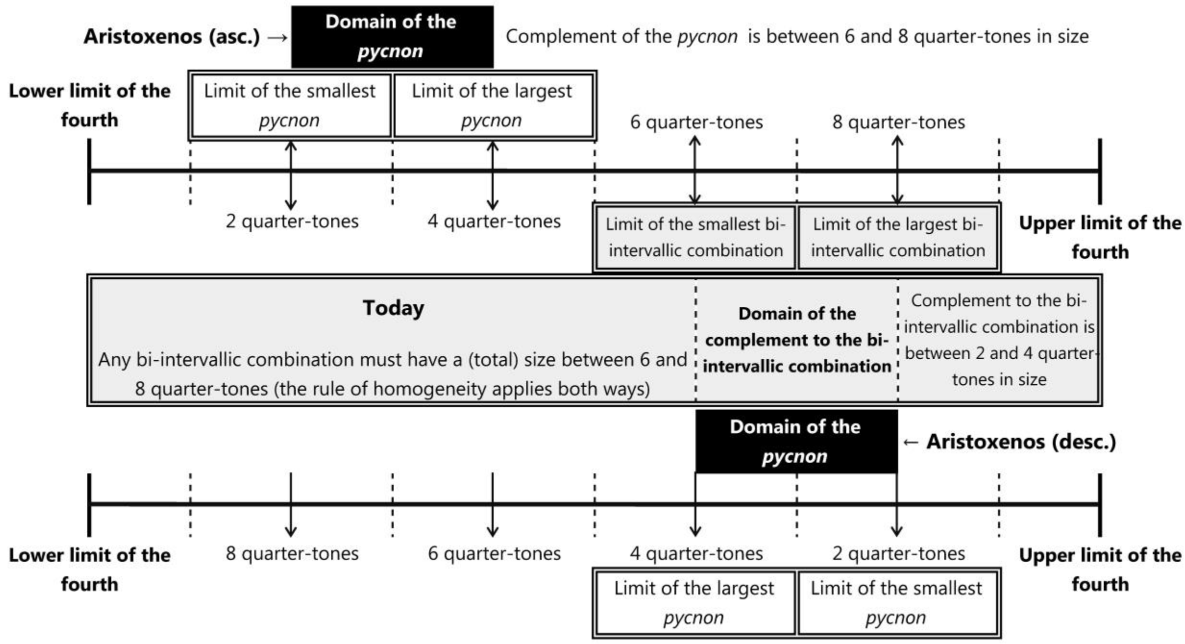


Fig. 30 The homogeneity rule, or reverse *pycnon* rule. If Aristoxenos' tetrachord is falling, the domain of the *pycnon* is the domain of the complement of the bi-interval combination (within a fourth) in today's traditional heptatonic modal music. This applies to all tetrachords of common use in Arabian music, including the chromatic tetrachord *ḥijāz* (the symmetrical 262 in multiples of the quarter-tone) and its (most probably) original forms in 352 and 253 (the latter is more related to *maqām Ḥijāz-Kār*).

Aristoxenos' *pycnon* rule says that a *pycnon* (a bi-interval scale element composed of two small intervals within a fourth) must be smaller or equal to the one tone interval.[175]

The rule of homogeneity observed with common tetrachords, which we could also qualify as reverse *pycnon*, says the contrary (Fig. 30). The complement (here of any bi-interval combination inside the fourth) must have the same limitations as those for Aristoxenos' *pycnon*, and the bi-interval combination, although equal to, or greater than the one-tone interval (not a *pycnon* in Aristoxenos), has the same limitation as for the complement of the *pycnon* with Aristoxenos.

This important difference may have one of the following causes:

1. With our modern music as with traditional forms, such as with the *maqām*, there has been important evolutions diverging from their initial form, which initially, might have been close to Aristoxenos' descriptions.
2. Arabian music and Ancient Greek music were never connected, and the former evolved independently from the latter.[176]
3. Aristoxenos' theoretical description of the music of his time was not accurate or had, notably for his theoretical use of the *pycnon*, no relation with practice.

intervals must be such as 6 ≦ sum ≦ 8) and its corollary (complement value to any two conjunct intervals is such as 2 ≦ i ≦ 4 – where i is the complement value), the only remaining tetrachords in fourths are the commonly used tetrachords in both ditonic (semitone based – on black background in the figure) and Arabian music (both grey and black backgrounds).

[175] See [Mathiesen, 1999], p. 49: "If the interval between the *lichanos* and the *hypate* is smaller than the interval between the *lichanos* and the *mese*, the smaller interval is called a *pycnon*..."; and Mathiesen's figure 51, p. 313. The author gives the *pycnon* a range of 5 quarter-tones, although this would apply to the low diatonic tetrachord of Aristoxenos, and the *pycnon* would then be equal to its complement in the just fourth. The tetrachord with the greatest *pycnon* with Aristoxenos is the "whole-tone color", the tense chromatic tetrachord in Mathiesen with a *pycnon* (composed of the smallest two intervals) equal to the one-tone interval, *i.e.*, smaller than its complement within a fourth. The smallest *pycnon* occurs, according to Aristoxenos, in the enharmonic tetrachord, with a sum value of 2 quarter-tones.

[176] The Arabs used Ancient Greek theories (and them extensively – see [Beyhom, 2010b]) and Byzantine music praxis. Separate paths for Ancient Greek and Arabian musics seems, however, unlikely due to the many similar influences on these musics (see notably [Beyhom, 2016]) and due to their interaction.

- As a corollary: the descending dimension of Ancient Greek theoretical descriptions of scale elements (Aristoxenos’ descriptions included), is… theoretical.[177]

Applying the reverse *pycnon* rule to the fifth and the octave

The last filter has shown the most commonly used tetrachord. Consequently, it would be interesting to apply this principle to the fifth, or to the octave. This is simple enough, with the fifth, and consists in adding an interval at one end and at the other of the *genus*, within the rules of homogeneity (Fig. 31), and then verifying the sums of the resulting combinations.[178]

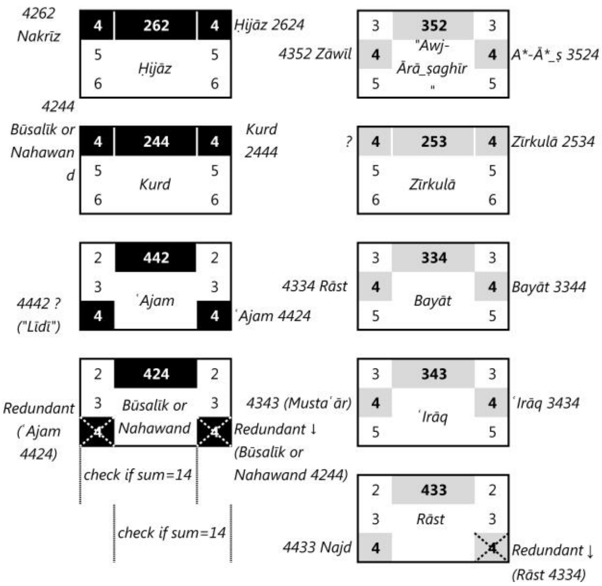


Fig. 31 Extending the homogeneity rule to the fifth: names of *genera* in Arabian music stand below the tri-interval combinations.[179]

As expected, this shows that most of the pentachords resulting from this operation have their equivalence in both literature and practice, although some of possible pentachords do not appear in the series.[180]

Fig. 32: 43 shows an example of scale building beginning with the *ḥijāz* tetrachord. This is very similar to the generation of fifths, although less than half of the combinations (with a black background on the figure) exist in the literature or in the practice, with the remaining scale elements not found in the literature.

Possibilities for some limited hexatonic elements (for example 626262 and 262626 in the figure) also exist.[181]

As a consequence, whenever the rule of homogeneity applies to commonly used genera, its extension to the fifth and octave intervals is either inadequate or too restrictive, although it shows that the full potential of Arabian music, even with such a restrictive criterion, is still not fulfilled.

However, there is a noticeable exception with the *maqām Mukhālif* which in Arabic means ‘infringer’, which has a limited scale of b^{-} 3 *c’* 2 d^{b}’ 4 e^{b}’ 2 f^{b}’ where the two first intervals breach the rule of homogeneity. There are other *maqām* where conjunct tetrachords may form neighboring semi-tones as for example in the *maqām Nawā-Athar* where the interval/tetrachord distribution is [4] {26*2*} {*2*62} (or a disjunctive one tone interval followed by two *ḥijāz* tetrachords, where the two neighboring semi-tones (underscored in italics) also breach this rule (when applied to the octave).

This is the main reason why, although the homogeneity rule is a perfect matchmaker for tetrachords, I shall keep, for the following statistical studies in the frame of a fifth or an octave, the initial criteria given in Fig. 25: 37.[182]

[177] Another possibility is that this was not accurately translated and explained until now: the issue of the continuity between Ancient Greek and Arabian (and other *maqām*) musics is complex, and frequently obscured by ideological biases as shown in [Beyhom, 2016].

[178] This corresponds to a tree-like generative process with additional intervals chosen among the alphabet in order to comply with the homogeneity rule. Sums are checked afterwards to verify if the fifth is reached.

[179] Names of the resulting pentachords in fifth (sum = 14) figure at the sides of the successful combinations (ditonic combinations have a black background – left. Arabian configurations have a grey background – right). Different names for 4244 result from different positions of the tetrachord in the general scale of Arabian music theoretical literature; 3524 exists in one single reference, but is compatible with our present knowledge and understanding of *maqām* music – the conclusion is that common pentachords in Arabian music are based on the fourth + one tone configuration, with one of the successful combinations ([4]253) not found in the reviewed literature but in tune with traditional music.

[180] See [Beyhom, 2003b], p. 7-13, and Appendix B – these pentachords are either rarely used, or are doubtful.

[181] Most of these do not leave way for a possible combination of two tetrachords and a one-tone interval. The remaining set, *i.e.*, 3524262, 3434262, 2624253, 2624343 and 2624352, are probably in tune with the aesthetic criteria of Arabian music, but may be difficult to perform on the *ʿūd* (for non-virtuoso performers) in its usual tuning (mainly in ascending fourths).

[182] Also to clarify the effect of each criterion on the outcome of the generative process.

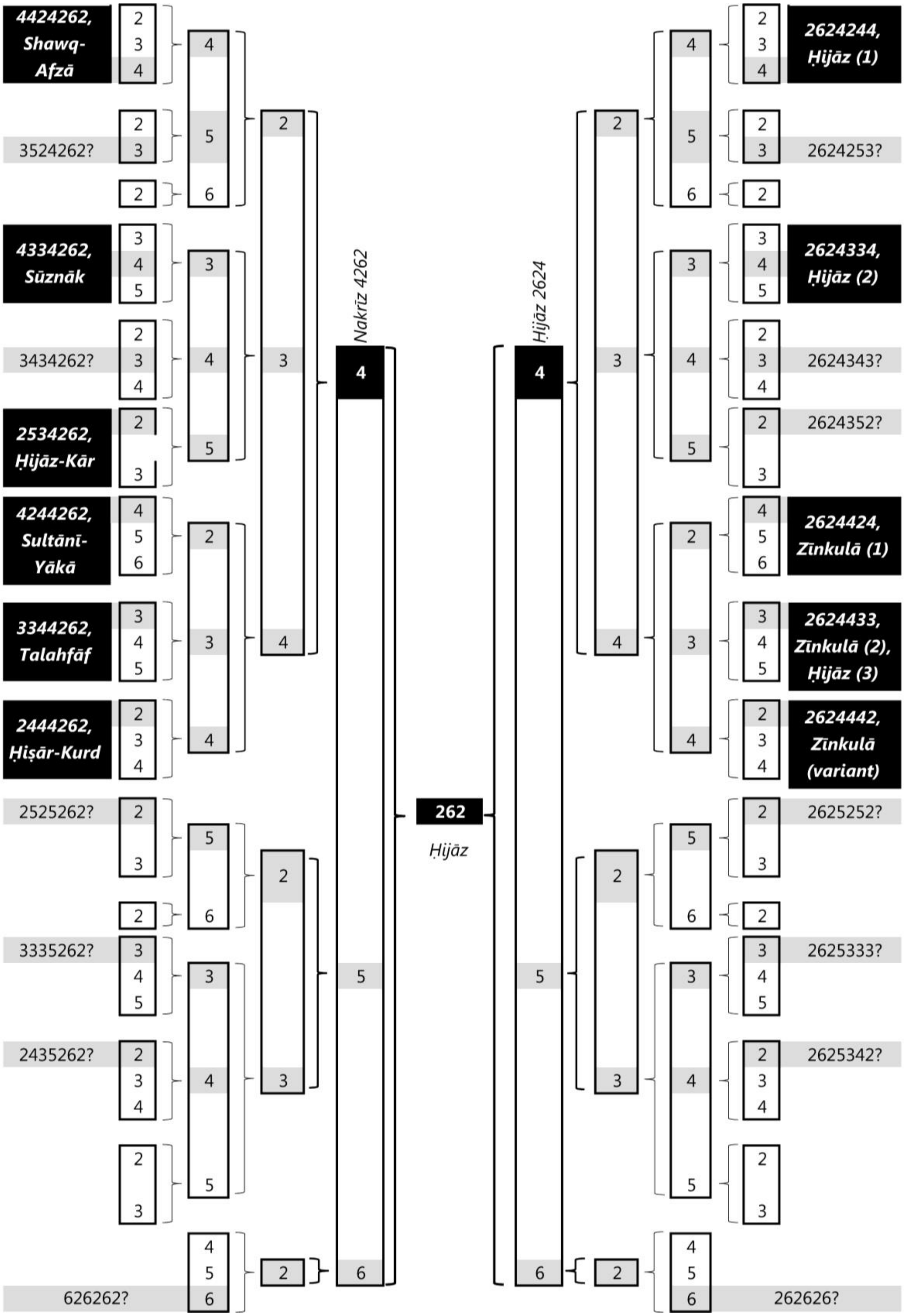


Fig. 32 Extending the homogeneity rule to the octave using tree processing of intervals, on the example of an initial *ḥijāz* tetrachord. In case of success (the homogeneity rule is respected), intervals figure on a grey background, and names of resulting scales of Arabian *maqām* stand at the side of each attested combination (black background).

A little incursion in the eighth-of-a-tone model

The reader may be wondering why this study does not give more refined models, such as the eighth of a tone, for example. A first answer was given above and said that the purpose of interval generation was to use the least possible divisions in a containing interval with the utmost number of combinations, according to the principle of economy.

A second answer comes from the definition of the conceptual interval. Any interval in use in a scale should be relatively easily identified,[183] both by performers and listeners alike (this procedure becomes difficult in practice whenever the elementary intervals are smaller than the one-quarter-tone).[184]

However, and as a confirmation of the principle of relative size of intervals within a containing interval, we shall have a quick look at this possibility, in fourth.

When dealing with a new interval model, it must be first determined which are conceptual, elementary, or measurement intervals.

When the measurement interval is one-eighth-of-a-tone, what would be the smallest conceptual interval? Two-eighths-of-a-tone would be too small because it equals a quarter-tone which is too small for being conceptual. A three-eighths-of-a-tone interval, as used by Aristoxenos in his hemiolic chromatic tetrachord,[185] with two conjunct intervals of three-eighths of a tone and one interval of fourteen-eighths – or seven-quarters-of-a-tone, would restrict us to the 17-ET inspired by Urmawī's theory (Fig. 33: 44, central one-tone interval), with a three-eighths interval equivalent to a *leimma*, an elementary quarter-tone used as an auxiliary interval, and with two possibilities for the *mujannab* interval (see the three one-tone intervals to the right of Fig. 33).

On the other hand, four-eighths-of-a-tone is equivalent to one-half-tone, and choosing such a small conceptual interval, we would lose the benefit of having a smaller division of the tone.

As long as we do not want to differentiate conceptual intervals using too small elementary intervals, dividing the tone further than the quarter-tone (with the smallest conceptual interval set to the semi-tone value) would be pointless for the model, but could bring a better approximation of intervals used in practice.

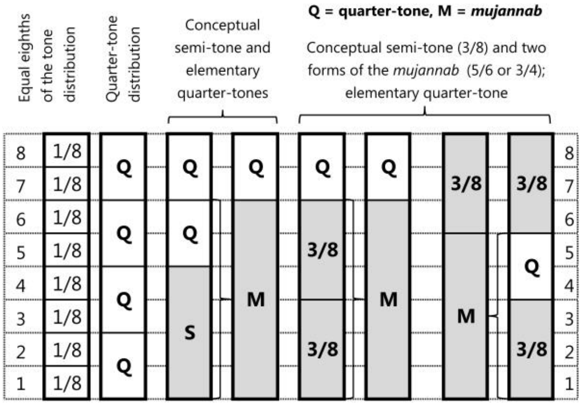


Fig. 33 Modeling the one-tone interval with eighths of a tone.

Fig. 34 shows the graphic results of a generation in eighths-of-a-tone with the smallest conceptual interval being a semi-tone (4/8 of a tone), and elementary intervals being one-eighth-of-a-tone. This leaves space between the semi-tone and the tone for three intermediate intervals of five, six and seven-eighths-of-a-tone.[186]

The optimal number of intervals remains three (NI = 3) with changes to the general curve of the graph. With four intervals and a very small increment such as one-eighth-of-a-tone, we have more possibilities than we had with the quarter-tone generation (for example for the case NI = 4), but NI = 3 remains the optimal value.

If we add the principle of memory to the principle of economy, or the need for performers of traditional

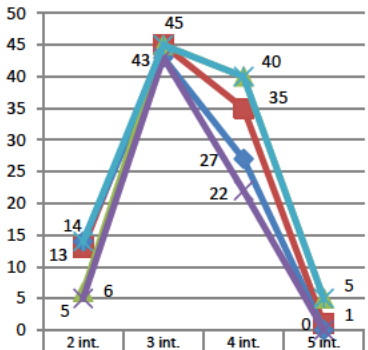
[183] This is different from pitch or interval differences perception and discrimination, and will be further explained in the Synthesis.

[184] Perception of differences of pitches as low as 5 cents (and even as low as 2 cents) are possible through careful listening to pitches close one to the other, an experiment I propose in the accompanying Power Point show to [Beyhom, 2016]. This is however far more difficult in practice performance. While musicians (this includes singers) may well perceive small variations of intonations that they perform, either intentionally or not, it remains that these small variations are not structural, and will not be identified as such even by listeners who can perceive them.

[185] See [Barbera, 1977], p. 311.

[186] The complete alphabet is, in multiples of the eighth of a tone, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, with the last value (16) representing the di-tone, which is the largest possible interval (in the frame of a fourth and with the semitone as smallest conceptual interval) in this model: for a complete listing of the results, see Appendix A.

music to memorize the elementary scale divisions of the fourth (or archetypal tetrachords) in order to reproduce them effortlessly while performing, we end up concluding that the eighth-of-a-tone model simply gives too many possibilities, which would also be difficult to distinguish from one another. One would associate the difficulty of perceiving intermediate intervals for the audience and the performer (the eighth-of-a-tone is 25 cents in size, very close to the Pythagorean comma which is approximately 23 cents), with a major difficulty (a huge number of tetrachords to memorize) which introduces a *quasi*-impossibility for the existence of a traditional repertoire based, as already stated, on the memorization and identification of melodic patterns.



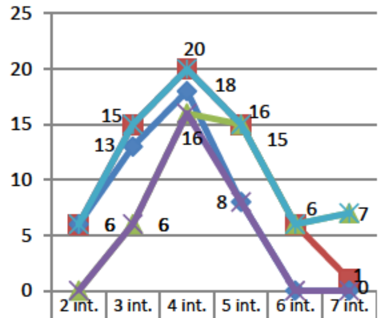
	2 int.	3 int.	4 int.	5 int.
Non redundant	13	45	35	1
Non conjunct semi-tones	14	43	27	0
No conjunct big intervals	6	45	40	5
Intersecting criteria 1	5	43	22	0
Initial	14	45	40	5

Fig. 34 Statistical results of the generation for a just fourth in eights of the tone, with the smallest conceptual interval chosen as the semi-tone (= one half-tone).

To conclude, let us note that within a fourth, the case NI = 3 (intervals) is the only one (still) that does not generate redundant sub-systems, a characteristic I have already underlined for the other two models (with semi-tones and quarter-tones). This discussion is continued at the end of next section.

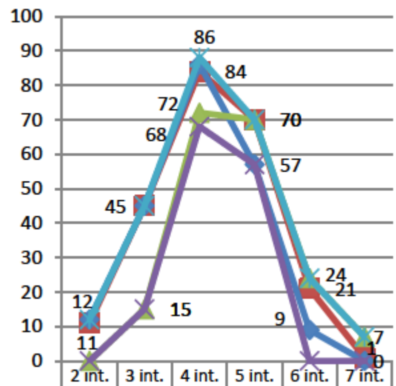
Combining intervals within the fifth

Modeling the fifth in semi-tones or with quarter-tones (with the restriction to the semi-tone as the smallest conceptual interval) gives additional information on the internal structure of containing intervals (Fig. 36 and Fig. 36).[187]



	2 int.	3 int.	4 int.	5 int.	6 int.	7 int.
Non redundant	6	15	20	15	6	1
No conjunct semi-tones	6	13	18	8	0	0
No conjunct big intervals	0	6	16	15	6	7
Intersecting criteria 1	0	6	16	8	0	0
Initial	6	15	20	15	6	7

Fig. 35 Graph for the semi-tone generation of the fifth, with the unlimited alphabet.



	2 int.	3 int.	4 int.	5 int.	6 int.	7 int.
Non redundant	11	45	84	70	21	1
No conjunct semi-tones	12	45	86	57	9	0
No conjunct big intervals	0	15	72	70	24	7
Intersecting criteria 1	0	15	68	57	0	0
Initial	12	45	88	70	24	7

Fig. 36 Graph for the quarter-tone generation of the fifth, with the unlimited alphabet.[188]

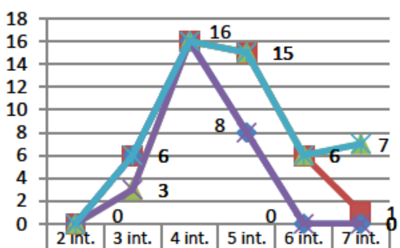
[187] The full results for the semi-tone model can be found in Appendix C.

[188] The optimal generations are at NI = 4 in both cases (semi-tone and quarter-tone), but in a clearly shaped form for the first (with

NI = 4, in both models, is the optimal value although noticeable differences exist between the two. The optimal value for the semi-tone model is clearly shaped, and accentuated with the application of filters to the sub-systems.[189]

With the quarter-tone model, this optimal value has NI = 5 as a competitor, and the filters give the latter a more important role, although less than for NI = 4. Another difference is that the semi-tone model generates no redundancies (except for NI = 5 which is a trivial case with 5 semi-tones in a row) whenever redundant sub-systems may be found in the quarter-tone model, including for NI = 4.[190] As a consequence, the semi-tone model is, within the fifth, more appropriate than the quarter-tone model.

For example, when reducing the results to the limited alphabet of 1, 2, 3 for the semi-tone model, the results (Fig. 37, compare with Fig. 36 above) show that the most effective filter is the disjunct large interval criterion which eliminates sub-systems containing intervals equal to, or greater than 3 semi-tones.



	2 int.	3 int.	4 int.	5 int.	6 int.	7 int.
Non redundant	0	6	16	15	6	1
No conjunct semi-tones	0	6	16	8	0	0
No conjunct big intervals	0	3	16	15	6	7
Intersecting criteria 1	0	3	16	8	0	0
Initial	0	6	16	15	6	7

Fig. 37 Graph for the semi-tone model of the fifth with the limited alphabet 1, 2, 3.[191]

Discussing the preliminary results

Interval distribution within the fourth or the fifth provides with a preliminary answer to our greater question concerning heptatonism. Combination processes applied to conceptual intervals show that three intervals in a fourth and four intervals in a fifth correspond to an optimal value (a maximum of different polychords for the least possible number of conceptual intervals) which reflects a balance between complexity (smaller interval identifiers such as the eighth of the tone or others, more intervals in a containing interval) and productivity in terms of independent (and fit for their role in music performance) interval combinations.

This applies with or without the filters in resulting sub-systems. These filters reduce possibilities and give a hold on the internal mechanisms of modal music. Interval combinations chosen throughout history can be described and recognized – their positioning and qualitative sizes within the fourth or the fifth is not a coincidence.

Furthermore, as we try to reduce the steps between intermediary intervals (as in the eighth-of-a-tone model of the fourth), the tendency towards a balance of the generations around the (same) optimal value remains, with however quantitative differences between models.

The semi-tone model seems to be best suited to the fifth, rather than to the fourth: the optimal value in the semi-tonal modeling of the fifth is very stable and the angle formed by the two bordering segments of the line is acute and (Fig. 36) accented in the case of a limited alphabet (Fig. 37); this optimal value still exists for the fourth, in the semi-tone model, but with a very limited number of combinations: in this case, only four major (ditonic) combinations may be used by the performer, which is somewhat limited compared to the twelve combinations in the quarter-tone model of the fourth (Fig. 25, p. 37: nine tetrachords are left if we filter the sub-systems with the second set of intersecting criteria).

Twelve (or nine) combinations within a fourth seems a suitable reservoir for modal possibilities, alone or in combination, in performance or as paradigms for

intersecting criteria), whenever the quarter-tone model's optimal value at NI = 4 has a competition at NI = 5. The no conjunct semi-tones criterion applies to suites of three or more semi-tones in a row, and the no conjunct big intervals criterion to intervals equal to or greater than 3 semi-tones.

[189] The no conjunct semi-tones criterion applies to suites of three or more semi-tones in a row.

[190] Complete results in appendices B and C.

[191] The shape of the intersecting criteria 1 line is narrower (values for NI = 3 are relatively smaller than for an unlimited alphabet) and confirms the optimum for NI = 4.

a repertoire as it gives the performer good possibilities for modulations, with the fourth as a starting containing interval that he can elaborate further and further (by modifying its internal structure – or interval composition), and then perhaps expand the span of the melody to the fifth or more.

An eighth-of-the-tone model gives too many intermediate possibilities while adding perception difficulties (for example, an eighth-of-a-tone is much more difficult to recognize than an interval of one-quarter-tone, and the difference between a three-quarter-tone interval and a one-tone interval is much easier to distinguish from the difference between a six-eighths-of-a-tone interval and a seven-eighths-of-a-tone interval).

With the fifth, however, the quarter-tone model becomes too rich,[192] and too complicated. Almost seventy possible combinations are available to the performer, which would be difficult to memorize.[193] It is easier to add a one-tone interval below or above the bordering intervals of the fourth (Fig. 31: 42). This is a process that would give some fifteen interval patterns available within the fifth.

This is a practical means for enriching the repertoire with the least possible number of conceptual intervals. Even then, the semi-tone possibilities of the fifth compete with the potential of this last model.

This is mainly due to the fact that the addition of one tone to the fourth reinforces the ditonic nature of interval combinations, as well as the possibilities for bi-fourth configurations (two intersecting fourths with successive ranks – Fig. 38).

Should we start our scale element with a one-tone interval (Fig. 38, left, the one-tone interval equates to the 4 quarter-tones), possible combinations complying with both rules of sum (for the adjacent fourth – in order to obtain a fifth) and the rule of homogeneity are more or less balanced between elements with zalzalian intervals (five) and elements with (exclusively) ditonic intervals (four).

If we begin our element (ascending from left to right) with a zalzalian interval such as the three-quarter-tone interval (Fig. 38, right), the remaining three intervals cannot make a fourth (their sum is always equal to 11 quarter-tones).

In order to make a fifth, we are in some cases, for example 3344, 3434 and 3524, compelled to complete first the just fourth, then to add to it the one-tone interval, at the end. This process leaves us with only three possible combinations having both fourth and fifth, which is very little when compared to the nine possible combinations in the preceding case in which we have set the first interval to 4, and in which all combinations have both fourth and fifth.

In an open process, however, not taking into account the fifth as a necessary step on the way to the octave, the reduced potential of the starting zalzalian three-quarter-tone interval widens up very quickly (before being restricted once again by the octave).

As a preliminary conclusion, we may say that the quarter-tone model is particularly suited to the just fourth, whilst the semi-tone model is better suited to the fifth as a containing interval. Both models, however, show that the number of four or three intervals within a fifth or a fourth, is not coincidental, but it is the result of an optimization process between complexity and expressivity.

A further remark can be made concerning octave systems of scales. What is applicable to the fourth also applies to a combination of two fourths with a one tone interval, or to combinations of fourths and fifths within the octave.

Adding up the numbers of optimized interval repartitions for two fourths (twice three optimal conceptual intervals) + a one-tone interval, the optimal number of intervals for the octave is seven – the same applies to the total optimized number of intervals from the combinations of fourths (three optimal intervals) and fifths (four optimal intervals).[194]

[192] Including redundant sub-systems in the optimal case for NI = 4, which differs from all other above seen optimal cases.

[193] Performers find it difficult to memorize more than a few dozen heptatonic scales, even when they are classified with the beginning tetrachord and further combinations in Arabian theory. Modes may be taken as belonging to a family whose main characteristic is determined by the lowest tetrachord – this is a method which makes it easier to remember *maqāmāt* (pl. of *maqām*). However, this consists only of some 30 basic scale combinations. If such an arsenal is needed in order to memorize 30 scales, it seems clear that memorizing 70 pentachords, with a subsequent and much greater number of octave scales, is simply an impossible task for the common musician.

[194] This is a well-known process in Ancient Greek and in Arabian theory. An example is given in details in [Beyhom, 2003a], p. 301-312.

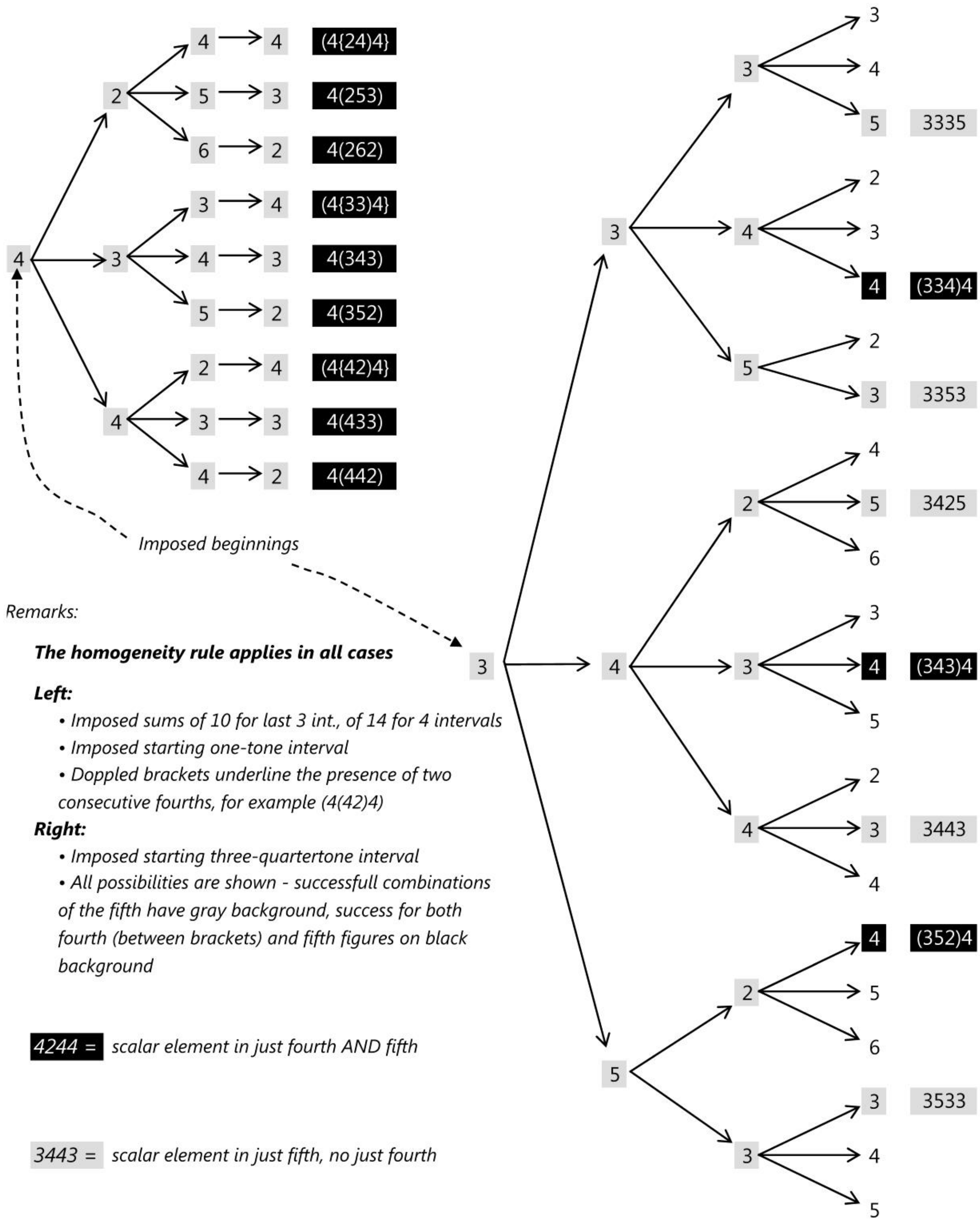


Fig. 38 Modeling the fifth with the one-tone (left) then three-quarter-tones (right) intervals initial conditions and the homogeneity rule.[195]

[195] Beginning with a one-tone interval (left) increases the number of regular (and ditonic) fourths and fifths, as well as bi-fourth combinations within the fifth. Starting with a zalzalian interval such as the three-quarter-tones (right) lessens the possibilities for a fourth/fifth combination, as well as for bi-fourth configurations.

However, not all scales do follow the fourth-plus-fifth, or the two-fourths plus a one-tone arrangement of interval combination. In the following section we shall repeat the process used for the fourth, and apply it to octave scale elements, while further explaining, for readers unfamiliar with statistics, how filters work.

Generating scales in the semi-tone and quarter-tone approximation models: preliminary exposé

With modal systematics, octave scales are represented as suites of conjunct intervals the sums of which are equal to the number of elementary intervals within the octave.

This means that they must be equal to 12 semi-tones in the semi-tone model, or to 24 quarter-tones in the quarter-tone model. In both models, the smallest conceptual interval is the semi-tone. Let us remember that all systems (and sub-systems) of the semi-tone model are, obviously, part of the quarter-tone system (Fig. 39).[196]

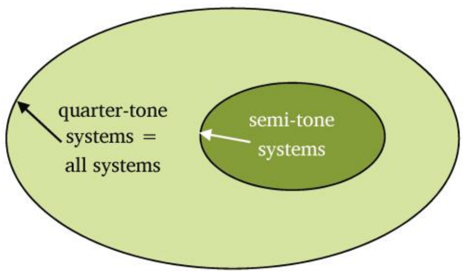


Fig. 39 Semi-tone systems as part of the quarter-tone system: they are kept in the statistic study on quarter-tone sub-systems.[197]

From both sets, only non-redundant scales[198] are further selected, and redundant sub-systems are excluded (Fig. 40 and Fig. 41) as they give no new combinations, and no new information to the current study.[199]

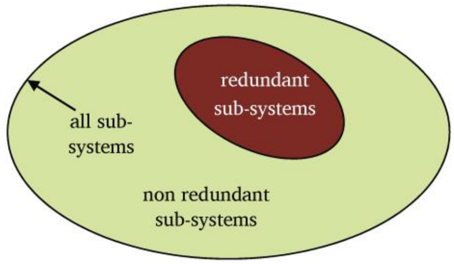


Fig. 40 In both semi-tone and quarter-tone generations we get redundant sub-systems, which are excluded (filtered – see next figure) from the database.

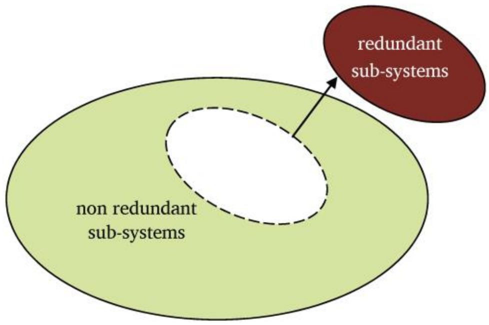


Fig. 41 Redundant sub-systems are excluded from the search process; the remaining sub-systems are non-redundant (criterion "_NR" in the following graphs).

The same applies to the "min", "umin"[200] and "max" criteria (Fig. 42).

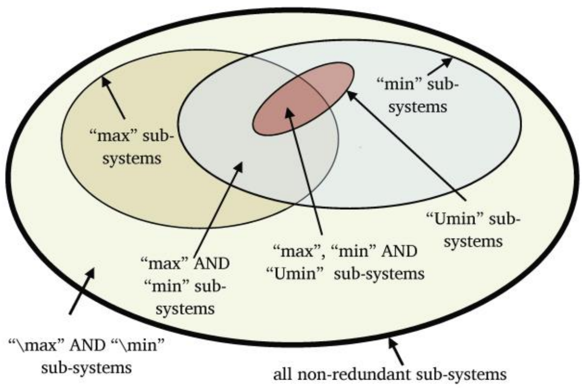


Fig. 42 How the filters "\max", "\min" and "\umin" work.[201]

[196] Although each set is generated separately in our case, with filter and criteria applied separately too.

[197] Arrows in this figure point to the curves, which means that all systems within the curve are included in the limits of the curve.

[198] The vast majority of all sub-systems in each generation.

[199] A completely redundant system, for example, is system 11111 1111111 (twelve semi-tones in a row), which will give, by de-ranking, 12 identical (redundant) sub-systems, in which case only the head sub-system is kept (one out of twelve). Redundant systems, or "scales with limited transposition", are explored at length in Appendix G.

[200] Used further for octavial scales generation – see also footnote 201.

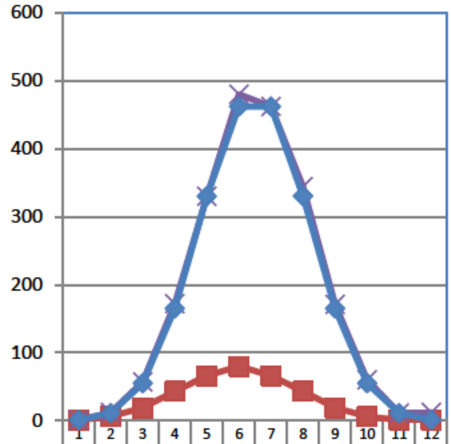
[201] Arrows pointing to curves mean that they characterize the whole of sub-systems included in the curve; arrows pointing to areas delimitated by regular or broken curves characterize this area. Further combinations of criteria use the logical "OR" expression, either in a positive or a negative way; these are basics of statistics which are explained in [Beyhom, 2003c], but some explanations are given below. In the caption, symbol "\" marks a logical negation, for example a \umin sub-system comprises no suites of 3 or more semi-tones, whenever "\min" indicates the same, but only for two consecutive semi-tones in the scale (sub-system). A cross-criterion with logical "AND" means that both conditions are met; a

Further criteria such as searching for fourths and fifths from the first interval of each sub-system, work in the same way, except that sub-systems are not discarded, but simply counted.[202]

Further: in this study, as for the statistical studies of the fourth and the fifth, I extend the definition of the conceptual intervals beyond the restricted alphabet[203] (2, 3, 4, 5 and 6 quarter-tones in the quarter-tone model). Thus, the smallest number of conceptual intervals to an octave – or NI – is one, and the largest NI is equal to 12 (Fig. 43: 50 for an example of results in the semi-tone model), or 12 semi-tones in a row (or the smallest conceptual interval twelve times in a row).[204]

Intermediate cases (*i.e.*, NI = 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11 conceptual intervals to the octave) have an intermediate behavior, with a tendency to concentrate larger intervals for smaller values of NI, and semi-tone suites of intervals for larger values of NI. This is self-evident from the cases for NI = 1 and NI = 12, but two further examples will help the reader better understand the phenomenon:

- NI = 2 in Fig. 43 generates six different hyper-systems in the semi-tone model which are 1 11; 2 10; 3 9; 4 8; 5 7; 6 6. In turn they generate unique systems (identical to the hyper-systems) with two sub-systems for each configuration (there are only two possibilities for combining two numbers, here taken as a and b: a b and b a). System 6 6 is fully redundant (this means that whatever combinatory process (de-ranking included) is applied to its intervals, we end up having the same configuration because all intervals are of the same class). The total number of generated independent[205] sub-systems for the entirety of hyper-systems for this case (NI = 2) is consequently equal to 11 (Fig. 43, var. NSS_NR).



	1	2	3	4	5	6	7	8	9	10	11	12
NS	1	6	19	43	66	80	66	43	19	6	1	1
NSS	1	12	57	172	330	480	462	344	171	60	11	12
NSS_NR	1	11	55	165	330	462	462	330	165	55	11	1

Fig. 43 Systems and sub-systems in an octave, from the initial generation and filtered for redundancies – semi-tone model. Full alphabet.[206]

- When NI increases, the largest possible intervals become smaller in size: for NI = 3 with 19 systems, (same figure) for example, the largest possible interval is the ten-semi-tones interval which appears in the first hyper-system 1 1 10 (or two intervals of one-semi-tone in a row and one ten-semi-tones interval).[207] The size of the largest interval decreases regularly with the increase of the NI, and reciprocally that is if we increment NI by one unit, the largest interval generated is one-semi-

"\min AND \max" sub-system is a scale with no suites of 2 semi-tones or more AND no suites of intervals greater or equal to the maximum interval (generally the one-and-a-half-tones interval). The "OR" logical expression works in a more complex way. As a last example: sub-system (2 2 4 2 4 2 2 4 2) with nine intervals (in quarter-tones) to the octave meets the criterion "min" (it has two concomitant intervals of semi-tone – underlined above – in two positions of the scale), but not the "umin" criterion (3 adjacent semi-tones): its ninth de-ranked sub-system will meet this criterion, as 2 2 2 4 2 4 2 2 4 comprises a suite of three successive semitones in first position of the scale (beginning with the first interval).

202 Other, more refined filters and criteria are used in Modal systematics, some of which are explained at the beginning of Appendix I (download from http://nemo-online.org/articles), and further in [Beyhom, 2003c].

203 These intervals are too large, since they are greater than the one-and-a-half-tones interval and as such cannot be considered, ultimately, as conceptual intervals. However, the aim of the statistical study consists partly in determining the boundaries of the alphabet of these conceptual intervals.

204 The self-evident case for NI = 1 appears only in this preliminary generative process (graphs of Fig. 43 to Fig. 46). See Appendix D for the list of the Hyper-systems for the semi-tone generation with the complete alphabet of intervals.

205 *i.e.* non-redundant.

206 NS = number of systems; NSS = number of sub-systems; NSS_NR = NSS with redundant sub-systems excluded.

207 The reader may wonder how to read and concatenate intervals greater than '9', here semi-tones: in such case, it suffices to change the basis of numeration from decimal to duodecimal (see [Anon. "Duodecimal", 2017] for more explanations), assigning letters 'A' and 'B' for instance to intervals '10' and '11': hyper-system 1 1 10 would be then transcribed, in this new basis and in concatenated form, as '11A'; the same applies for the quarter-tone model, with basis 24; in the following explanations, however, all interval numbers have been kept in the decimal basis, for the sake of clarity.

tone smaller than for the preceding generation (with a smaller NI). When we get closer to the upper limit of NI, the largest generated conceptual interval has decreased in such a way that only small intervals are generated: for NI = 11, for example, we obtain one single hyper-system of 1 1 1 1 1 1 1 1 1 1 2 (10 semi-tones in a row and one one-tone interval), which still generates one unique (identical) system, with however eleven different subsystems generated by the de-ranking process which are:

- 1 1 1 1 1 1 1 1 1 1 2
- 1 1 1 1 1 1 1 1 1 2 1
- 1 1 1 1 1 1 1 1 2 1 1
- 1 1 1 1 1 1 1 2 1 1 1
- 1 1 1 1 1 1 2 1 1 1 1
- 1 1 1 1 1 2 1 1 1 1 1
- 1 1 1 1 2 1 1 1 1 1 1
- 1 1 1 2 1 1 1 1 1 1 1
- 1 1 2 1 1 1 1 1 1 1 1
- 1 2 1 1 1 1 1 1 1 1 1
- 2 1 1 1 1 1 1 1 1 1 1

Consequently, the last case (NI = 11, Fig. 43) generates, with one and only hyper-system which is identical to the one and only system it generates, the same number of independent (non-redundant) sub-systems as with NI = 2 above (Fig. 43, var. NSS_NR).

This is a first indicator of symmetry for generations with different NI, which is obvious in Fig. 43 (var. NSS_NR) which shows the statistical results of a full scale generation in the semi-tone model of the octave. Values around NI = 6 are symmetrically placed for the numbers of systems, (var. NS) however, this symmetry does not apply to hyper-systems (Fig. 45: 54, var. NH: var. NSSU_NR is explained below).

- ➢ As a next step after determining the numbers of sub-systems, we exclude redundant sub-systems from the whole set (Fig. 45 and Fig. 46: 55 – this also shows the numbers of hyper-systems). Redundant sub-systems occur whenever an interval configuration is repeated twice or more in order to cover the complete range of intervals within a system. System 4 4 4 in the semi-tone model (three – or NI = 3 – successive di-tones which form an octave) is completely redundant, as any de-ranking process gives the same combination as the original one (this is a mono-interval element repeated 3 times in order to form an octave).
  - Another example is the one-tone scale used by Debussy, 2 2 2 2 2 2 (NI = 6), which is also completely redundant. More elaborated semi-redundant systems (which generate a limited number of sub-systems – such as Messiaen's scales with limited transposition) exist, such as 1 1 2 1 1 2 1 1 2 containing three successive three-interval identical combinations of two conjunct semi-tones and one one-tone intervals (1 2 1 1 2 1 1 2 1 and 2 1 1 2 1 1 2 1 1 are independent sub-systems of the latter). There can only be in this case three distinct sub-systems (scales).[208]
- ➢ Results for sub-systems are then expressed, for both generations (*i.e.,* with the complete or with restricted alphabets), through the Unitary number of non-redundant sub-systems, or the total number of non-redundant sub-systems divided by the corresponding NI (see for example Fig. 47: 55 and Fig. 48: 56). This process is explained in details in the following section.
- ➢ To the results of the previous process, we apply then the two following filters and keep track of the results for both, as well as for the unitary numbers of sub-systems (Fig. 47 *sq.*,[209] with these filters, successful combinations are kept, not excluded):[210]
  - Firstly find all sub-systems with a fourth starting with the first interval that we shall call a direct

[208] As a general rule, scales with a NI as a prime number may not generate redundant sub-systems unless NI divides the sum of elementary elements within the scale (12 for the semi-tone model and 24 for the quarter-tone model). This is due to the characteristics of these numbers as explained in note 170: 40. For NI = 2, with 2 being the second prime number (which divides itself and 1 only after 1 (NI = 1 is a trivial case), two divides twelve and twenty four. As a consequence, there is a fully redundant system for NI = 2, composed of two tri-tones (6 6 in semi-tones, or 12 12 in quarter-tones – for the latter, read twelve and twelve – or 'C C' in the duo-decimal basis as explained in footnote 207). The same applies for NI = 3, 4 or 6, with hyper-systems 4 4 4, 3 3 3 3 and 2 2 2 2 2 2 in the semi-tone model – redundant sub-systems are further explored in Appendix G.

[209] Starting with these graphs, systematic comparison is undertaken between the two models (semi-tone and quarter-tone).

[210] From this point on, only generations with a restricted alphabet are shown in the body of the article. For generations with the complete alphabets, with the exclusion of the one quarter-tone interval for the quarter-tone model, see Appendix E.

fourth. This limitation is due to the fact that a fourth, in second position, for example, in a sub-system is the first fourth of the lower ranking sub-system (by a de-ranking process).[211] The values on the graphics (var. NSS5U_NR, beginning with Fig. 47) indicate that the filtered remaining sub-systems have each a direct fifth (which starts with the first interval of the sub-system – these are labeled NSS5U_NR on the graphs, for 'Numbers of Sub-Systems in 5th Unitary, Non redundant'). As long as we are searching for statistical results, this is the same as searching for direct fourths, as a complement of the fifth (the fourth) can be obtained by de-ranking the sub-system four times.[212] This filter keeps the filtered sub-systems, and excludes the others (as if we excluded all sub-systems that do not have a direct fourth); original results with unitary sub-systems are however kept for further comparisons.

- The next step consists in verifying for systems with a direct fourth enclosed in a direct fifth (labeled FFU_NR, or 'Fourth in a Fifth, Unitary and Non-Redundant'), for example in {(442)[4]}(352). With the latter, the direct fourth is 442, and the direct fifth is {442[4]} with the complement of the fourth within the fifth being the one-tone interval, or [4] – in such cases, the configuration of the sub-system is equivalent to a combination of two fourths and a one-tone interval (4th + T + 4th – see example above). This filter is named the direct Fourth in a Fifth, or FF, process (same figures as above).

➢ Now that we have representative graphics for the overall statistical distribution of sub-systems, including the ones containing direct fourths and/or fifths, we may apply, separately, as a first approach, two additional filters which are very close to the ones used for the fourth and fifth containing intervals explored in the previous sections:

- The conjunct semi-tones criterion (which operates here for three or more semi-tones in a row – (Fig. 51: 57 and Fig. 52: 57).[213]
- The conjunct large intervals criterion, which operates for intervals greater or equal to the one-tone-and-a-half interval (3 in semi-tones, 6 in quarter-tones – Fig. 51: 57 and Fig. 52: 57).[214]

➢ The final stage is reached by applying the last two filters simultaneously (Fig. 53: 58 and Fig. 54: 58).

All these graphics and filtering procedures are discussed in the next sections.

From hyper-systems to unitary sub-systems: an example based on the semi-tone model

We shall begin our investigation of the octave with a full scale generation in the semi-tone model using the complete alphabet, from the one-semi-tone interval to the twelve-semi-tone interval. A complete generation includes statistical results for numbers of conceptual intervals NI distributed between NI = 1 to NI = 12. The case for NI = 1 (one single octave interval in the system) is shown on the first four graphs only.

A. Generation of octave systems with the full alphabet of conceptual intervals

This first example of octave generation in semi-tonal conceptual intervals shows that the results in numbers

[211] In the quarter-tone sub-system 3(244)362, for example, the fourth in second position (the 244 in brackets) is the first fourth of (244)3623, which is the next sub-system resulting from the de-ranking process.

[212] This means that for each sub-system having a direct fifth, there is always a corresponding sub-system (which is obtained by de-ranking four times the initial sub-system with the direct fifth) with a direct fourth. In the previous sub-system (see previous footnote), the direct fourth is 244 with for complement 3623 fifth. De-ranking three times (*i.e.*, beginning with 2443623, 4436232, 436232, 3623244) we get a sub-system with a direct fifth 3623, but not necessarily a direct fourth. If we de-rank four times the last sub-system beginning with a direct fifth, we get the initial sub-system 2443623 with a direct fourth, but no direct fifth. Consequently, the number of sub-systems containing a direct fifth (in any of the generations shown) is equal to the number of sub-systems containing a direct fourth.

[213] The extension from two to three semi-tones (in a row) in this filter allows for the existence of bi-fourth configurations (within a scale) with bordering semitones, for example two *ḥijāz* conjunct tetrachords – or (2 6 2) (2 6 2) in quarter-tones.

[214] This filter is more permissive than the one used for the fourth and the fifth, due to the fact that some (very few, and mostly questionable) scales found in literature include conjunct one-tone and one-and-a-half-tones intervals – see [Beyhom, 2003b], notably p. 33, 38 and 42.

of systems for NI = 1 have a symmetrical correspondent which is NI = 11 (Fig. 43: 50). The optimal value for systems with this process is reached for NI = 6, for which the number of systems is at its highest value (80 systems are produced for this number of conceptual intervals to the octave and 480 sub-systems). Furthermore, results (for systems – NS – still) for intermediate values of NI (from NI = 2 to NI = 10) are symmetrically distributed around the optimal value (for NI = 6).

However, the non-redundant sub-systems are also distributed symmetrically around the bi-optimal at NI = 6, 7. If we look at the numbers of hyper-systems (NH) generated by this process (Fig. 45: 54)[215], they have a distribution which is different from the distribution of the number of systems (NS). This is because and, although for example NI = 4 generates the largest number of hyper-systems (in this case 15), each hyper-system in this configuration can generate a limited number of systems since there are only a small number of positions (four in this case) in which conceptual intervals may be combined in order to obtain systems,[216] whenever the corresponding (symmetrical in terms of numbers of generated systems) case is NI = 8, which generates a lesser number of hyper-systems and have the same number of systems because of its eight (twice more as for NI = 4) possible positions for conceptual intervals. In the latter case, there are fewer possibilities for different classes of intervals within the hyper-system,[217] but more positions (eight) that conceptual intervals can fill.

This explains why the results are balanced although we still have no explanation for the perfect symmetry of the resulting numbers of systems around NI = 6.[218] The symmetry equally applies for the Unitary Number of Sub-Systems (NSSU), from which Non-Redundant sub-systems have been excluded (NSSU_NR on the graph in Fig. 45: 54). The latter is a weighted variable which reproduces the effect of the principle of economy explained in the first section of the second part of the article.

If we transpose this principle to the statistical generative models explored here, an increase of complexity (*i.e.,* of the number of conceptual intervals, or NI, needed in order to compose the octave), even if it produces more sub-systems must bring a relative increase of the latter. In other words, each supplementary interval needed to compose the octave must be justified by a proportional (qualitative) increase of the number of generated sub-systems, not only by augmentation of the total (quantitative) number of sub-systems.

This proportional increase criterion can be included from the results by dividing the total number of sub-systems, for each NI, by the number of conceptual intervals needed in order to complete the octave, that is by NI itself, which gives us NSSU = NSS/NI. This variable (NSSU) is equivalent to NS (or the total number of systems for each different NI),[219] and gives us, as such, no additional information.

However, if we exclude the redundant (R) sub-systems[220] from the total number of sub-systems, we obtain the final (weighted) variable NSSU_NR which is equal to the total number of sub-systems minus the number of redundant sub-systems for each NI, the whole being divided by NI itself, or NSSU_NR = (NSS - R)/NI. NSSU_NR is, as a result, a compound variable that integrates the principle of economy. It shows the need for each supplementary conceptual interval used in a scale to be justified by a proportional increase in the number or resulting sub-systems.

In the graph of Fig. 45: 54 the values for NSSU_NR are close to the ones expressing the total number of systems (as there are few, comparatively, redundant sub-systems in each case, except for NI = 12 which is a trivial

[215] The shape of the broken lines representing distributions of NS and NSSU_NR in Fig. 45: 56 can be compared to a regular normal (law of) distribution in statistical studies, or bell-type distribution – the results do not correspond, however, to the analytical expression of that law.

[216] See Appendix D for a full list of hyper-systems for this generation, together with the numbers of systems and sub-systems in each hyper-system.

[217] For NI = 8 (where as the first hyper-system is 1 1 1 1 1 1 1 5) we may not use intervals larger than the five-semi-tones, whenever we may use intervals as large as the nine-semi-tones interval for NI = 4 (where the first hyper-system is 1 1 1 9 – or three one-semi-tone and one nine-semi-tones adding up to 4 conceptual intervals the sum of which equals to twelve half-tones, or the octave).

[218] This *lacuna* is due to my own limitations in statistical and mathematical sciences. Any explanation of the phenomena by a specialist in this field would be greatly appreciated.

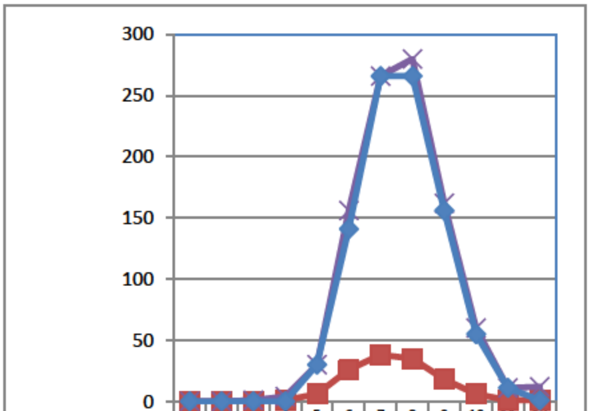
[219] Because NSS is, by definition, equal to NS x NI.

[220] These redundant sub-systems are useless in the traditional concept of modal music.

case), and the corresponding broken line is also symmetrical around NI = 6.[221]

B. Generation of octave systems with reduced alphabet of conceptual intervals 1, 2, 3, compared to full alphabet generation

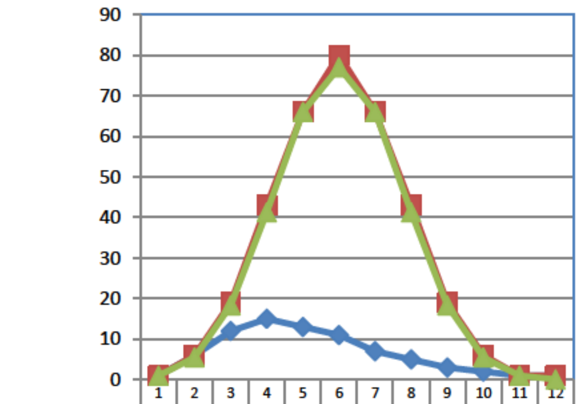
When we limit the largest interval in the semi-tone model to the one-and-a-half-tones interval (limited alphabet), the symmetry observed for systems and sub-systems in the previous generation disappears (Fig. 44: 54 and Fig. 46: 55 – symmetry shifts around the bi-optimal values NI = 7, 8, in Fig. 44, for non-redundant sub-systems) and the optimal value NI for systems (NS) shifts to the value NI = 7 instead of NI = 6, while smaller values for NI (up to 3) simply do not generate any scale element.



	1	2	3	4	5	6	7	8	9	10	11	12
NS	0	0	0	1	6	26	38	35	18	6	1	1
NSS	0	0	1	4	30	156	266	280	162	60	11	12
NSS_NR	0	0	0	0	30	141	266	266	156	55	11	1

Fig. 44 Systems and sub-systems in an octave: restricted alphabet (1, 2 and 3 semi-tones only).

The smallest productive value of NI in this generation is NI = 4, with the unique hyper-system/system/sub-system 3 3 3 3.[222] Furthermore, the number of pentatonic (with NI = 5) systems diminishes considerably,[223] and values of NS and NSSU_NR (Fig. 46: 55) for slightly larger values of NI (NI = 6 to NI = 8) are also considerably reduced when compared to those of the full generation in Fig. 45, whenever results for still larger values of NI are less affected.



	1	2	3	4	5	6	7	8	9	10	11	12
NH	1	6	12	15	13	11	7	5	3	2	1	1
NS	1	6	19	43	66	80	66	43	19	6	1	1
NSSU_NR	1	5.5	18.33	41.25	66	77	66	41.25	18.33	5.5	1	0.08

Fig. 45 Hyper-systems and systems in an octave: unrestricted alphabet in multiples of the semi-tone – as in previous figure (alphabet = 1 to 12).[224]

Octatonic systems (NI = 8) compete with the heptatonic models (NI = 7) for the optimal value (especially in Fig. 44, where the numbers of sub-systems are not weighted) and, beginning with NI = 9, generations are non-economical in all reviewed cases and figures, which means that increasing the number of conceptual intervals to more than eight in the octave gives a rapidly decreasing number of new systems.[225]

[221] The use of the Unitary Number of Non Redundant Sub-Systems in the previous generations for the fourth and the fifth would have emphasized the optimum at NI = 3 for the fourth, and at NI = 4 for the fifth. The lesser numbers of results for the previous generations have allowed us, however, to try to go deep inside the structure of the fourth and the fifth, without having recourse to the weighted variables used for the octave generations. In the latter case, it would be too long a task because of the very important numbers of sub-systems involved.

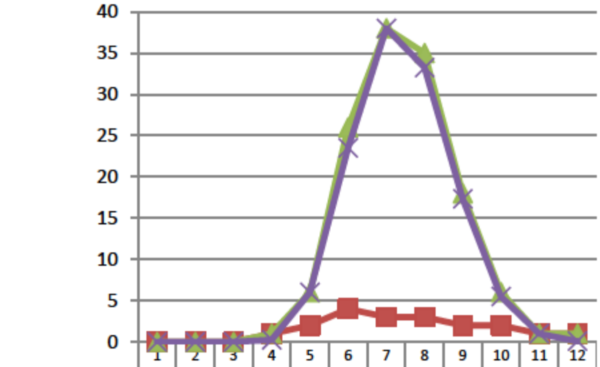
[222] In this system, three out of four sub-systems obtained by de-ranking are redundant. Consequently, this makes of it the unique sub-system.

[223] With a limited alphabet, the two pentatonic hyper-systems come to 12333 and 22233 (see Appendix D). Only the last one allows for a simultaneous direct fourth and fifth configuration, or fourth in a fifth. In this case, the chosen alphabet can for example be extended to the di-tone (4), a step permitting the usage of four additional hyper-systems (namely 11244, 11334, 12234 and 22224), and multiplies by five the reservoir of systems (22224 is a poor candidate in this case as it generates one single system), and by four the reservoir of sub-systems which include a fourth in a fifth.

[224] NH = Number of Hyper-systems (for each NI), NS = Number of Systems, NSSU_NR is the Number of Sub-Systems in Unitary weighting with the Redundant sub-systems excluded (NR = non-redundant).

[225] These results encourage questions about properties of numbers and their relations with the models in use.

Comparing Fig. 45 and Fig. 45: 55, with Fig. 43: 50 and Fig. 44: 54 also shows that there is no direct correlation between sub-systems and systems. The optimal values are still, however, restricted to a limited number of possibilities, from NI=6 to NI=8.



	1	2	3	4	5	6	7	8	9	10	11	12
NH	0	0	0	1	2	4	3	3	2	2	1	1
NS	0	0	0	1	6	26	38	35	18	6	1	1
NSSU_NR	0	0	0	0.25	6	23.5	38	33.25	17.33	5.5	1	0.08

Fig. 46 Hyper-systems and systems in an octave: restricted alphabet in semi-tones (alphabet = '1, 2, 3').

As a next step, we shall include the direct fourth (or direct fifth) and the fourth in a fifth filters in our models, and compare the results with those of the quarter-tone model.

Comparing generations in the semi-tone and quarter-tone models: looking for direct fourths and fifths

The direct fourth (*i.e.,* a fourth starting with the first interval of a sub-system) and the fourth in a fifth (see above) criteria may serve as supplementary filters for comparison with the remaining sub-systems. These filters are given at Fig. 47 (semi-tone model) and Fig. 48: 56 (quarter-tone model), applied to the results of the realistic generation in the preceding stage, *i.e.*, to the unitary non-redundant[226] sub-systems with the limited intervallic alphabet of Fig. 44: 54 and to its equivalent in the quarter-tone model.[227]

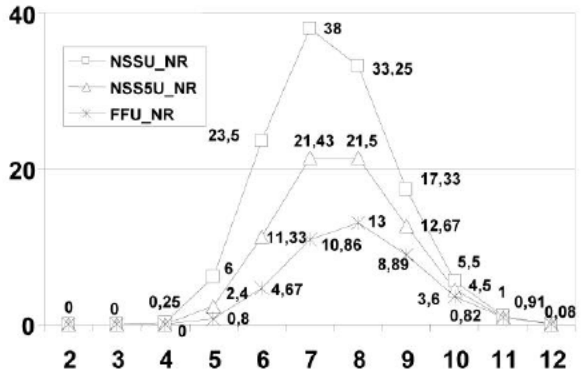


Fig. 47 Unitary non-redundant sub-systems in an octave, restricted alphabet (alphabet = 1, 2, 3) – semi-tone model.[228]

A few remarks may be made about these results:

- The optimal value for the Unitary sub-systems occur, in both models, for NI=7,[229] although in the quarter-tone model this optimal value has a serious competitor for NI=8, with the latter being also the optimum for numbers of sub-systems including a direct fourth (or fifth), or a fourth in a fifth[230].
- The ratio of unitary sub-systems in the quarter-tone model (Fig. 48: 56, var. NSSU_NR) to the corresponding sub-systems in the semi-tone model (Fig. 47: 55, var. NSSU_ NR) is about 20 to 1, whenever this proportion diminishes, for sub-systems with the fourth or the fifth (NSS5U_NR – around 10 to 1), it is even less for the fourth in a fifth criterion (6 to 1 for the latter). This means

226 Redundant sub-systems have a limited role in the quarter-tone model. Their weight in proportion to the total number of sub-systems is around 0,5%, whenever it is around 3% for the semi-tone model (with the exception for NI=12, with all sub-systems being redundant). The qualitative results (optimal placements) are consequently not strongly affected by this criterion, in particular for the quarter-tone model, particularly for NI=7 (no redundancies).

227 The results in the following figures relate only to the restricted alphabet in order to give the most pertinent information. Graphic results for generations with the full alphabet are shown for both models, in Appendix E. Synoptic results for the quarter-tone model (full alphabet) are listed in Appendix F.

228 NSSU_NR is the Number of Sub-Systems in Unitary weighting with the redundant sub-systems excluded (NR=non-redundant). NSS5U_NR is the Unitary number of Non-Redundant Sub-Systems with a direct fifth (or fourth). FFU_NR sub-systems include a direct fourth in a fifth. See Appendix E, FHT 1: 75 (for "Figure Hors Texte 1, p. 75"="Plate 1, p. 75") for the full alphabet generation.

229 The full alphabet generation shows a maximal NSSU_NR value for N=6. All other optimal (NSS5U_NR and FFU_NR) occur for NI=7 – see Appendix E, FHT 1: 75. In all the graphs, some of the results are corrected to the first decimal place.

230 This would explain (see also the Synthesis) the tendency of Arabian modes to use frequently, as with *maqām Ṣabā* (see for instance [Beyhom, 2016], the discussion on Curt Sachs theory of the scale and the counter-example of *maqām Ṣabā* in Chapter III) and others, non-octavial scales which come short from the octave ("lo" or "lower than the octave" systems), and with no direct fourth or fifth. The (almost, as the smallest interval is the semi-tone) full alphabet generation shows a steady optimal value for NI=7, shared in the case of FFU_NR with NI=8 (Appendix E, FHT 5: 76).

that, although the semi-tone model generates considerably fewer sub-systems, the proportion of sub-systems in this model with direct just fourths, or combined fourths and fifths (fourth in a fifth criterion), is larger than in the quarter-tone model. However, the optimal value for these sub-systems occurs for NI = 8. This is because larger numbers of NI work in favor of increased numbers of semi-tones in a scale. In turn, this applies in favor of the presence of fifths or fourths in a scale.[231]

- All results for values of NI around the optimal value decrease in an almost exponential manner (for values of NI less than, or equal to, six, or greater than, or equal to, nine). This means that optimal generations are concentrated for values of NI between (and including) six and nine, which gives us a preliminary answer to our initial question in the introduction to this article.

These results are, however, still not completely satisfactory, as they do not clearly show the expected optimal value for N = 7. Let us remember that sub-systems in these generations may include tri-interval suites of semi-tones, or large conjunct intervals of the second, both of which do not fit with the aesthetics of modal traditional music.

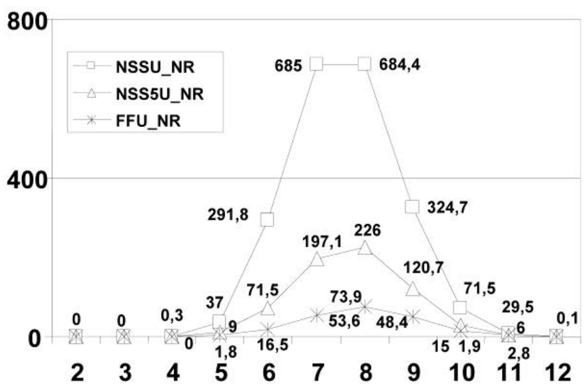


Fig. 48 Same as above, but for the quarter-tone model (alphabet = 2, 3, 4, 5, 6 quarter-tones) – see FHT 5, p. 74[232], for the (nearly) full alphabet generation.

The results of the application for these complementary criteria are dealt with in the following section.

Using conjunct interval filters

As a complementary step towards a better understanding of heptatonic scales, excluding conjunctions of small or large intervals from the previous resulting sub-systems, seems to be a suitable filtering criterion.

I have already shown in the sections dedicated to models of the fourth and the fifth, conjunctions of semi-tones are rare in heptatonic scales, and occur mainly between two conjunct tetrachords. The extension of the filter to three semi-tones in a row (which seems to be a non-existent combination in the scales of traditional music as we know it today)[233] makes a good aesthetical criterion when searching for generative optima (Fig. 49 and Fig. 50: 57).This filter is called '\umin', or exclude ultra-minimal combinations – here of three – semitones in a row.

In Fig. 49 and Fig. 50, the results for the '\umin' filter are shown separately:they are independent from the '\max(6)' – or '\max(3)' – filter, with inversed influences on the curves (Fig. 51 and Fig. 52, p. 57 for the latter).

The conjunct semi-tones filter (Fig. 49 and Fig. 50) affects only sub-systems for NI greater than or equal to 5 (compare with Fig. 47: 55 and Fig. 48: 56), with an increased effect for larger values of NI (the last three generations with NI = 10, 11, 12 – in the semi-tone model – have zero values as a result).[234]

At this stage of the study, these results are obvious: semi-tones are predominant for larger values of NI, making of it a particularly effective filter. On the far side

[231] Semi-tones combine easily in the one-tone interval, as well as in the fourth or the fifth – see also Fig. 38: 50 and section "Discussing the preliminary results" above.

[232] Reminder: for "Figure Hors Texte 5, p. 76" = "Plate 5, p. 76").

[233] Ancient Arabian theory and practice seem to exclude these as well – other Ancient forms of music must still be thoroughly checked for conformity with this criterion.

[234] With the quarter-tone model, sub-systems for NI greater than nine subsist principally because of the possibility to use the three-quarter-tone interval in conjunction with the semi-tone (for example combinations such as 223, 232, and 223): these combinations were excluded for the generations in just fourth, notably with the Conjunct small intervals criterion or through the homogeneity rule.

of the alphabet (Fig. 51[235] and Fig. 52[236]), conjunct large intervals restrict combination possibilities. This makes it impossible to get fourths, for example, as two conjunct one-and-a-half-tones intervals (which form a tri-tone) are already larger than the fourth.

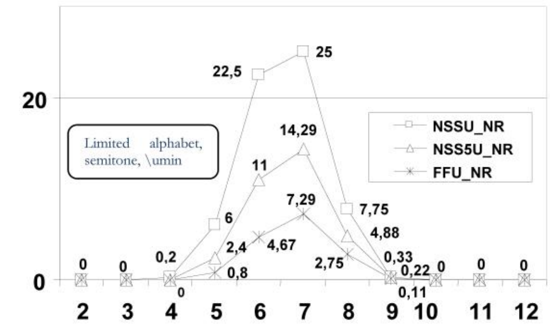


Fig. 49 Unitary non-redundant sub-systems in an octave, restricted alphabet – semi-tonal model with sub-systems containing tri-interval (or more) suites of semi-tones excluded.[237]

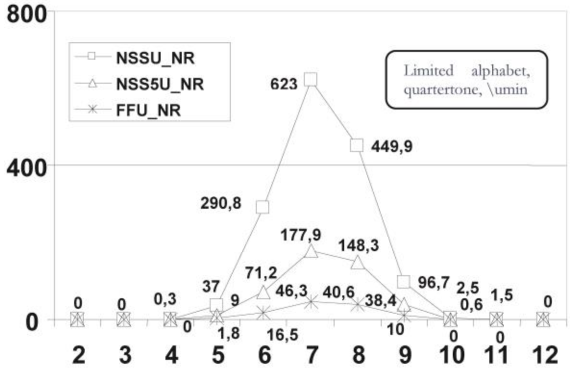


Fig. 50 Same as above, but for the quarter-tone model (alphabet = 2, 3, 4, 5, 6 quarter-tones).[238]

To exclude such sub-systems with two conjunct intervals equal to, or bigger than, the one-and-a-half-tones interval we must apply the second filter, '\max(3)' or '\max(6)' (or exclude sub-systems with two or more conjunct intervals equal to – or greater than – 3 semi-tones or 6 quarter-tones).

The evolution of the curves in Fig. 51 and Fig. 52: 57, if compared with those of Fig. 47: 55 and Fig. 48: 56 is remarkable. Although it excludes conjunctions of large intervals, this filter has no effect for values of NI equal to, or greater than, 9, smaller values of this variable are the most affected with a tendency to favor the NI = 8 generation as an optimal value. All systems for NI less than 5 are excluded.

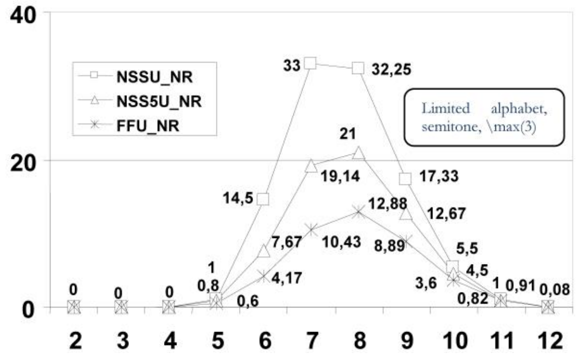


Fig. 51 Unitary non-redundant sub-systems in an octave, restricted alphabet (alphabet = 1, 2, 3), filtering of sub-systems containing two conjunct intervals greater or equal to 3 semi-tones – semi-tone model.[239]

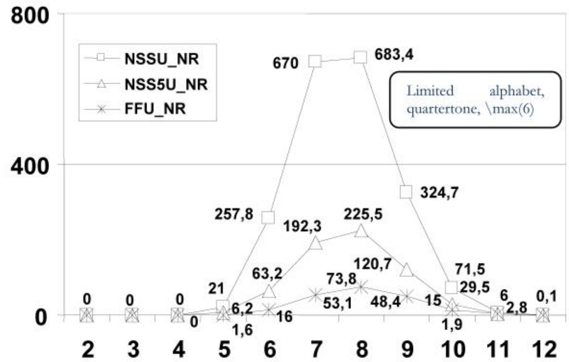


Fig. 52 Same as above, but for the quarter-tone model (alphabet = "2, 3, 4, 5, 6" quarter-tones); filter applies for two conjunct intervals ≥ 6 (quarter-tones).[240]

[235] All optimal values of the full alphabet generation in semi-tones occur for NI = 7 – see Appendix E, FHT 2: 75.

[236] The almost full alphabet generation in quarter-tones shows optimal values for NI = 7, except for FFU_NR (or DQQU_NR in the appendix) with NI = 8 – see Appendix E, FHT 6: 76.

[237] NSSU_NR = Number of Sub-Systems in Unitary weighting with the Non-redundant subsystems excluded, NSS5U_NR = unitary number of redundant sub-systems with a direct fifth, and FFU_NR with a direct fourth in a fifth. The full alphabet generation in semi-tones shows that optimal values occur for NI = 6, except for NSSU_NR for which the optimal case is NI = 5 (pentatonic scales, Appendix E, FHT 3: 75).

[238] The (almost) full alphabet generation in quarter-tones shows that the optimal values occur for NI = 7 for NSSU_NR, and NI = 8 for the other variables – see Appendix E, FHT 7: 76.

[239] See Appendix E, FHT 2: 75, for the generation with the full alphabet.

[240] The (nearly) full alphabet generation shows optima for NI = 7, except for FFU_NR (or DQQU_NR in the Appendix) with NI = 8 – see Appendix E, FHT 6: 76.

This may be explained by the fact that smaller values of NI facilitate the existence of larger intervals, whenever larger values of NI tend to exclude the latter from sub-systems.[241]

The two filters for conjunct small (semi-tones) or big (larger than the one-and-a-half-tones interval) intervals have, when applied separately, complementary effects: if applied simultaneously, they give most interesting results (Fig. 53 and Fig. 54)[242].

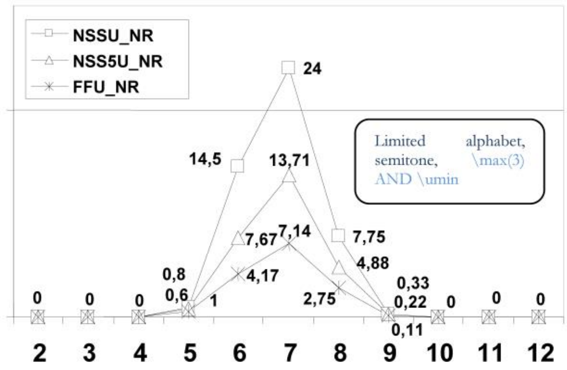


Fig. 53 Unitary non-redundant sub-systems in an octave, restricted alphabet (alphabet = 1, 2, 3) – semi-tone model with intersecting criteria (\umin OR \max(3) are excluded).[243]

All optimal values, for both the semi-tone[244] and quarter-tone[245] models, occur for NI = 7, with neatly shaped acute angles around the latter, *i.e.,* with rapidly decreasing values as we move away from the optimal NI.

Whenever unfiltered generations of scale element show optimal values for a reduced ambitus of possible numbers of conceptual intervals to the octave (between 6 and 8 conceptual intervals to the octave), and although it is possible that, to start with, scales other than heptatonic may have been used in traditional modal music, further aesthetical (sizes of intervals and their patterns in conjunct forms) and economical (optimal productivity) considerations have stabilized this optimal value at NI = 7, confirming thus the predominant role of heptatonism with this music.

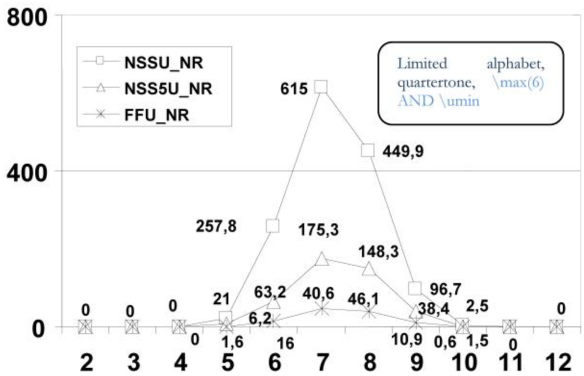


Fig. 54 Same as above, but for the quarter-tone model (alphabet = 2, 3, 4, 5, 6 quarter-tones) – see Appendix E, FHT 8, p. 74, for the full alphabet generation.

Conclusion of the statistical study of the scale

Although other models and filters can be applied to the process of interval combination[246] or to particular sub-divisions of modal music[247], we can draw a simple conclusion from this second part of the article. Heptatonism is, at least partly, the result of an optimization process within interval structure of the containing intervals of the fourth, the fifth and the octave.

[241] Beginning with NI = 10, the largest interval is one single one-and-a-half-tones interval – see Appendix D for details about the internal structure of hyper-systems for these generations for the semi-tone model.

[242] This filter excludes sub-systems containing sequences of three or more conjunct semi-tones as well as sub-systems with two conjunct intervals equal to or greater than 3 (semi-tones) or 6 (quarter-tones).

[243] For variables: see previous captions (Appendix E, FHT 4: 75, for the full alphabet generation).

[244] The full alphabet generation shows that optimal values occur for NI = 6 – see Appendix E, FHT 4: 76.

[245] The almost full alphabet generation shows that all optimal values occur for NI = 7 – see Appendix E, FHT 8: 76.

[246] Refining filters for the quarter-tone model, for example, in order to verify better adequacy to the heptatonic model, setting the value of the largest interval of the alphabet to the 5 quarter-tones while testing for large conjunct intervals (this would tighten the results around NI = 7), or by applying the conjunct small intervals criterion already used for generations within the 'one fourth' containing interval, or still by verifying the conformity of heptatonic sub-systems to the criteria of transitional two-interval semi-tones. This last one keeps only two-interval, and excludes three-interval conjunctions of semi-tones which occur on the transition from a fourth to a fifth, or from a fourth to another fourth, or from one octave to the other – see also the next note.

[247] Other models include the 'LO-GO' generations, with Lower than the Octave, or Greater than the Octave, sums for the sub-systems and models, etc. This can be equivalent to models of the octave in, for example, 23, 22, 21, or 25, 26, 27, etc. equal-temperament divisions of the octave) – see [Beyhom, 2003c]. This generation confirms the adequacy of heptatonism in relation with the interval characteristics of modal music, notably in the domain of *maqām*.

Synthesis

The results of the research shown in Parts I and II tend to prove that traditional choices for containing intervals such as the fourth, the fifth and the octave are not arbitrary decisions but the result of a real need for optimal melodic expression. Within the potentially infinite vertical space of pitches, melodic music seems to have followed a very rational, although intuitive and pragmatic, search for a limitation of combinations for conceptual intervals[248] in order to arrange them as useful paradigms, notwithstanding the unlimited variations of pitches on the boundaries defined by the components of these interval combination paradigms.

These variations have been the subject of endless speculations and mathematical expressions in terms, notably, of string and frequency ratios, which contributed in creating confusion between the two processes of (1) discrimination and (2) identification of intervals. The first process is mainly quantitative, whereas the second is purely qualitative. The first process is related to interval tonometry, while the second relates to the comparison of interval qualities within the frame of a scale or a melodic pattern (or formulae).

These considerations led me to the formulation of new concepts including the differentiation between conceptual (qualitative) and measuring (quantitative) intervals.

Some small intervals within a combination have qualities that distinguish them, in the concept of melodic music, from others. These become stand-alone entities[249] within larger containing intervals which, in turn, have other intrinsic qualities,[250] making them a perfect receptacle for smaller conceptual intervals[251]. With time, these larger intervals became the fourth, the fifth and the octave, because of the particular relevance of these terms in relation to their interval capacity.

For these numbers of identified classes of smaller conceptual intervals, within the containing larger intervals, the number of useful paradigms is optimal, which means that the number of paradigms ready for immediate, or delayed, composition is at its maximal potential, although the number of identified smaller conceptual intervals is at the minimal which allows for their identification.

In parallel to the relative wealth of expression, the optimal numbers of conceptual intervals (within the larger containing intervals) carry other qualities, especially their ability to produce, when combining smaller conceptual intervals, unique patterns (combinations)[252] within the containing intervals. This non-redundancy among the potential musical paradigms increases the efficiency of the means available for melodic music.

These characteristics make it possible today to formulate two hypotheses on (1) the process of formation of the heptatonic scale, and (2) on the conceptual tools that may be used in the search for the possible origin of this scale.

A hypothesis for the formation of the heptatonic scale

The consonance of the fourth, the fifth and the octave seem to be the common denominator for a large variety and types of music in the world, whilst other intervals have historically been considered as dissonant.[253] This position has been supported by arithmetic (Pythagorean tetrad) or acoustic (theory of resonance) considerations. However, acoustic agreement between partial harmonics of different pitches is not the only criterion on which music is based, and although the Pythagorean tetrad is an ingenious means for ratios of the larger consonant[254] intervals, it remains, regardless that small conjunct and fluctuating intervals (“dissonant”) compose the immense majority of the traditional melodic repertoire related to *maqām* music.

[248] Reminder: conjunct seconds in the scale.

[249] Un-composed within the containing interval, although measurable with the help of elementary, and measuring, intervals.

[250] Notably acoustic.

[251] These are needed for the composition of the melody.

[252] Except for the quarter-tone model for the fifth containing interval, in which redundancies, although very limited, occur: we have seen that this model fits better the fourth containing interval, with the homogeneity rule leading to unique (non-redundant) tetrachords, which represent all the common tetrachords in Arabian music (the last one including all tetrachords based on semi-tone classes of intervals).

[253] Because of the possible disagreement between the harmonics which compose, in different proportions, their spectrum, or because of extra-musical reasons, sometimes linked to their numeric properties.

[254] In the acoustic meaning: for the differences between the Pythagorean intervals resulting from the tetrad and acoustic resonance, see [Beyhom, 2016], chapters I and III.

Whereas consonance is not a real issue for these small intervals, the most important criteria, when composing melodies with a reduced span such as with most traditional music of heptatonic expression, are aesthetical adequacy and musical expressionism. Now I simply cannot imagine someone starting a musical repertoire, which would at the end of the way lead to the heptatonic meta-system of scales, with the help of interval leaps of combined fourths, fifths and/or octaves in order to arrange a couple of musical sounds together inside a melody.

This could be compared to travelling from one's own village to the large and far away city, then following another section of the highway in order to go to the village immediately across the valley. It just does not make sense, if there is a road between the two neighboring villages. If not, it is much easier to build the road between the two villages to start with, and then try to go to the large city (the octave)[255] or, before we reach it have a break at a pleasant inn in an average sized town on the way.[256] One can also wander off the road, or take shortcuts to the next break.

This is the heart of interval fluctuations within a scale. Small discrepancies in comparison to the theoretical path assigned between two pitches, due to the morphology of each performer, the organological particularities of the instrument[257], it can be the voice or any other instrument, regional or cultural differences, etc. The way in which we walk to the medium sized town may be different,[258] and the particular place within the village, our destination, may be a little bit off limits (one might take a break at a different place within the village),[259] but the destination remains the same.[260]

Combining a few conjunct intervals and going up or down the smaller scale, we may want to change direction and decide to play other pitches corresponding to different intervals, but that would still get us to the limits of the first established path between two pitches. The more possibilities we have in order to switch from one path to another, the more pleasant is our trip whenever we need to travel around a specific region, especially whenever we may find another intermediate middle-sized town in which to set base for further explorations.[261]

This is the essence of modulation, or varying the paths by moving from one established pattern of pitches to another.

While improvising (or exploring) new ways, one must avoid perpetual change of intermediate stops; in order not to burden our fellow travelers we guide after all the explorations already undertaken. The guide may achieve the balance between complexity and expressionism, where the pleasure of reminiscence is mixed with the pleasure of perpetual discovery, and thus avoid excessive strain for the listeners.

This is the essence of *maqām* music as I came to understand it.[262]

On this basis, the formation process of a scale seems to become evident. Starting with a single pitch, neighboring pitches may have been explored in succession until attaining the fourth or the fifth which, because of acoustic qualities and the need to mark a pause, or start a further stage, became the new turning point of the melody. From there on, our original performer may have chosen to go back to the starting pitch, and even beyond for a few notes and then back to it, then explore the same path, or change it for the sake of varying the original melodic pattern.[263]

Therefore, in a reduced span of one smaller containing interval and with occasional overtaking of its boundaries, the performer can have obtained an ensemble of key-patterns of interval sizes, clearly distinguishable for the ear of his listeners which became, in time, identified qualities of intervals within this first containing interval, the fourth (or the fifth – I explore this possibility in the next section).

At this point, the musician could explore two ways of enriching his music: he may choose to slightly change

[255] If octave intervals were explored at that time.

[256] The fourth or the fifth, for example.

[257] In our geographical example: the particularities of the landscape.

[258] One might decide to walk (or ride) through different villages.

[259] It is not an exact temperament that is used by the performer.

[260] The ultimate destination being generally the return home (to the final resting note of the *maqām*).

[261] Whenever we stop at a pitch other than the original beginning one, making the former, permanently or (mostly) temporarily, the basis for new developments of the melody.

[262] Mainly in its improvisation form in the 20th century.

[263] This is defined as "generalized pitch heterophony" in [Beyhom, 2016, p. 76].

the intervals he uses to enrich the hearing experience,[264] depending however on the listeners awareness of such small variations:[265] further differentiation of the small identified intervals may well begin to seem too esoteric for the listeners, as the discrepancies will seem too small (when they are smaller than a third of a tone, or a quarter-tone) to be clearly distinguished, and identified; the performer has reached a state of balance between his musical expressionism and the listeners ability to follow his more or less subtle modifications of the melody.[266]

This is the point when spatial extension, in either of both directions must have become indispensable in order to pursue melodic composition (it may be spontaneous or delayed, as stated above), notwithstanding the other variations he already have used for the limited melodic pattern(s) he has already used,[267] which can also be used, in the same or in a parallel way, with the extended pattern(s). From there we have many possibilities, all of them, considering the original process of composing the fourth, leading to the same result: the heptatonic scale.

From the fourth to the octave

Possible ways of reaching the octave (or avoiding it as some *maqām* do)[268] are:

1. The exploration of the large containing octave interval in a linear manner, that is by testing conjunct intervals in succession or in alternation (in the latter case with intermediate pitches being part of the resulting scale).
2. The addition of smaller containing intervals to one another (for example two fourths and a one-tone interval, or a fourth and a fifth) and use each as an almost independent entity.
3. The expansion of a relatively small containing interval (a fourth or a fifth) by:
   - searching for successive or alternate notes inside the upper (or lower) fifth or fourth, the boundaries of either of the latter being the new starting point for this exploration,
   - choosing any intermediate pitch in the original fourth or fifth (or any other initial configuration of conjunct intervals) and applying any of the three processes explained above,
   - combining any of the above.

With all these processes, the containing intervals must not be considered as imposing strictly delimited boundaries for the scale, but as indicating sizes of intervals justified by their acoustic characteristics. In other words, the three consonant containing intervals within the octave do not *bind* the performer (and the music), but *guide* him in the creative process of music composition.[269]

Whatever processes the performer chooses he will reach the same conclusion. The optimal repartition for intervals within the boundaries of the three containing intervals is three to a fourth, four to a fifth, and seven to an octave. The performer may decide to avoid the aesthetics implied in the process,[270] but optimal expressivity is reached with these numbers and remains an unavoidable conclusion.

On both sides of the octave

Now that we have reached the big city and that the intermediate stops are already explored, now that one has even determined alternative routes avoiding the heart of the city or the passage into smaller, intermediate towns, the performer may decide to conclude his composition or he may wish to undertake further explorations of the space beyond the boundaries. He could decide for example to jump (take a shortcut) from one pitch to another one a fourth or a fifth apart, and then

[264] Which I define as "localized pitch heterophony" in [Beyhom, 2016, p. 76].

[265] And on the performer's ability to memorize them, as well as to conceptualize (and possibly, eventually, explain) and reproduce them.

[266] This state of balance is reached by the performer depending on his ability to (1) identify these slightly different intervals, and/or (2) reproduce them with his voice or his instrument.

[267] *i.e.* localized and generalized heterophony.

[268] For example *maqām Ṣabā* in Arabian music, the scale of which may be expressed as $d\ e\text{-}\ f\ g^b\ a'\ b^b{}'\ c'\ d^b{}'$; the upper octave is generally different from the lower one, and occurrences for *d'* are exceptional (commonly, the transition from the first to the second octave uses $d^b{}'$ e' f' to complete the ascending *ḥijāz* tetrachord beginning with *c'*). Please note that that about 20 other Arabian modes have similar characteristics as *maqām Ṣabā* – see [Beyhom, 2016], Chapter III.

[269] This explains why, as an aesthetic choice, performers who are well aware of the importance of the three consonant containing intervals may deliberately ignore them in order to obtain a different combination (such as avoiding the fourth and the octave in *maqām Ṣabā* – see previous footnote).

[270] For example: (1) use relatively large intervals within a containing interval, (2) avoid the consonances of fourth, fifth or the octave, (3) use a certain number of conjunct semi-tones in a row, etc.

come back, or go further, in order to explore the intermediate, or upper or lower, pitches until he and his listeners are satisfied with the new voyage where he guided them.

Eventually, with the increasing number of musicians in one location, performers came together to play alternative forms, each of them exploring parallel or separate ways of getting from one point to another of the containing interval, each of them with his own morphology, instrument(s), artistic taste, and origins. Each of them would listen to other musicians' performance and support or be inspired by it, or would be supported by those and inspire them himself.

This process may have strengthened the predominance of what we call today heterophony, in the large sense of the word: it may well be that, whenever this liberty of exploration vanished and became bounded by more or less strict patterns of progression of simultaneous musical parts, or whenever the octave (or largest) containing interval became prominent in a particular musical culture,[271] another form of music came to light, the one which is today called polyphony.

Clues about the possible origins of the heptatonic scale

If culture differs from one civilization to another, some characteristics are common almost to all. Heptatonic scales, in the historical realm of modal music, are one of these common denominators. It seems that the number of seven conceptual intervals to the octave is the result of musically shared aesthetical criteria over a large region and for a long historical period. These criteria, which may probably be further enriched, are:

- the consistency of bi-interval combinations (the use of middle-sized conceptual intervals) within a scale, *i.e.* avoiding:
  - successions of very small (like the semi-tones) or large (like the one-tone-and-a-half) elements (intervals),
  - conjunctions of very small elements (like the semi-tone and the three-quarter-tone intervals) and,
  - successions of large elements within the fourth (like adjacent zalzalian augmented seconds or more, or alternating tones and bigger intervals in conjunction, etc.,
- the use of an optimal step, also a smallest scale interval, for interval differentiation and identification,
- the use of a limited alphabet of intervals of the second,
- the acoustic guidance of the main three large containing intervals (the fourth, the fifth, and the octave).

Other numbers of conceptual intervals may have been used for the octave, for example when these criteria did not apply very strictly, or when the need for particular combinations arose (for example on aesthetical or social grounds).

Whenever a specific culture decided to choose a lesser number of intervals in a scale, aesthetic criteria may have varied. In pentatonic music, for example, such a limitation as the three-semi-tones interval being the greatest conjunct interval in the scale, may have been set at a higher value. This makes it more difficult to create smaller containing intervals, especially the fourth, but leaves the larger containing intervals (like the fifth and the octave) role as acoustic guides for the performer (about) unchanged.

Choosing a number of intervals larger than seven, further possibilities appear. However, they are simple extensions of the optimized octave scales (containing seven conjunct conceptual intervals), or possible loop lines around some of the aesthetic criteria listed above (for example the inclusion of conjunct semi-tones).[272]

If a culture decides that the acoustic characteristics of containing intervals are the leading criterion, the

[271] Or whenever this simultaneous emission of more or less parallel melodic patterns was part of the local culture – the hypothesis developed in this paragraph does not necessarily apply to this type of music as for example the 'Are 'Are music of the Solomon Islands, but may apply to improvised polyphonic music, in which the freedom of expression with the single performer is replaced by the freedom of vertical improvisation within a party of musicians. The hypothesis is that, even in the latter case, a preliminary process of scale calibration, as the one explained in the text above, is at the origin of heptatonic scales (if used in that particular music).

[272] Octatonic or enneatonic scales found in some literature may also be the result of the inclusion of modulation variants for a scale, or for part of it, at least in music theory.

choice of the fourth may have led to the use of the intermediate zalzalian intervals composing it, in order to maximize its possibilities, whenever the choice of the fifth maximized the use of semi-tones, which favored in its turn the appearance of tense diatonism (based on successions of tones and semi-tones).

The choice of the octave as the main acoustic criterion may, on the other side, have precipitated a process of equivalence between intervals with a difference of an octave (for example between a fourth and an octave-and-a-fourth), and the use of parallel lines in polyphonic music.

All of these criteria have different powers according to the culture in which they appear. The balance between them has led to different subdivisions of one main form of music, called heptatonic modality.

Later on, and in order to arrange musical systems of intervals within a coherent music theory, different civilizations have sometimes chosen different formulations, some to keep a firm connection with music performance, and some others based on a mathematical, seemingly more elegant basis, having some connections with musical practice or acoustic characteristics of musical intervals.

With time theory became an entity of its own and was developed by scholars for the sake of the beauty of mathematical constructions which were confused by their promoters, and later by their followers, being a generative theory, and whenever any musical theory should first rely on practice.

The mathematical expression of intervals through string ratios or through other, very small, quantifying intervals gave theoreticians the illusion that intervals do have exact sizes in performance, even if modal practice refutes this assertion.

The map became the territory, whenever it should have been, at most, a conventional sketch of the territory, or a more or less precise guide within the infinite possibilities of pitches within a containing interval. In order to remain a guide, and not become a rigid yoke to musical expressivity, theoretical expressions of scales should, first of all, differentiate between quantitative and qualitative intervals, and between conceptual, quantifying and elementary intervals, in order to stay, where possible, close to music performance and far from interval quantization.

As an overall conclusion to this study, this research gives a new, plausible explanation for heptatonism as a privileged receptacle for modal scales. Some criteria underlined in the article, like the homogeneity rule, the insistence on the fourth or fifth, or any other indication of a calibration process of the scale, may give complementary information in the search for its origin.

APPENDIX A: SCALE ELEMENTS IN EIGHTHS OF THE TONE, WITHIN THE CONTAINING INTERVAL OF THE FOURTH (= 20 EIGHTHS OF THE TONE)

Remarks:

- ni: number of intervals within the scale elements
- $^{>}$: large intervals
- *: double semi-tone criterion
- **Bold**: commonly used genera in Arabian music
- *Italics* and ~~stricken~~: redundant combinations
- Underlined: semi-tone equivalent combinations

ni = 2

4 16$^{>}$, 16 4$^{>}$
5 15$^{>}$, 15 5$^{>}$
6 14$^{>}$, 14 6$^{>}$
7 13$^{>}$, 13 7$^{>}$
8 12, 12 8
9 11, 11 9
10 10, _~~10 10~~_

ni = 3

4 4 12*, **4 12 4**, 12 4 4*
4 5 11, 5 11 4, 11 4 5
4 11 5, 11 5 4, 5 4 11
4 6 10, **6 10 4**, 10 4 6
4 10 6, 10 6 4, 6 4 10
4 7 9, 7 9 4, 9 4 7
4 9 7, 9 7 4, 7 4 9
4 8 8, **8 8 4**, **8 4 8**
5 5 10, 5 10 5, 10 5 5
5 6 9, 6 9 5, 9 5 6
5 9 6, 9 6 5, 6 5 9
5 7 8, 7 8 5, 8 5 7
5 8 7, 8 7 5, 7 5 8
6 6 8, **6 8 6**, **8 6 6**
6 7 7, 7 7 6, 7 6 7

ni = 4

4 4 4 8*, 4 4 8 4*, 4 8 4 4*, 8 4 4 4*
4 4 5 7*, 4 5 7 4, 5 7 4 4*, 7 4 4 5*
4 4 7 5*, 4 7 5 4, 7 5 4 4*, 5 4 4 7*
4 5 4 7, 5 4 7 4, 4 7 4 5, 7 4 5 4
4 4 6 6*, 4 6 6 4, 6 6 4 4*, 6 4 4 6*
4 6 4 6, 6 4 6 4, _~~4 6 4 6~~_, _~~6 4 6 4~~_
4 5 5 6, 5 5 6 4, 5 6 4 5, 6 4 5 5
4 5 6 5, 5 6 5 4, 6 5 4 5, 5 4 5 6
4 6 5 5, 6 5 5 4, 5 5 4 6, 5 4 6 5
5 5 5 5, _~~5 5 5 5~~_, _~~5 5 5 5~~_, _~~5 5 5 5~~_

ni = 5

4 4 4 4 4*, _~~4 4 4 4 4~~_*, _~~4 4 4 4 4~~_*, _~~4 4 4 4 4~~_*, _~~4 4 4 4 4~~_*

* * *

Appendix B: Tables of the combination process for a just fifth, with NI = 4 (quarter-tone model) and a reduced alphabet of intervals (from the semi-tone to the one-and-a-half-tones interval)

Remarks:

- ns: number of systems
- *: conjunct semi-tones
- §: scale elements that contain 'conjunct big intervals', *i.e.*, at least two conjunct intervals that are bigger or equal to the one-tone interval, and among which one is at least bigger than the tone
- **Bold font**: main pentachords in use in Arabian music
- c: scale elements to which a semi-tone must be added in order to complete the *ḥijāz* tetrachord ('262')
- *Italic font*: pentachords that, to my knowledge, are not in use in Arabian music
- *Italic font* and *~~stricken~~*: redundant pentachords
- underlined with gray background: semi-tone-compatible pentachords

1st column: number of the hyper-system, intervallic composition of the hyper-system, and number of systems ('ns') related to it

2nd column: number of the hyper-system ('No. hyp.')

3d column: number of the system ('No. sys.')

4th column: number of the sub-system or 'pentachord' ('No. pent.')

5th column: intervals of the sub-system in integer multiples of the quarter-tone ('value')

Hyper-system	No. hyp.	No. sys.	No. pent.	value
No. 1 2246 ns: 3	1	1	1	*2246**§
	1	1	2	*2462*§
	1	1	3	*4622**§
	1	1	4	*6224**
	1	2	1	**2426**^{c}
	1	2	2	**4262**
	1	2	3	**2624**
	1	2	4	*6242*
	1	3	1	*2642*
	1	3	2	*6422**§
	1	3	3	*4226**
	1	3	4	*2264**§

Hyper-system	No. hyp.	No. sys.	No. pent.	value
No. 2 2255 ns: 2	2	1	1	2525
	2	1	2	*5252*
	2	1	3	*~~2525~~*
	2	1	4	*~~5252~~*
	2	2	1	*2552*§
	2	2	2	*5522**§
	2	2	3	*5225**§
	2	2	4	*2255**§

Hyper-system	No. hyp.	No. sys.	No. pent.	*value*
No. 3 2336 ns: 3	3	1	1	*2336*
	3	1	2	*3362*
	3	1	3	*3623*
	3	1	4	*6233*
	3	2	1	*2363*
	3	2	2	*3632*
	3	2	3	*6323*
	3	2	4	*3236*
	3	3	1	*2633*
	3	3	2	*6332*
	3	3	3	**3326**^{c}
	3	3	4	*3263*

Hyper-system	No. hyp.	No. sys.	No. pent.	*value*
No. 4 2345 ns: 6	4	1	1	*2345*[§]
	4	1	2	*3452*[§]
	4	1	3	*4523*[§]
	4	1	4	5234
	4	2	1	*2354*[§]
	4	2	2	*3542*[§]
	4	2	3	*5423*[§]
	4	2	4	*4235*
	4	3	1	*2435*
	4	3	2	**4352**
	4	3	3	3524
	4	3	4	5243
	4	4	1	*2453*[§]
	4	4	2	*4532*[§]
	4	4	3	5324
	4	4	4	*3245*[§]
	4	5	1	**2534**
	4	5	2	*5342*
	4	5	3	*3425*
	4	5	4	4253
	4	6	1	*2543*[§]
	4	6	2	*5432*[§]
	4	6	3	*4325*
	4	6	4	*3254*[§]

Hyper-system	No. hyp.	No. sys.	No. pent.	value
No. 5 2444 ns: 1	5	1	1	**2444**
	5	1	2	**4442**
	5	1	3	**4424**
	5	1	4	**4244**

Hyper-system	No. hyp.	No. sys.	No. pent.	value
No. 6 3335 ns: 1	6	1	1	3335
	6	1	2	*3353*
	6	1	3	*3533*
	6	1	4	*5333*

Hyper-system	No. hyp.	No. sys.	No. pent.	**value**
No. 7 3344 ns: 2	7	1	1	**3344**
	7	1	2	**3443**
	7	1	3	**4433**
	7	1	4	**4334**
	7	2	1	**3434**
	7	2	2	**4343**
	7	2	3	~~*3434*~~
	7	2	4	~~*4343*~~

***

___Interval ‘2’ occurs 80 times (included 4 times in redundant sub-systems)

___Interval ‘3’ occurs 72 times (included 4 times in redundant sub-systems)

___Interval ‘4’ occurs 60 times (included 4 times in redundant sub-systems)

___Interval ‘5’ occurs 44 times (included 4 times in redundant sub-systems)

___Interval ‘6’ occurs 24 times (not in redundant sub-systems)

Note: the total number of pentachords is 72, of which 4 are redundant.

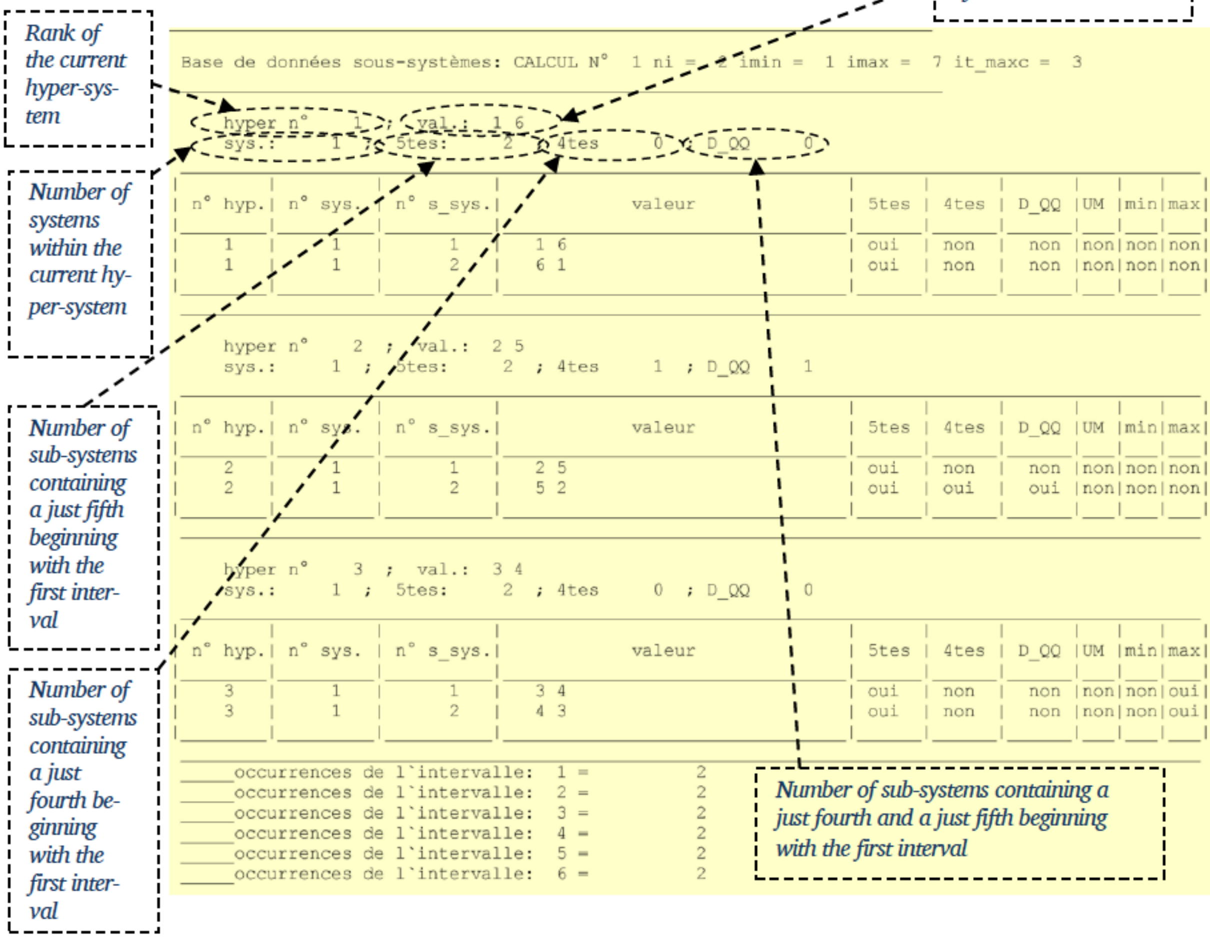
***

Appendix C: Complete results of the semi-tone generation within a Containing interval of fifth

(The results were obtained through the computer program modes V. 5.2 *developed by the author)*

Additional remarks:

- "ni": number of conceptual intervals per system
- "non" = "no", "oui" = "yes" as an answer for the detection of various below listed criteria
- "5tes": test on the presence of a just fifth beginning with the first interval
- "4tes": test on the presence of a just fourth beginning with the first interval
- D_QQ: test on the presence of a just fourth AND a just fifth beginning with the first interval (like FF)
- UM: 'ultra-min' criterion for the detection of suites of three (or more) semi-tones ('1') in a row
- min: 'min' criterion for the detection of suites of two semi-tones ('1') in a row
- max: 'max' criterion for the detection of suites of two (or more) intervals equal or superior to 'it_maxc' (the value of the latter is set for this generation to '3' semi-tones)
  - Additional remark for the last three criteria: these are equally effective for the detection of intervals in a double-fifth (the checked system is the double-fifth composed of two identical sub-systems); for the results shown in the article (Fig. 37), the results were subsequently adapted for a single fifth.
- n° hyp.: rank of the hyper-system for the current ni
- n° sys.: rank of the system for the current hyper-system
- n° s-sys.: rank of the sub-system for the current system
- imin: smallest interval used for the generation
- imax: largest interval used for the generation
- redundant sub-systems for ni = 7 are in **bold**
- "occurrences de l'intervalle '*'": number of times interval '*' is detected in the sub-systems for the current ni



New ni = 3

Base de données sous-systèmes: CALCUL N° 2 ni = 3 imin = 1 imax = 7 it_maxc = 3

hyper n° 1 ; val.: 1 1 5
sys.: 1 ; 5tes: 3 ; 4tes 1 ; D_QQ 1

n° hyp.	n° sys.	n° s_sys.	valeur	5tes	4tes	D_QQ	UM	min	max
1	1	1	1 1 5	oui	non	non	non	oui	non
1	1	2	1 5 1	oui	non	non	non	oui	non
1	1	3	5 1 1	oui	oui	oui	non	oui	non

hyper n° 2 ; val.: 1 2 4
sys.: 2 ; 5tes: 6 ; 4tes 2 ; D_QQ 2

n° hyp.	n° sys.	n° s_sys.	valeur	5tes	4tes	D_QQ	UM	min	max
2	1	1	1 2 4	oui	non	non	non	non	non
2	1	2	2 4 1	oui	non	non	non	non	non
2	1	3	4 1 2	oui	oui	oui	non	non	non
2	2	1	1 4 2	oui	oui	oui	non	non	non
2	2	2	4 2 1	oui	non	non	non	non	non
2	2	3	2 1 4	oui	non	non	non	non	non

hyper n° 3 ; val.: 1 3 3
sys.: 1 ; 5tes: 3 ; 4tes 0 ; D_QQ 0

n° hyp.	n° sys.	n° s_sys.	valeur	5tes	4tes	D_QQ	UM	min	max
3	1	1	1 3 3	oui	non	non	non	non	oui
3	1	2	3 3 1	oui	non	non	non	non	oui
3	1	3	3 1 3	oui	non	non	non	non	oui

hyper n° 4 ; val.: 2 2 3
sys.: 1 ; 5tes: 3 ; 4tes 2 ; D_QQ 2

n° hyp.	n° sys.	n° s_sys.	valeur	5tes	4tes	D_QQ	UM	min	max
4	1	1	2 2 3	oui	non	non	non	non	non
4	1	2	2 3 2	oui	oui	oui	non	non	non
4	1	3	3 2 2	oui	oui	oui	non	non	non

occurrences de l`intervalle: 1 = 15
occurrences de l`intervalle: 2 = 12
occurrences de l`intervalle: 3 = 9
occurrences de l`intervalle: 4 = 6
occurrences de l`intervalle: 5 = 3

New ni=4

Base de données sous-systèmes: CALCUL N° 3 ni = 4 imin = 1 imax = 7 it_maxc = 3

hyper n° 1 ; val.: 1 1 1 4
sys.: 1 ; 5tes: 4 ; 4tes 2 ; D_QQ 2

n° hyp.	n° sys.	n° s_sys.	valeur	5tes	4tes	D_QQ	UM	min	max
1	1	1	1 1 1 4	oui	non	non	oui	oui	non
1	1	2	1 1 4 1	oui	non	non	oui	oui	non
1	1	3	1 4 1 1	oui	oui	oui	oui	oui	non
1	1	4	4 1 1 1	oui	oui	oui	oui	oui	non

hyper n° 2 ; val.: 1 1 2 3
sys.: 3 ; 5tes: 12 ; 4tes 5 ; D_QQ 5

n° hyp.	n° sys.	n° s_sys.	valeur	5tes	4tes	D_QQ	UM	min	max
2	1	1	1 1 2 3	oui	non	non	non	oui	non
2	1	2	1 2 3 1	oui	non	non	non	oui	non
2	1	3	2 3 1 1	oui	oui	oui	non	oui	non
2	1	4	3 1 1 2	oui	oui	oui	non	oui	non
2	2	1	1 1 3 2	oui	oui	oui	non	oui	non
2	2	2	1 3 2 1	oui	non	non	non	oui	non
2	2	3	3 2 1 1	oui	oui	oui	non	oui	non
2	2	4	2 1 1 3	oui	non	non	non	oui	non
2	3	1	1 2 1 3	oui	non	non	non	non	non
2	3	2	2 1 3 1	oui	non	non	non	non	non
2	3	3	1 3 1 2	oui	oui	oui	non	non	non
2	3	4	3 1 2 1	oui	non	non	non	non	non

hyper n° 3 ; val.: 1 2 2 2
sys.: 1 ; 5tes: 4 ; 4tes 3 ; D_QQ 3

n° hyp.	n° sys.	n° s_sys.	valeur	5tes	4tes	D_QQ	UM	min	max
3	1	1	1 2 2 2	oui	oui	oui	non	non	non
3	1	2	2 2 2 1	oui	non	non	non	non	non
3	1	3	2 2 1 2	oui	oui	oui	non	non	non
3	1	4	2 1 2 2	oui	oui	oui	non	non	non

_____occurrences de l`intervalle: 1 = 40
_____occurrences de l`intervalle: 2 = 24
_____occurrences de l`intervalle: 3 = 12
_____occurrences de l`intervalle: 4 = 4

* * *

Appendix D: Hyper-systems of the semi-tone octave complete alphabet generation

Remarks:

- "ni": number of conceptual intervals per system
- "hyper": hyper-system
- "Sys.": number of systems for the current hyper-system
- NSS5, NSS4: number of systems with a just fifth, or a just fourth, beginning with the first interval
- "Value": explicit intervallic suite representing the hyper-system
- NDFF: number of systems that pass the test on the presence of a just fourth and a just fifth beginning with the first interval
- '*Italic*': systems or hyper-systems containing redundant sub-systems
- '***Bold and italic***': completely redundant hyper-systems

On grey or golden background: hyper-systems that use the limited alphabet '1, 2, 3'

Lastly: hyper-systems that generate redundant sub-systems have a structure in which there is room for repeated patterns of intervals within the complete scale, as for example in hyper-system '1 1 1 1 4 4' (for ni = 6); in this configuration of interval capacity, we may obtain the scheme '1 1' '1 1' '4 4' (three pairs of identical intervals in all): this means that there exists at least one possibility of combining these intervals, in patterns of three conjunct intervals, in a system configuration which generates redundant sub-systems. One such system for the latter case is "1 1 4 1 1 4" in which the tri-intervallic combination "1 1 4" is repeated twice, and generates three redundant sub-systems (beginning with the fourth de-ranking process – the first one corresponding to the initial configuration) as shown below:

- 1st sub-system: 1 1 4 1 1 4
- 2nd sub-system: 1 4 1 1 4 1
- 3rd sub-system: 4 1 1 4 1 1
- 4th sub-system: 1 1 4 1 1 4 (identical to No. 1)
- 5th sub-system: 1 4 1 1 4 1 (id. to No. 2)
- 6th sub-system: 4 1 1 4 1 1 (id. to No. 3)

ni = 2

hyper no. 1	value: 1 11	NS: 1	NSS5: 0	NSS4: 0	NDFF: 0
hyper no. 2	value: 2 10	NS: 1	NSS5: 0	NSS4: 0	NDFF: 0
hyper no. 3	value: 3 9	NS: 1	NSS5: 0	NSS4: 0	NDFF: 0
hyper no. 4	value: 4 8	NS: 1	NSS5: 0	NSS4: 0	NDFF: 0
hyper no. 5	value: 5 7	NS: 1	NSS5: 1	NSS4: 1	NDFF: 0
hyper no. 6	***value: 6 6***	***NS: 1***	***NSS5: 0***	***NSS4: 0***	***NDFF: 0***

ni = 3

hyper no. 1	value: 1 1 10	NS: 1	NSS5: 0	NSS4: 0	NDFF: 0
hyper no. 2	value: 1 2 9	NS: 2	NSS5: 0	NSS4: 0	NDFF: 0
hyper no. 3	value: 1 3 8	NS: 2	NSS5: 0	NSS4: 0	NDFF: 0
hyper no. 4	value: 1 4 7	NS: 2	NSS5: 2	NSS4: 2	NDFF: 0
hyper no. 5	value: 1 5 6	NS: 2	NSS5: 2	NSS4: 2	NDFF: 0
hyper no. 6	value: 2 2 8	NS: 1	NSS5: 0	NSS4: 0	NDFF: 0
hyper no. 7	value: 2 3 7	NS: 2	NSS5: 2	NSS4: 2	NDFF: 0
hyper no. 8	value: 2 4 6	NS: 2	NSS5: 0	NSS4: 0	NDFF: 0
hyper no. 9	value: 2 5 5	NS: 1	NSS5: 2	NSS4: 2	NDFF: 1
hyper no. 10	value: 3 3 6	NS: 1	NSS5: 0	NSS4: 0	NDFF: 0
hyper no. 11	value: 3 4 5	NS: 2	NSS5: 2	NSS4: 2	NDFF: 0
hyper no. 12	***value: 4 4 4***	***NS: 1***	***NSS5: 0***	***NSS4: 0***	***NDFF: 0***

ni = 4

hyper no. 1	value: 1 1 1 9	NS: 1	NSS5: 0	NSS4: 0	NDFF: 0
hyper no. 2	value: 1 1 2 8	NS: 3	NSS5: 0	NSS4: 0	NDFF: 0
hyper no. 3	value: 1 1 3 7	NS: 3	NSS5: 3	NSS4: 3	NDFF: 0
hyper no. 4	value: 1 1 4 6	NS: 3	NSS5: 4	NSS4: 4	NDFF: 0
hyper no. 5	*value: 1 1 5 5*	*NS: 2*	*NSS5: 4*	*NSS4: 4*	*NDFF: 1*
hyper no. 6	value: 1 2 2 7	NS: 3	NSS5: 3	NSS4: 3	NDFF: 0
hyper no. 7	value: 1 2 3 6	NS: 6	NSS5: 4	NSS4: 4	NDFF: 0
hyper no. 8	value: 1 2 4 5	NS: 6	NSS5: 10	NSS4: 10	NDFF: 4
hyper no. 9	value: 1 3 3 5	NS: 3	NSS5: 3	NSS4: 3	NDFF: 0
hyper no. 10	value: 1 3 4 4	NS: 3	NSS5: 4	NSS4: 4	NDFF: 0
hyper no. 11	value: 2 2 2 6	NS: 1	NSS5: 0	NSS4: 0	NDFF: 0
hyper no. 12	value: 2 2 3 5	NS: 3	NSS5: 7	NSS4: 7	NDFF: 4
hyper no. 13	*value: 2 2 4 4*	*NS: 2*	*NSS5: 0*	*NSS4: 0*	*NDFF: 0*
hyper no. 14	value: 2 3 3 4	NS: 3	NSS5: 4	NSS4: 4	NDFF: 0
hyper no. 15	***value: 3 3 3 3***	***NS: 1***	***NSS5: 0***	***NSS4: 0***	***NDFF: 0***

ni = 5

hyper no. 1	value: 1 1 1 1 8	NS: 1	NSS5: 0	NSS4: 0	NDFF: 0
hyper no. 2	value: 1 1 1 2 7	NS: 4	NSS5: 4	NSS4: 4	NDFF: 0
hyper no. 3	value: 1 1 1 3 6	NS: 4	NSS5: 6	NSS4: 6	NDFF: 0
hyper no. 4	value: 1 1 1 4 5	NS: 4	NSS5: 10	NSS4: 10	NDFF: 4
hyper no. 5	value: 1 1 2 2 6	NS: 6	NSS5: 6	NSS4: 6	NDFF: 0
hyper no. 6	value: 1 1 2 3 5	NS: 12	NSS5: 24	NSS4: 24	NDFF: 10
hyper no. 7	value: 1 1 2 4 4	NS: 6	NSS5: 12	NSS4: 12	NDFF: 4
hyper no. 8	value: 1 1 3 3 4	NS: 6	NSS5: 12	NSS4: 12	NDFF: 0
hyper no. 9	value: 1 2 2 2 5	NS: 4	NSS5: 10	NSS4: 10	NDFF: 6
hyper no. 10	value: 1 2 2 3 4	NS: 12	NSS5: 24	NSS4: 24	NDFF: 8
hyper no. 11	value: 1 2 3 3 3	NS: 4	NSS5: 6	NSS4: 6	NDFF: 0
hyper no. 12	value: 2 2 2 2 4	NS: 1	NSS5: 0	NSS4: 0	NDFF: 0
hyper no. 13	value: 2 2 2 3 3	NS: 2	NSS5: 6	NSS4: 6	NDFF: 4

ni = 6

hyper no. 1	value: 1 1 1 1 1 7	NS: 1	NSS5: 1	NSS4: 1	NDFF: 0
hyper no. 2	value: 1 1 1 1 2 6	NS: 5	NSS5: 8	NSS4: 8	NDFF: 0
hyper no. 3	value: 1 1 1 1 3 5	NS: 5	NSS5: 14	NSS4: 14	NDFF: 6
hyper no. 4	*value: 1 1 1 1 4 4*	*NS: 3*	*NSS5: 10*	*NSS4: 10*	*NDFF: 5*
hyper no. 5	value: 1 1 1 2 2 5	NS: 10	NSS5: 27	NSS4: 27	NDFF: 14
hyper no. 6	value: 1 1 1 2 3 4	NS: 20	NSS5: 58	NSS4: 58	NDFF: 20
hyper no. 7	*value: 1 1 1 3 3 3*	*NS: 4*	*NSS5: 11*	*NSS4: 11*	*NDFF: 0*
hyper no. 8	value: 1 1 2 2 2 4	NS: 10	NSS5: 26	NSS4: 26	NDFF: 12
hyper no. 9	value: 1 1 2 2 3 3	NS: 16	NSS5: 44	NSS4: 44	NDFF: 16
hyper no. 10	value: 1 2 2 2 2 3	NS: 5	NSS5: 17	NSS4: 17	NDFF: 12
hyper no. 11	***value: 2 2 2 2 2 2***	***NS: 1***	***NSS5: 0***	***NSS4: 0***	***NDFF: 0***

ni = 7

hyper no. 1	value: 1 1 1 1 1 1 6	NS: 1	NSS5: 2	NSS4: 2	NDFF: 0
hyper no. 2	value: 1 1 1 1 1 2 5	NS: 6	NSS5: 20	NSS4: 20	NDFF: 10
hyper no. 3	value: 1 1 1 1 1 3 4	NS: 6	NSS5: 24	NSS4: 24	NDFF: 12
hyper no. 4	value: 1 1 1 1 2 2 4	NS: 15	NSS5: 56	NSS4: 56	NDFF: 28
hyper no. 5	value: 1 1 1 1 2 3 3	NS: 15	NSS5: 58	NSS4: 58	NDFF: 21
hyper no. 6	value: 1 1 1 2 2 2 3	NS: 20	NSS5: 80	NSS4: 80	NDFF: 46
hyper no. 7	value: 1 1 2 2 2 2 2	NS: 3	NSS5: 12	NSS4: 12	NDFF: 9

ni = 8

hyper no. 1	value: 1 1 1 1 1 1 1 5	NS: 1	NSS5: 4	NSS4: 4	NDFF: 2
hyper no. 2	value: 1 1 1 1 1 1 2 4	NS: 7	NSS5: 34	NSS4: 34	NDFF: 20
hyper no. 3	*value: 1 1 1 1 1 1 3 3*	*NS: 4*	*NSS5: 21*	*NSS4: 21*	*NDFF: 11*
hyper no. 4	value: 1 1 1 1 1 2 2 3	NS: 21	NSS5: 108	NSS4: 108	NDFF: 62
hyper no. 5	*value: 1 1 1 1 2 2 2 2*	*NS: 10*	*NSS5: 51*	*NSS4: 51*	*NDFF: 34*

ni = 9

hyper no. 1	value: 1 1 1 1 1 1 1 1 4	NS: 1	NSS5: 6	NSS4: 6	NDFF: 4
hyper no. 2	value: 1 1 1 1 1 1 1 2 3	NS: 8	NSS5: 52	NSS4: 52	NDFF: 34
hyper no. 3	*value: 1 1 1 1 1 1 2 2 2*	*NS: 10*	*NSS5: 66*	*NSS4: 66*	*NDFF: 48*

ni = 10

hyper no. 1	value: 1 1 1 1 1 1 1 1 1 3	NS: 1	NSS5: 8	NSS4: 8	NDFF: 6
hyper no. 2	*value: 1 1 1 1 1 1 1 1 2 2*	*NS: 5*	*NSS5: 41*	*NSS4: 41*	*NDFF: 33*

ni = 11

hyper no. 1	value: 1 1 1 1 1 1 1 1 1 1 2	NS: 1	NSS5: 10	NSS4: 10	NDFF: 9

ni = 12

hyper no. 1	***value: 1 1 1 1 1 1 1 1 1 1 1 1***	***NS: 1***	***NSS5: 12***	***NSS4: 12***	***NDFF: 12***

* * *

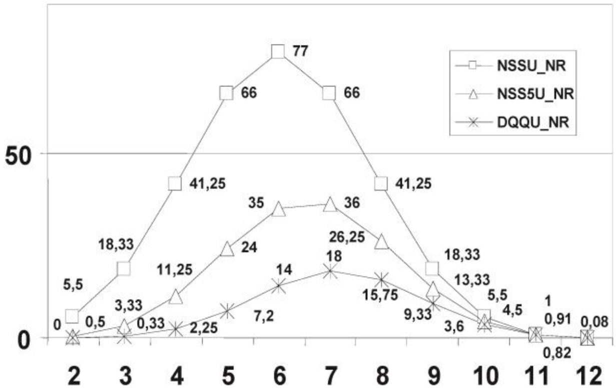
Appendix E: Additional graphs for octave generations with the extended alphabet

The database of *systems*[273] with the extended alphabet (2 to 24-quarter-tones intervals) is available (raw results from computer program Modes V. 5) in Appendix J, downloadable at http://nemo-online.org/articles.

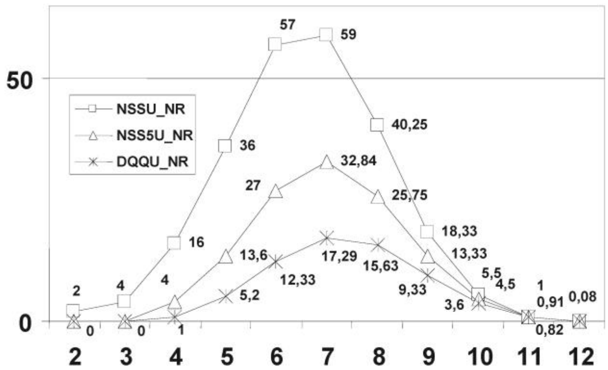
Additional remarks:

- NSSU_NR: Number of Sub-Systems in Unitary weighting with the Non-redundant sub-systems excluded (Unitary)
- NSS5U_NR: Unitary number of non-redundant sub-systems with a direct fifth (or fourth)
- DQQU_NR ("*nombre de sous-systèmes Non Redondants en Double Quarte ET Quinte justes – Unitaire*"): Unitary number of non-redundant sub-systems with a direct fourth in a fifth
- D_QQ: test on the presence of a just fourth AND a just fifth beginning with the first interval
- "umin": 'ultra-min' criterion for the detection of suites of three (or more) semi-tones ('1') in a row
- "max": 'max' criterion for the detection of suites of two (or more) intervals equal or superior to 'it_maxc' (the latter's value is set for this generation to '3' semi-tones)
- "\umin": 'non-ultra-min' – without suites of three (or more) semi-tones ('1') in a row
- "\max": 'non-max' – without suites of two (or more) intervals equal or superior to 'it_maxc' (the latter's value is set for this generation to '3' semi-tones)

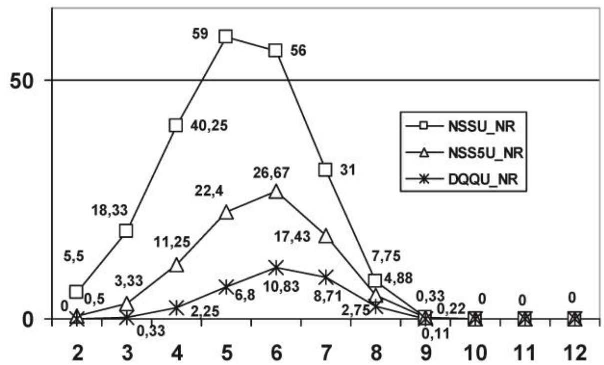
1. Semi-tone generations



FHT 1 Evolution with NI of the numbers of non-redundant systems in Unitary (weighted) variables, with test on the presence of a fourth AND fifth (DQQU_NR); f(NI): ½ tone, NR, complete alphabet (compare with Fig. 47: 55).

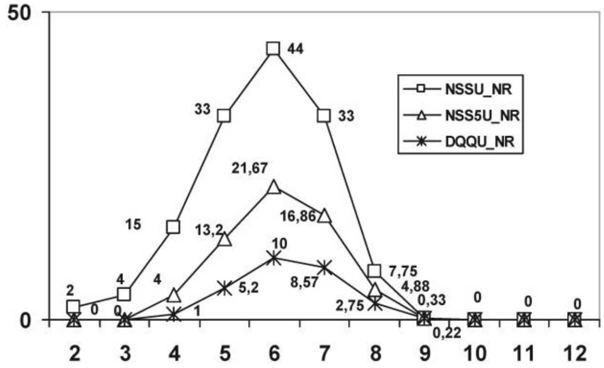


FHT 2 As previous figure, with **\max** criterion (compare with Fig. 51: 57).

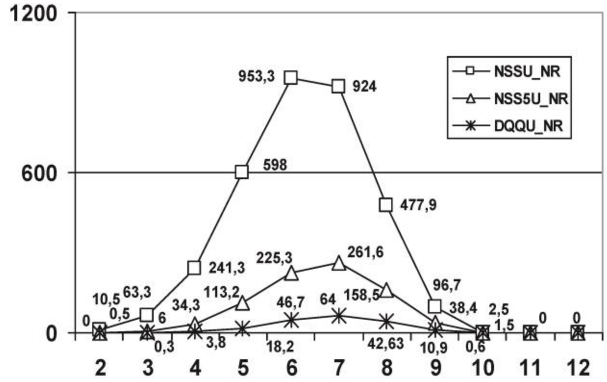


FHT 3 As above, but with **\umin** criterion instead (compare with Fig. 49: 57).

[273] Sub-systems can be deduced by de-ranking the systems.

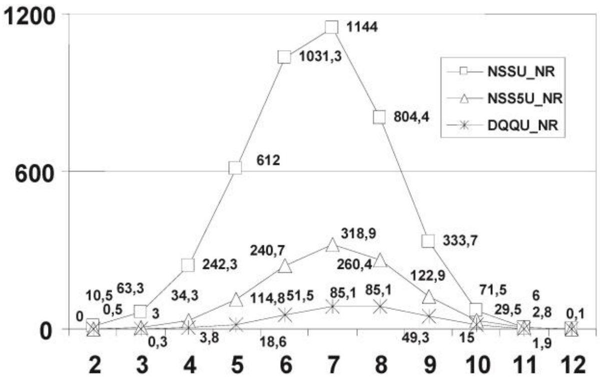


FHT 4 As above, but with both **\umin** and **\max** criteria applied (compare with Fig. 53: 58).

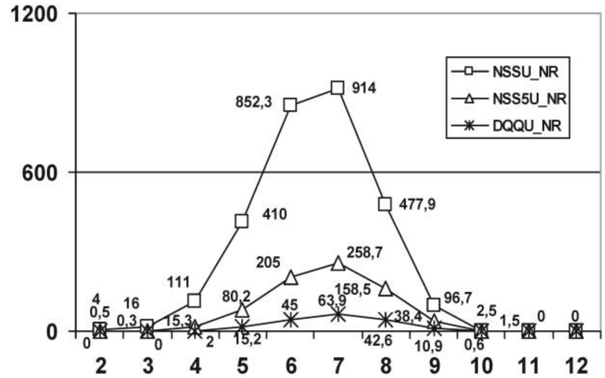


FHT 7 As previous figure, but with the **\umin** filter applied (compare with Fig. 50: 57).

2. Quarter-tone generations

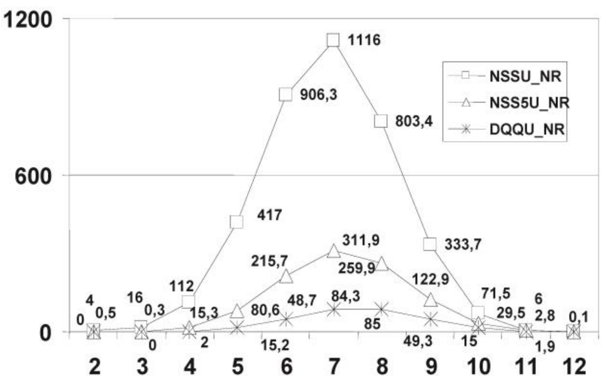


FHT 5 Evolution with NI of the numbers of non-redundant systems in Unitary (weighted) variables, with test on the presence of a fourth AND fifth (DQQU_NR); f(NI): ¼ tone, NR, extended alphabet (the one-quarter-tone interval is excluded – compare with Fig. 48: 56).



FHT 8 As above, but with both filters **\umin** and **\max(6)** applied (compare with Fig. 54: 58).

***



FHT 6 As above, but with the **\max(6)** filter applied (compare with Fig. 52: 57).

Appendix F: Synoptic results for the quarter-tone generations, with the smallest conceptual interval (imin) set to “2” quarter-tones and no limitations for the largest interval

Remarks:

- Smallest interval in use: 2 quarter-tones
- Largest interval in use: 24 quarter-tones
- Range of NI: 2 to 12
- Presence of a direct fifth: ‘D. fifth’
- Presence of a direct fourth: ‘D. fourth’
- Conjunct two semi-tones: ‘min’
- Conjunct three semi-tones: ‘umin’
- Conjunct big intervals (6 quarter-tones or greater): ‘max’
- ‘R+’: including redundancies
- ‘R-’: excluding redundancies
- Filters excluding sub-systems (‘NON’) are preceded by ‘\’

NI	Subdivisions	Without filters		\max (6)		\min		\min AND \max		\umin		\umin AND \ max	
		R+	R-	R+	R-	R+	R-	R+	R-	R+	R-	R+	R-
2	systems	11	**10.5**	4	**4**	11	**10.5**	4	**4**	11	**10.5**	4	**4**
	sub-systems: - D. fifth	.5	**.5**	0	**0**	.5	**.5**	0	**0**	.5	**.5**	0	**0**
	- D. fourth	.5	**.5**	0	**0**	.5	**.5**	0	**0**	.5	**.5**	0	**0**
	- D. fifth AND D. fourth	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**
3	systems	64	**63.33**	16	**16**	63	**62.33**	15	**15**	64	**63.33**	16	**16**
	sub-systems: - D. fifth	6	**6**	.33	**.33**	6	**6**	.33	**.33**	6	**6**	.33	**.33**
	- D. fourth	6	**6**	.33	**.33**	6	**6**	.33	**.33**	6	**6**	.33	**.33**
	- D. fifth AND D. fourth	.33	**.33**	0	**0**	.33	**.33**	0	**0**	.33	**.33**	0	**0**
4	systems	245	**242.25**	114	**112**	229	**226.25**	107	**105**	244	**241.25**	113	**111**
	sub-systems: - D. fifth	34.5	**34.25**	15.5	**15.25**	33	**32.75**	15.5	**15.25**	34.5	**34.25**	15.5	**15.25**
	- D. fourth	34.5	**34.25**	15.5	**15.25**	33	**32.75**	15.5	**15.25**	34.5	**34.25**	15.5	**15.25**
	- D. fifth AND D. fourth	3.75	**3.75**	2	**2**	3.5	**3.5**	2	**2**	3.75	**3.75**	2	**2**
5	systems	612	**612**	417	**417**	507	**507**	355	**355**	598	**598**	410	**410**
	sub-systems: - D. fifth	114.8	**114.81**	80.6	**80.6**	97.6	**97.6**	71	**71**	113.2	**113.2**	80.2	**80.2**
	- D. fourth	114.8	**114.81**	80.6	**80.6**	97.6	**97.6**	71	**71**	113.2	**113.2**	80.2	**80.2**
	- D. fifth AND D. fourth	18.6	**18.6**	15.2	**15.2**	14.8	**14.8**	13	**13**	18.2	**18.2**	15.2	**15.2**
6	systems	1038	**1031.33**	913	**906.33**	679	**672.83**	628	**621.83**	960	**953.33**	859	**852.33**
	sub-systems: - D. fifth	242.17	**240.67**	217.17	**215.67**	162.17	**161**	153.67	**152.5**	226.83	**225.33**	26.5	**205**
	- D. fourth	242.17	**240.67**	217.17	**215.67**	162.17	**161**	153.67	**152.5**	226.83	**225.33**	26.5	**205**
	- D. fifth AND D. fourth	51.67	**51.5**	48.83	**48.67**	30	**30**	30	**30**	46.83	**46.67**	45.17	**45**

FHT 9 Synoptic table (1): Results for the quarter-tone generations, with the smallest conceptual interval (imin) set to “2” quarter-tones and no limitations for the largest interval

NI	Subdivisions	Without filters		\max (6)		\min		\min AND \max		\umin		\umin AND \ max	
		R+	R-	R+	R-	R+	R-	R+	R-	R+	R-	R+	R-
7	systems	1144	**1144**	1116	**1116**	474	**474**	473	**473**	924	**924**	914	**914**
	sub-systems: - D. fifth	318.86	**318.86**	311.86	**311.86**	134.86	**134.86**	134.57	**134.57**	261.57	**261.57**	258.71	**258.71**
	- D. fourth	318.86	**318.86**	311.86	**311.86**	134.86	**134.86**	134.57	**134.57**	261.57	**261.57**	258.71	**258.71**
	- D. fifth AND D. fourth	85.29	**85.29**	84.29	**84.29**	27.29	**27.29**	27.29	**27.29**	64	**64**	63.86	**63.86**
8	systems	810	**804.58**	809	**803.38**	142	**138.38**	142	**138.38**	483	**477.88**	483	**477.88**
	sub-systems: - D. fifth	262	**260.38**	262	**259.88**	46	**45**	46	**45**	160.25	**158.5**	160.25	**158.5**
	- D. fourth	262	**260.38**	262	**259.88**	46	**45**	46	**45**	160.25	**158.5**	160.25	**158.5**
	- D. fifth AND D. fourth	85.75	**85.13**	85.63	**85**	7.75	**7.75**	7.75	**7.75**	43	**42.63**	43	**42.63**
9	systems	335	**333.67**	335	**333.67**	9	**8.33**	9	**8.33**	98	**96.67**	98	**96.67**
	sub-systems: - D. fifth	123	**122.89**	123.56	**122.89**	3.78	**3.56**	3.78	**3.56**	39.11	**38.44**	39.11	**38.44**
	- D. fourth	123	**122.89**	123.56	**122.89**	3.78	**3.56**	3.78	**3.56**	39.11	**38.44**	39.11	**38.44**
	- D. fifth AND D. fourth	49.56	**49.33**	49.56	**49.33**	.56	**.56**	.56	**.56**	11.11	**10.89**	11	**10.89**
10	systems	73	**71.5**	73	**71.5**	0	**0**	0	**0**	3	**2.5**	3	**2.5**
	sub-systems: - D. fifth	30	**29.5**	30.5	**29.5**	0	**0**	0	**0**	1.8	**1.5**	1.8	**1.5**
	- D. fourth	30	**29.5**	30.5	**29.5**	0	**0**	0	**0**	1.8	**1.5**	1.8	**1.5**
	- D. fifth AND D. fourth	15.6	**15**	15.6	**15**	0	**0**	0	**0**	.7	**.6**	.7	**.6**
11	systems	6	**6**	6	**6**	0	**0**	0	**0**	0	**0**	0	**0**
	sub-systems: - D. fifth	2.82	**2.82**	2.82	**2.82**	0	**0**	0	**0**	0	**0**	0	**0**
	- D. fourth	2.82	**2.82**	2.82	**2.82**	0	**0**	0	**0**	0	**0**	0	**0**
	- D. fifth AND D. fourth	1.91	**1.91**	1.91	**1.91**	0	**0**	0	**0**	0	**0**	0	**0**
12	systems	1	**.08**	1	**.8**	0	**0**	0	**0**	0	**0**	0	**0**
	sub-systems: - D. fifth	1	**.08**	1.0	**.08**	0	**0**	0	**0**	0	**0**	0	**0**
	- D. fourth	1	**.08**	1.0	**.08**	0	**0**	0	**0**	0	**0**	0	**0**
	- D. fifth AND D. fourth	1	**.08**	1	**.08**	0	**0**	0	**0**	0	**0**	0	**0**

FHT 10 Synoptic table (2): Results for the quarter-tone generations, with the smallest conceptual interval (imin) set to "2" quarter-tones and no limitations for the largest interval.

***

Appendix G: Octavial scales with limited transposition – with an addendum for scale elements in the fourth and in the fifth[274]

With interval combination, we frequently find redundant (or hyper-redundant, when the hyper-system is completely redundant) combinations, of which the Western equivalents are the scales with limited transposition. I explore here, apart from the filtering process used for identifying (and eliminating) such sub-systems in the general database of sub-systems used in my thesis, the reverse process, *i.e.* applying formulae for the (nearly) direct obtainment (and understanding) of such scales.

* * *

Let us first explore two examples of redundant systems:

1. The tone-scale of Debussy (2 2 2 2 2 2 in multiples of the semi-tone).
2. Scale ("mode") no. 3 of Messiaen's (1 1 2 1 1 2 1 1 2) with nine intervals to the octave.[275]

In the first case (Debussy – hyper-redundant system), de-ranking the first interval(s) will always give the same system (2 2 2 2 2 2) which is equivalent to its sub-systems; in the case of scale 1 1 2 1 1 2 1 1 2 (a redundant system with limited transposition), sub-systems generated by a de-ranking (here also a rotation) process will all be redundant beginning with the fourth de-ranking[276]) and give equivalent scales to the first three (*i.e.*: 1 1 2 1 1 2 1 1 2, 1 2 1 1 2 1 1 2 1, 2 1 1 2 1 1 2 1 1).

Completely redundant systems

Scales such as Debussy's (the first case above, a hyper-redundant system with all identical intervals) can be characterized with the formula:

- **i*N = S**, with $2 \leq i \leq S$ and $1 \leq N \leq S$ **(1)**
  - to be read: "For any given number of repetitions 'i' of an integer (interval), with value comprised between 2 and the total integer sum S of a combination (of integer intervals), there exists at least one integer (interval) N, with value comprised between 1 and S, which divides i multiplied by S".

In formula (1), i, N, and S are integers. 'i' is the number of times the interval is repeated (six times in Debussy's scale) within a combination (two intervals are at least needed to form a combination); "N" is the numerical value of the interval (2 in Debussy's scale), while "S" is the sum of the intervals in the combination (in this case, 12 semi-tones).

The corollary of formula (1) is that for any sum S having a divider $i \geq 2$, there is at least one hyper-redundant sub-system in the set.

Particular case of the semi-tonal model with the sum S = 12

In the case when S = 12, dividers of S are 1, 2, 3, 4, 6 and 12; for dividers greater than 1, we find the following hyper-redundant systems:

- 2*N = 12, N = 6, with system 6 6, two tritones in the octave.
- 3*N = 12, N = 4, with system 4 4 4, three ditones to the octave.
- 4*N = 12, N = 3, with system 3 3 3 3, three one-and-a-half-tones to the octave.
- 6*N = 12, N = 6, Debussy's scale (system) 2 2 2 2 2 2, with six tones to the octave.
- 12*N = 12, N = 12, with the obvious 1 1 1 1 1 1 1 1 1 1 1 1, twelve semi-tones to the octave.

[274] This appendix is an extension of a footnote in the 2010 version of this article; it is also part of a course on Modal systematics I taught at a Lebanese university in the summer of 2007, and of the original French version of this article, which was proposed to Musicological reviews in France (and not accepted for publication). Audio examples, together with a simplified presentation of redundant sub-systems and systems, are provided in the dedicated Power Point show (downloadable at http://nemo-online.org/articles).

[275] Messiaen's scales with limited transposition are taken from Vol. 1 of [Nelson, 1992].

[276] Reminder: the first de-ranking gives the original system.

Formulae for the general case of redundancy

The general case (with 1 1 2 1 1 2 1 1 2 as an example) can be formulated:

- ➢ **$i*\Sigma N_j = S$**, with $1 \leq i \leq S$, $1 \leq j \leq j_{max}$, $1 \leq j_{max} \leq S$ and $1 \leq N \leq S$ **(2)**
  - i is the number of repetitions of an intervallic suite (a combination of integers) within the octave (a delimited set of integers),
  - N_1, N_2, … , N_j are the successive intervals of the repeated combination in the set,
  - S is (still) the sum of the intervals (integers) forming the set,
  - j_{max} is the upper bound of j.

By definition (formula 2), i and ΣN_j divide S; the case of hyper-redundancy is a particular case of formula (2), with $j = j_{max} = 1$ and $N_1 = N_2 = \ldots = N$. Applying formula (2) with the 1 1 2 1 1 2 1 1 2 semi-tonal octavial system, we have, $i = 3$, $N_1 = 1$ as well as N_2; N_3 is 2 with $S = 12$, while i (=3) and ΣN_j (=4) divide S (=12) – see FHT 11.

$$\ldots\ i = 3,\ j = 1 \text{ to } 3,\ j_{max} = 3$$

$$\overbrace{1 + 1 + 2} + \overbrace{1 + 1 + 2} + \overbrace{1 + 1 + 2} = 12$$

$$(N_1 + N_2 + N_3) + (N_1 + N_2 + N_3) + (N_1 + N_2 + N_3) = S$$

FHT 11 Applying formula (2) for generating redundant sub-systems to Messiaen's "mode no. 3".

Let NI be the total number of intervals to the octave, then (applying formula 2):

- ➢ **$NI = i*j_{max}$**, with $2 \leq NI \leq S$, $1 \leq i \leq S$ and $1 \leq j_{max} \leq S$ **(3)**

then apply this formula back to hyper-redundant systems.

A necessary and sufficient condition for the obtainment of hyper-redundant systems

By definition of formula (3), i and j_{max} divide NI. NI is comprised between (and including) 2 and S for the obvious reasons that a combination can only exist if it has 2 or more intervals, while this number of intervals cannot exceed the total number of intervals that can be fit in the scale (= S if all intervals are equal to 1, or semi-tones in the semi-tone model for example)[277].

In the particular case when $j_{max} = 1$, $NI = i$ (hyper-redundant systems), and with i being by definition a divider of S (formula 2) as well as a divider of NI (formula 3), a necessary condition for the existence of hyper-redundant systems with NI intervals to the octave is the existence of a common divider i for NI and S; it shall be demonstrated that this condition is also sufficient.

Sufficient condition for the obtainment of hyper-redundant systems

Let i be a common divider of numbers NI and S, with $NI \leq S$; applying formulae (2) and (3) above we deduce formulae (4) and (4'):

- ➢ **$(NI/j_{max})*\Sigma N_j = S$**, with $1 \leq i \leq S$, $2 \leq NI \leq S$, $1 \leq j \leq j_{max}$ and $1 \leq j_{max} \leq S$ **(4)**

or

- ➢ **$NI = (S*j_{max})/\Sigma N_j$**, with $1 \leq i \leq S$, $2 \leq NI \leq S$, $1 \leq j \leq j_{max}$ and $1 \leq j_{max} \leq S$ **(4')**

This proposition can only be true if ΣN_j divides ($S*j_{max}$): while ΣN_j is a divider of S (formula 2), ΣN_j is then a divider of ($S*j_{max}$) for all possible cases, provided that i is a common divider of NI and S, QED.

Redundant systems in the semi-tone model

For a semi-tone octavial model, formula (2) – *redundant systems* – is reformulated thus:

- ➢ **$i*\Sigma N_j = 12$**, with $1 \leq i \leq 12$, $1 \leq j \leq 12$ and $1 \leq N \leq 12$ **(2')**

Dividers of 12 greater than 1 are 2, 3, 4, 6 and 12; corresponding values for ΣN_j are:

- for $i = 2$, $\Sigma N_j = 6$, $j_{max} = 6$
- for $i = 3$, $\Sigma N_j = 4$, $j_{max} = 4$
- for $i = 4$, $\Sigma N_j = 3$, $j_{max} = 3$
- for $i = 6$, $\Sigma N_j = 2$, $j_{max} = 2$
- for $i = 12$, $\Sigma N_j = 1$, $j_{max} = 1$

It is then sufficient to find, for each value of i, all possible combinations for j intervals (with $1 \leq j \leq 12$):

❖ for $i = 2$, $\Sigma N_j = 6$, $j_{max} = 6$:

[277] In the quarter-tone model with extended alphabet (one-quarter-tone intervals excluded, this would be S/2.

- **j = 1, N_1 = 6, NI = 2 → 6 6 – hyper-redundant**
- **(i*N_1 = 12):NI = 2, j = 2**, NI = 4
  - N_1 = 1, N_2 = 5 → 1 5 1 5
  - N_1 = 2, N_2 = 4 → 2 4 2 4
  - **N_1 = 3, N_2 = 3 → 3 3 3 3 – hyper-redundant**
  - *N_1 = 4, N_2 = 2 → 4 2 4 2 – equivalent to case ii above*[278]
  - *N_1 = 5, N_2 = 1 → 5 1 5 1 – equivalent to case i above*

- **j = 3**, NI = 6
  - N_1 = 1, N_2 = 1, N_3 = 4 → 1 1 4 1 1 4
  - N_1 = 1, N_2 = 2, N_3 = 3 → 1 2 3 1 2 3
  - N_1 = 1, N_2 = 3, N_3 = 2 → 1 3 2 1 3 2
  - *N_1 = 1, N_2 = 4, N_3 = 1 → 1 4 1 1 4 1 – equivalent to case i above*
  - *N_1 = 2, N_2 = 1, N_3 = 3 → 2 1 3 2 1 3 – equivalent to case iii above*
  - **N_1 = 2, N_2 = 2, N_3 = 2 → 2 2 2 2 2 2 – hyper-redundant**
  - *N_1 = 2, N_2 = 3, N_3 = 1 → 2 3 1 2 3 1 – equivalent to case ii above*
  - *N_1 = 3, N_2 = 1, N_3 = 2 → 3 1 2 3 1 2 – equivalent to case ii above*
  - *N_1 = 3, N_2 = 2, N_3 = 1 → 3 2 1 3 2 1 – equivalent to case iii above*
  - *N_1 = 4, N_2 = 1, N_3 = 1 → 4 1 1 4 1 1 – equivalent to case i above*

- **j = 4**, NI = 8
  - N_1 = 1, N_2 = 1, N_3 = 1, N_4 = 3 → 1 1 1 3 1 1 1 3
  - N_1 = 1, N_2 = 1, N_3 = 2, N_4 = 2 → 1 1 2 2 1 1 2 2
  - *N_1 = 1, N_2 = 1, N_3 = 3, N_4 = 1 → 1 1 3 1 1 1 3 1 – equivalent to case i above*
  - N_1 = 1, N_2 = 2, N_3 = 1, N_4 = 2 → 1 2 1 2 1 2 1 2
  - *N_1 = 1, N_2 = 2, N_3 = 2, N_4 = 1 → 1 2 2 1 1 2 2 1 – equivalent to case ii above*
  - *N_1 = 1, N_2 = 3, N_3 = 1, N_4 = 1 → 1 3 1 1 1 3 1 1 – equivalent to case i above*
  - *N_1 = 2, N_2 = 1, N_3 = 1, N_4 = 2 → 2 1 1 2 2 1 1 2 – equivalent to case ii above*
  - *N_1 = 2, N_2 = 1, N_3 = 2, N_4 = 1 → 2 1 2 1 2 1 2 1 – equivalent to case iv above*

[278] Redundant sub-systems are shown in italics, hyper-redundant systems in bold font.

  - *N_1 = 2, N_2 = 2, N_3 = 1, N_4 = 1 → 2 2 1 1 2 2 1 1 – equivalent to case ii above*
  - *N_1 = 3, N_2 = 1, N_3 = 1, N_4 = 1 → 3 1 1 1 3 1 1 1 – equivalent to case i above*

- **j = 5**, NI = 10 : N_1 = 1, N_2 = 1, N_3 = 1, N_4 = 1, N_5 = 2 → 1 1 1 1 2 1 1 1 1 2 – *other cases are all equivalent*
- **j = 6**, NI = 12 : **N_1 = 1, N_2 = 1, N_3 = 1, N_4 = 1, N_5 = 1, N_6 = 1 → 1 1 1 1 1 1 1 1 1 1 1 1 – hyper-redundant**

Complete catalogue of redundant systems and sub-systems in the semi-tone model

- **NI = 2**
  - **6 6: hyper-redundant, (*c f# c’ or do fa# do*)**

    composing 8.33 % of the sub-systems modeled with NI = 2

- **NI = 3**
  - **4 4 4: hyper-redundant, (*c e g# c’* or *do mi sol# do*)**

    composing 3.51 % of the sub-systems modeled with NI = 3

- **NI = 4**
  - 1 5 1 5: *redundant in positions 3 and 4* (*c d♭ f# g* ***c’*** or *do ré♭ fa# sol do*)
  - 2 4 2 4: *redundant in positions 3 and 4* (*c d f# g#* ***c’*** or *do ré fa# sol# do*)
  - **3 3 3 3: hyper-redundant, (*c e♭ f# a c’* or *do mi♭ fa# la do*)**

    composing 4.07 % of the sub-systems modeled with NI = 4

- **NI = 6**
  - 1 1 4 1 1 4: *redundant in positions 4, 5 and 6* (Messiaen’s mode M5, 6 notations) (*c d♭ d or e♭♭ f# g a♭* ***c’*** or *do ré♭ ré fa# sol la♭ do*)
  - 1 3 1 3 1 3: *redundant in positions 3, 4, 5 and 6* (*c d♭ e f g# a* ***c’*** or *do ré♭ mi fa sol# la do*)
  - 1 2 3 1 2 3: *redundant in positions 4, 5 and 6* (*c d♭ e♭ f# g a* ***c’*** or *do ré♭ mi♭ fa# sol la do*)
  - 1 3 2 1 3 2: *redundant in positions 4, 5 and 6* (*c d♭ e f# g a#* ***c’*** or *do ré♭ mi fa# sol la# do*)

- **2 2 2 2 2 2: hyper-redundant (Messiaen's mode M1, 2 notations) (*c d e f# g# a# c'* or *do ré mi fa# sol# la# do*)**

  composing 3.75 % of the sub-systems modeled with NI = 6

➢ **NI = 8**

- 1 1 1 3 1 1 1 3: *redundant in positions 5, 6, 7 and 8* (Messiaen's mode M4, 6 notations) (*c d♭ d e♭ f# g a♭ b* **c'** or *do ré♭ ré mi♭ fa# sol la♭ si do*)
- 1 1 2 2 1 1 2 2: *redundant in positions 5, 6, 7 and 8* (Messiaen's mode M6, 6 notations) (*c d♭ d e f# g a♭ b♭* **c'** or *do ré♭ ré mi♭ fa# sol la♭ si do*)
- 1 2 1 2 1 2 1 2: *redundant in positions 3, 4, 5, 6, 7 and 8* (Messiaen's mode M2, 3 notations) (*c d♭ e♭ e f# g a b♭* **c'** or *do ré♭ ré mi♭ fa# sol la♭ si do*)

  composing 4.07 % of the sub-systems modeled with NI = 8

➢ **NI = 9**

- 1 1 2 1 1 2 1 1 2: *redundant in positions 3, 4, 5, 6, 7 and 8* (Messiaen's mode M3, 4 notations) (*c d♭ d e f g♭ a♭ a bi♭* **c'** or *do ré♭ ré mi♭ fa# sol la♭ si do*)

  composing 3.51 % of the sub-systems modeled with NI = 9

➢ **NI = 10**

- 1 1 1 1 2 1 1 1 1 2: *redundant in positions 6, 7, 8, 9 and 10* (Messiaen's mode M7, 6 notations) (*c d♭ d e♭ e f# g a♭ a b♭* **c'** or *do ré♭ ré mi♭ fa# sol la♭ si do*)

  composing 8.33 % of the sub-systems modeled with NI = 10

➢ **NI = 12**

- **1 1 1 1 1 1 1 1 1 1 1 1: hyper-redundant (integrally chromatic)**

  composing 91.67 % of the sub-systems modeled with NI = 12

Complete catalogue of supplementary redundant systems in the quarter-tone model

➢ **NI = 2 :** no supplementary sub-system

➢ **NI = 3 :** no supplementary sub-system

➢ **NI = 4** (1.12 %)

- 3 9 3 9: red. in positions 3 and 4
- 5 7 5 7: red. in positions 3 and 4

➢ **NI = 6** (0.64 %)

- 2 3 7 2 3 7: red. in positions 4, 5 and 6
- 2 7 3 2 7 3: red. in positions 4, 5 and 6
- 2 5 5 2 5 5: red. in positions 4, 5 and 6
- 3 3 6 3 3 6: red. in positions 4, 5 and 6
- 3 5 3 5 3 5: red. in positions 3, 4, 5 and 6
- 3 4 5 3 4 5: red. in positions 4, 5 and 6
- 3 5 4 3 5 4: red. in positions 4, 5 and 6

➢ **NI = 8** (0.69 %)

- 2 2 3 5 2 2 3 5 : red. in positions 5, 6, 7 and 8
- 2 2 5 3 2 2 5 3 : red. in positions 5, 6, 7 and 8
- 2 3 2 5 2 3 2 5: red. in positions 5, 6, 7 and 8
- 2 3 3 4 2 3 3 4: red. in positions 5, 6, 7 and 8
- 2 3 4 3 2 3 4 3: red. in positions 5, 6, 7 and 8
- 2 4 3 3 2 4 3 3: red. in positions 5, 6, 7 and 8
- **3 3 3 3 3 3 3 3: hyper-redundant**

➢ **NI = 9** (0.40 %)

- 2 3 3 2 3 3 2 3 3: red. in positions 3, 4, 5, 6, 7 and 8

➢ **NI = 10** (2.05 %)

- 2 2 2 3 3 2 2 2 3 3: red. in positions 6, 7, 8, 9 and 10
- 2 2 3 2 3 2 2 3 2 3: red. in positions 6, 7, 8, 9 and 10

➢ **NI = 12** : no supplementary sub-system

Conclusions

Two main formulae have been proposed for the obtainment of redundant systems in the models proposed in this study (quarter-tone and semi-tone); firstly, a formula for hyper-redundant systems:

- **i*N = S**, with $2 \leq i \leq S$ and $1 \leq N \leq S$ **(1)**

in which i, N, and S are integers. "i" is the number of times the interval is repeated within a combination; "N" is the numerical value of the interval, while "S" is the sum of the intervals in the combination (in this case, 12 semi-tones).

Secondly, I proposed a formula for the general case of redundancy:

- **i*ΣN$_j$ = S**, with $1 \leq i \leq S$, $1 \leq j \leq j_{max}$, $1 \leq j_{max} \leq S$ and $1 \leq N \leq S$ **(2)**

in which:

- i is the number of repetitions of an intervallic suite within the octave,
- N_1, N_2, … , N_j are the successive intervals of the repeated combination in the set,
- S is the sum of the intervals forming the set,
- j_{max} is the upper bound of j.

It is possible, with the help of these formulae and their corollaries (shown above) to find manually all redundant sub-systems in the models. Note that for both models (semi-tone and quarter-tone) pentatonic and heptatonic generations do not have redundant systems, as the numbers 5 and 7 do not divide either 12 or 24 (S).[279]

A necessary and sufficient condition for the obtainment of hyper-redundant systems is the existence of a common divider for NI (number of intervals in the scale) and S (integer sum of the intervals in the scale).

In both cases (semi-tone and quarter-tone models), there exists no redundant system for NI = 5 (pentatonism) and 7 (heptatonism), or for NI = 11, because NI is in these cases is 1) a prime number that can be divided uniquely by itself or by one, and because 2) numbers 5, 7 and 11 do not divide either of S = 12 (with S = sum of the intervals in the system) in the semi-tone model or S = 24 in the quarter-tone one.

As a final note in what concerns octavial systems: for the semi-tone model, redundant sub-systems are 3.03 % of the total of sub-systems, while redundant sub-systems compose only 0.48 % of the total of sub-systems for the quarter-tone model.

Addendum: About redundancy in the fourth and the fifth Containing intervals

Concerning the generations of "fourths" and "fifths" shown in Fig. 35 and Fig. 36, p. 45: in the case of the fourth, for NI = 3, NI is once again a prime number that does not divide the sum S = 10 (of quarter-tones), neither does it divide S = 5 (semi-tones). For the fifth, as is shown in the same figure, the usual four intervals in the fifth generate independent (distinct) sub-systems only in the case of the semi-tone model, as NI = 4 and S = 7, and neither of the divisors of NI (*i.e.*, the numbers 1, 2 and 4), except the trivial case 1, divides seven.

In the quarter-tone model, however, S = 14 for the fifth, and 2 divides fourteen so we may be able to find a suite of two (J) intervals repeated twice (i times) systems provided that the sum of the two repeated intervals be equal to 14/2 = 7 (or S/i); this is verified for the suites 4 3 (or a one-tone interval followed by a three-quarter-tone interval) or 3 4 and 2 5 (or 5 2) repeated twice.[280]

As for the fourth, NI = 4 with S = 10 have as common divider 2, which creates redundant combination with two couples of identical intervals (2 3) (2 3) and (3 2) (3 2), the sum of which (2 + 3 = 3 + 2 = 5) is equal to S/i (10/2) – see Fig. 25: 37.

***

[279] Redundant sub-systems have been concomitantly filtered from the general database of sub-systems created as a tool for the thesis of the author, for verification of the aforementioned formulae and applications.

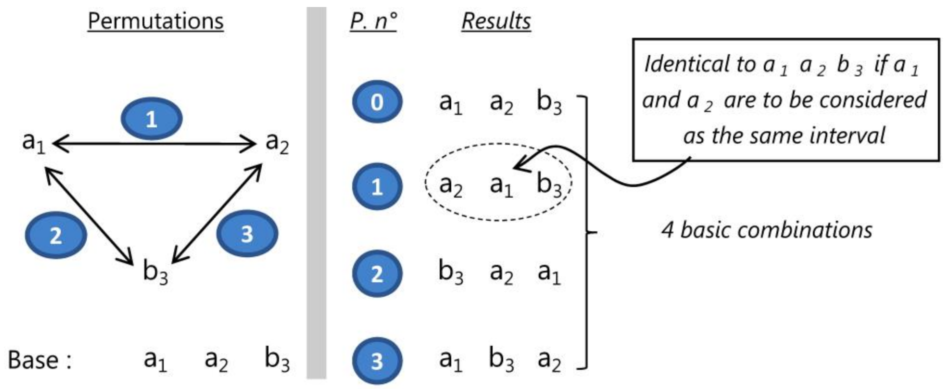
[280] See [Beyhom, 2003b, p. 12–13] for the complete generation with the reduced alphabet 2 3 4 5 6 – hyper-systems 2 and 7.

APPENDIX H: PERMUTATION PROCESSES FOR THE COMBINATION OF INTERVALS

Permutation exchanges one interval for another whilst others remain fixed. The same process is applied to another pair until all intervals have changed places.

With direct permutation (FHT 12), interval a_1 of the basic configuration a_1 a_2 b_3 is first changed with interval a_2. This results in combination a_2 a_1 b_3. Then, coming back to the original configuration, with b_3, which is the combination of b_3 a_2 a_1. As a_1 has already changed places with the two other intervals, we proceed with the second interval of the basic configuration, a_2, with the others. This interval has already changed places, in the previous process, with a_1: it should further change places with b_3 only with the combination a_1 b_3 a_2. The last interval has already changed places with both other intervals a_1 and a_2, and this is where the process ends.

If a_1 is different from a_2, and also from b_3, then the second combination: a_2 a_1 b_3 is different from the first combination, because it is a stand-alone interval system. The total number of distinct interval systems which result from the direct permutation process is 4, that is one more than with the rotational process. If both intervals are the same, however, if $a_1 = a_2$, the two first combinations are equal. The process only gives three different combinations, similarly to those in the rotation process.



FHT 12 Permutation of three intervals.

In order to obtain the full range of possible combinations for these three intervals, we could apply the process of direct permutations, not only to the original configuration of a_1 a_2 b_3, but also to each of the combinations which result from the direct combinations of a_2 a_1 b_3, b_3 a_2 a_1 and a_1 b_3 a_2.

If we apply this process to the second in the direct permutation process, combination b_3 a_2 a_1, we obtain the following combinations:

1. New base: b_3 a_2 a_1. This is the second combination in the direct permutation process.
2. Combination no. 2: a_2 b_3 a_1, consisting in exchanging the first interval with the second. This is a new combination, different from all the previous ones.
3. Combination no. 3: a_1 a_2 b_3, consisting in exchanging the first interval in the new basic configuration with the third one. This gives the same combination as the first one in the direct permutation process.
4. Combination no. 4: b_3, a_1, a_2, by exchanging the second interval in the new basic configuration with the third interval of the same. This is also a new combination.

Therefore, we have two new interval combinations which added to the four distinct combinations of the direct permutation, amount to six different combinations of the three intervals a_1, a_2 and b_3. These amount to the possible combinations with three distinct intervals. There is no need to apply the permutation process for the other combinations stemming from the first direct process.

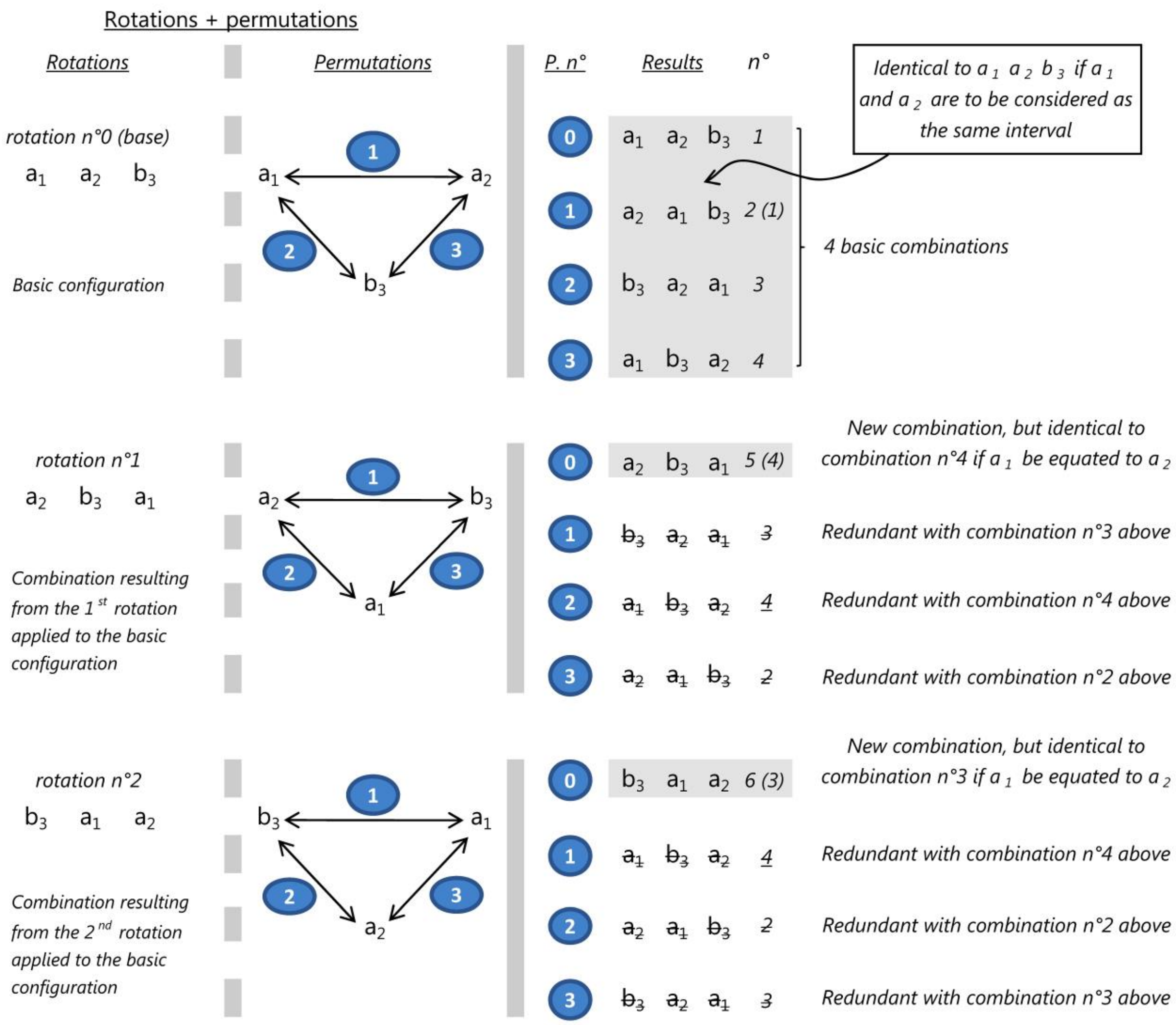
It is also possible to obtain a similar result with processes other than the successive permutations method, for example by applying rotation followed by a direct permutation process (FHT 13).

In this combination process, a direct permutation process is applied to each of the combinations coming from an initial rotation process (Fig. 9: 19). This gives six independent and distinct combinations out of twelve. The six remaining combinations are redundant.

As a conclusion to this appendix, let us be reminded of two characteristics of the reviewed combination processes:

1. The successive, or consecutive permutations and the alternate rotation/permutation processes generate a certain number of redundant combinations which have to be excluded from the outcome.

2. Out of six distinct resulting combinations obtained, three will be redundant if a_1 equals a_2. In this case, the outcome remains the same as for a simple rotation process (compare with Fig. 9).



FHT 13 Combining rotation and permutation for three intervals (the two 'a' are equal – if not, the numbers in subscript, which identify the initial ranks of each interval in the original basic configuration will differentiate them). The outcome here is 6 distinct combinations, but only 3 if 'a_1' and 'a_2' are identical. Remark: applying a rotation process (Fig. 9: 19) and a direct permutation process (FHT 12) to the combination a_1 a_2 b_3 (*i.e.* adding the two combinations from rotation no. 1 and rotation no. 2 in this figure to the outcome of the permutation process for the basic combination a_1 a_2 b_3) allows to find all six independent combinations, without redundancies except for the basic combination a_1 a_2 b_3 itself.

Appendix L: Core Glossary

This core glossary is a summary of the new (or renewed) concepts for characterizing intervals and their functions (for all these, see mainly Fig. 23: 30), for the arrangement of scales in Modal systematics, and for the rules and principles that structure intervals in the scale (these are mainly explained in Part II of the article).[281]

***

Intervals

Intervals in Modal music (and Modal systematics) may be characterized as *measuring*, *elementary*, *conceptual* and *Containing* (or *Container*):

- A *measuring interval* is an exact or approximate divider of other intervals: it may play no other role in the melody or the scale as the one of measuring these other intervals. It is generally the smallest interval of the scale in ET-systems (Equal-Temperament scales):
  - The Holderian comma (the approximate 9^{th} of a Pythagorean tone, with 53 HCs – Holderian commas, see Fig. 3: 12 – to the octave), the cent, the mil (a tenth of a cent), etc., are measuring intervals.
  - For the semi-tonal scales (12-ET – 12 equal intervals to the octave), the semi-tone usually suffices as an interval of measurement, although in this particular case,[282] it is the tone that is taken as the reference interval (the semi-tone being half… of the tone).
- An *elementary interval* is a small interval used for composing other intervals: it may play no other role in the melody or the scale as the one of composing these other intervals. It is generally the smallest interval of the scale in ET-systems (Equal-Temperament scales), or one (or more) smallest intervals in uneven divisions of the scale:
  - The Pythagorean *comma* and the *leimma* by Urmawī (see Fig. 1: 11 and Fig. 22: 28), the quarter-tone in the quarter-tone model of Modal systematics, the semi-tone in the corresponding model, are elementary intervals used in the composition of other, greater intervals.
  - Additionally, the semi-tone in the semi-tone model of the scale, or the 17^{th} of an octave in Urmawī's model, are also *conceptual intervals* (see next definition).
- A *conceptual interval* is one of the consecutive intervals of the second forming a musical system. For example, three seconds in a just fourth, four seconds in a just fifth, or seven seconds in an octave. Conceptual intervals can be measured either exactly or approximately with smaller intervals, usually of measurement, as in approximations using the quarter-tone or the HC:
  - In traditional heptatonic (Modal) musics, conceptual intervals follow rules and principles (see below). They have a guiding function for the melody, and establish a reference pattern for the performing musician. Their exact measure is secondary in relation to their role in the scale system (see Fig. 5: 14). Examples for conceptual intervals with Urmawī are provided in Fig. 1: 11 and Fig. 6: 16, and compared to other types of intervals used in systems (see *scale systems* below).
  - In theories of the scale which try to structure existing traditional musics, the concept for such intervals is indispensable in order to, for example, differentiate *generative* and *adaptive theories*, *i.e. prescriptive* or *descriptive theories*.
    - → *Generative theories* use arithmetic and mathematics to model, sometimes reduced, scale structures independently from the existing structure of musics, and base themselves on axioms which are frequently biased.
    - → *Adaptive theories* attempt to further adapt the generative procedure in order to better understand and explain existing musics. Modal systematics is typical of generative theories which adapt their axioms and sort the results in function of criteria stemming from existing musics.

[281] Note: appendices I, J and K are available for download at http://nemo-online.org/articles: they are not included in the printed or in-Volume version of the article.

[282] And others, such as for the quarter-tone model.

- *Containing (or Container) intervals* such as the fourth, the fifth or the octave, include other intervals which compose them (see examples for the fourth containing interval in Fig. 23: 30 and Fig. 25: 37). *Container intervals* possess acoustic qualities which differentiate them from other intervals, and play the role of a guide in music performance:
  - Although *container intervals* play an important role in melody and scale formation other, mainly aesthetical or traditional criteria result in overriding this guidance role (see the Synthesis and footnotes nos. 268 and 269, p. 61 and p. 61 on *maqām Ṣabā*).

Scale systems

Scale systems are defined as suites of conjunct intervals within a container element. These can be numerous, especially when the generative model is refined as is the case of the quarter-tone model (compared to the semi-tone model). A practical way of characterizing them is the systematic use of the *calibrated de-ranking process*, and their qualifications under *hyper-* (scale) *systems*, *systems* and *sub-systems*.

- The *regular* or *calibrated de-ranking process*, or *rotation process* (for octavial scales or for complete scalar systems only – see Fig. 8: 19), allows for an unambiguous generation and arrangement of scalar systems. It is based on regular repetitions of suites of conjunct intervals, generally within a *container interval* such as the fifth or the octave, and on successive rotations of the first interval in the scale system, which in each rotation is positioned after the last interval (and becomes the last interval – see Fig. 13: 21):
  - The *calibrated de-ranking process* has been used in music since at least the time of Aristoxenos (see Table 2: 9) for scale (*species*) generations. Modal systematics uses de-ranking as the basis for the classification and arrangement of scalar systems, including heptatonic octavial systems (see for example Fig. 16: 25 and Fig. 18: 25).
- For unambiguous classification of scales (Fig. 14: 21, Fig. 15: 22 and Fig. 17: 25), Modal systematics uses complementary definitions of scale elements, arranged as *hyper-systems*, *systems* and *sub-systems*:
  - → Hyper-systems are capacity indicators for all systems and sub-systems they generate; themselves also a (head) system and (head) sub-system, they are picked out of the generation because the number resulting from their concatenation is minimal.
  - → In Modal systematics arrangement of scale elements, hyper-systems generate, by a rotation process coupled with permutations, systems that are arranged in growing values of their concatenated intervals. The first system to be generated by the hyper-system (or head system) is the hyper-system itself.
  - → Systems, in turn, generate sub-systems by a calibrated de-ranking process, each sub-system being given its rank through this procedure. The first sub-system to be generated by the system (or head sub-system) is the system itself.

Concepts and rules

While the following principles and rules stem from traditional heptatonic music, and particularly from *maqām* music and the research of the author, they are also the result of common sense applied to heptatonic traditional musics in general.

- The *Principle of Memory* reflects the need for performers of traditional music to memorize the elementary scale divisions of the fourth (or archetypal tetrachords) in order to reproduce them effortlessly while performing. This applies equally (maybe even more) to Octavial scales, when the octave is the leading principle in a repertoire. In the latter case, scale species are so numerous that even in arranging (classifying) them in families of modal scales (such as in *maqām* musics) there is no practical way of memorizing them. In a traditional context, which generally includes improvisation, this is too much of a burden for musicians to carry in performance practice:
  - The *Principle of Memory* explains why theories of the scale should not use too small elementary intervals, as this would introduce a quasi-impossibility for the existence of a traditional repertoire based on the memorization and identification of melodic patterns. It is illustrated for example in Fig. 34: 45 and Appendix A, where results of the

generation of fourths in eights of the tone are too numerous to be memorized by the common musician, even when tradition is based on Oral transmission (which implies a memorization process).

- The *Principle of Memory* complements the *principle of economy* and the *homogeneity rule* and reduces the theoretical complexity of scales based on very small elementary intervals which create, additionally, problems with the identification of *conceptual intervals* in performance practice.

➢ The *Principle of Economy*[283] complements the *principle of memory* in that, in music performance in traditional music as well as in theories for such musics, the infinite vertical continuum of pitches must be restricted to a certain number of melodic or structural archetypes that both musicians and auditors would be able to identify and memorize, without however reducing the expressivity of the performed music. The connection between the search for this equilibrium (between complexity and expressivity) and the internal *composition* of container intervals is straightforward, and constitutes the basis of Modal systematics:

- for *maqām* music, which relies on subtle expressions of the melody, this optimum is reached within the general scale of 17 elementary intervals to the octave by Urmawī.[284] For western music (Common practice period), whose expressivity relies on the development of simultaneous vertical lines, it is the 12-intervals scale based on semitones which serves as a general scale.
- for both *maqām* and semi-tonal musics, however, optimal expressivity following the *principle of economy* is reached with 3 intervals to the fourth, 4 intervals to the fifth, and 7 intervals to the octave (Part II).

➢ The *Homogeneity rule* helps *structuring* the intervals in a composed container element. In practical terms, the *Homogeneity rule* says that the sum of any too adjacent intervals in a scale system must be comprised between (and including) 6 and 8 quarter-tones, or, with 's' being the sum of the two intervals, $6 \le s \le 8$ (quarter-tones). This rule is also called the *Reverse pycnon rule* because the principle of *pycnidium*, as formulated by Aristoxenos, is the exact opposite to what we know about the internal structure of *maqām* music today (Fig. 30: 41):

- The *Homogeneity rule* is nearly a perfect match[285] for modern *maqām* music. It allows for a particular generative process[286] which generates exclusively typical scale elements of the fourth and the fifth used in these musics (Fig. 28: 40, Fig. 29: 40 and Fig. 31: 42), as well as for expansions to the octave (Fig. 32: 43).
- The homogeneity rule helps in particular understanding why an extension from the fourth to the fifth favors the existence of tones and semi-tones in the scale elements (Fig. 38: 48), to the detriment of the presence of zalzalian intervals in them.

***

[283] See the corresponding section in Part II.

[284] Notwithstanding small variations of intonation which would further embellish the performance (if the performer is talented), but play no role in the identification of the intervals used in melody or scales.

[285] Some very rare exceptions exist, as explained in the main text. These are not included, however, within the typical tetrachords of *maqām* musics.

[286] Which is, in this case, restricted to *maqām* musics.

References

1. Anon. "Cairo Congress of Arab Music", *Wikipedia* |2016-10-10| [url: https://en.wikipedia.org/w/index.php?title=Cairo_Congress_of_Arab_Music&oldid=743580485].
2. Anon. "Duodecimal", *Wikipedia* |2017-1-14| [url: https://en.wikipedia.org/w/index.php?title=Duodecimal&oldid=760017759].
3. Anon. "*Lawrence of Arabia* (film)", *Wikipedia* |2016-12-11| [url: https://en.wikipedia.org/w/index.php?title=Lawrence_of_Arabia_(film)&oldid=754142234].
4. Aristoxenos, (Aristoxène de Tarente) and Henry Stewart Macran : *Aristoxenoy Armonika stoicheia: The harmonics of Aristoxenus*, Oxford The Clarendon Press |Chicago - EU, 1902|.
5. Azar Beyhom, Rosy : "La modalité écrite : un exemple avec Mīkhā'īl Mashāqa au XIXe siècle", *Near Eastern Musicology Online 1 1* |2012-11| [url: http://nemo-online.org/wp-content/uploads/2016/12/INTERNET-05.-Article-NEMO-n%C2%B01-1-Rozy-Azar-Beyhom-Reissue-201612S.pdf] p. 55–66.
6. Barbera, André : "Octave Species", *The Journal of Musicology 3 3* |1984-7-1| [url: http://www.jstor.org/stable/763813] p. 229–241.
7. Barbera, C. André : "Arithmetic and Geometric Divisions of the Tetrachord", *Journal of Music Theory 21 2* |1977-10-1| [doi: 10.2307/843492. url: http://www.jstor.org/stable/843492] p. 294–323.
8. Beyhom, Amine : *1. Systématique modale – Volume I*, Thèse de doctorat, Université Paris Sorbonne |2003a-9-1| [url: http://foredofico.org/CERMAA/publications/publications-on-the-site/publications-amine-beyhom].
9. Beyhom, Amine : *3. Systématique modale – Volume III*, Thèse de doctorat, Université Paris Sorbonne |2003b-9-3| [url: http://foredofico.org/CERMAA/publications/publications-on-the-site/publications-amine-beyhom].
10. Beyhom, Amine : *Systématique modale – En 3 volumes*, PhD Thesis, Université Paris Sorbonne |2003c-9-17| [url: http://www.sudoc.fr/075767538, http://foredofico.org/CERMAA/publications/publications-on-the-site/publications-amine-beyhom].
11. Beyhom, Amine : "Approche systématique de la musique arabe : genres et degrés système", *De la théorie à l'Art de l'improvisation : analyse de performances et modélisation musicale*, ed. Mondher Ayari, Delatour |Paris, 2005-12| [url: http://foredofico.org/CERMAA/publications/publications-on-the-site/publications-amine-beyhom] p. 65–114.
12. Beyhom, Amine : "Une étude comparée sur les intervalles des musiques orientales", publ. internet |Royaumont – France, 2006-10-7| [url: http://www.royaumont.com/fondation_abbaye/fileadmin/user_upload/dossier_PDF/programmes_musicaux/COLLOQUE_MAQAM_ET_CREATION_OCTOBRE_2005.pdf].
13. Beyhom, Amine : "Dossier : Mesures d'intervalles – méthodologie et pratique", *Revue des Traditions Musicales des Mondes Arabe et Méditerranéen 1 1* |2007a-6| [url: http://foredofico.org/CERMAA/publications/publications-on-the-site/publications-amine-beyhom] p. 181–235.
14. Beyhom, Amine : "Des Critères d'authenticité dans les musiques métissées et de leur validation : exemple de la musique arabe", *Filigrane. Musique, esthétique, sciences, société 5* |2007b-6| [url: http://foredofico.org/CERMAA/publications/publications-on-the-site/publications-amine-beyhom, URL : http://revues.mshparisnord.org/filigrane/index.php?id=168] p. 63–91.
15. Beyhom, Amine : "Arabité et modernité en musique, ou de quel modèle se démarquer", *Congrès des musiques dans le monde de l'islam du 8 au 13 août 2007* |Assilah – Morocco, 2007c-8-8| [url: http://www.mcm.asso.fr/site02/music-w-islam/articles/Beyhom-2007.pdf, http://www.mcm.asso.fr/site02/music-w-islam/congresfr.htm, http://www.mcm.asso.fr/site02/music-w-islam/intervenantsfr.htm].
16. Beyhom, Amine : "A new hypothesis on the elaboration of heptatonic scales and their origins", *ICONEA 2008*, Lulu on behalf of ICONEA PUBLICATIONS |London, 2010a| [url: http://foredofico.org/CERMAA/publications/publications-on-the-site/publications-amine-beyhom] p. 151–209.
17. Beyhom, Amine : *Théories de l'échelle et pratiques mélodiques chez les Arabes – Volume 1 : L'échelle générale et les genres – Tome 1 : Théories gréco-arabes de Kindī (IXe siècle) à Ṭūsī (XIIIe siècle) 1/4* (vols.), Librairie orientaliste Paul Geuthner |Paris, 2010b-11|.
18. Beyhom, Amine : "*Kashf al-Asrār ʿan Karkarat al-Aḥbār fī Taʾwīl al-Adwār* كشف الأسرار عن كركرةِ الأحبار في تأويل الأدوار", *Near Eastern Musicology Online 1 1* |2012-11| [url: http://nemo-online.org/articles] p. 67–88.
19. Beyhom, Amine : "Un lexique de la modalité", *Near Eastern Musicology Online 2 2* |2013-11| [url: http://nemo-online.org/articles] p. 5–24.
20. Beyhom, Amine : "*Dossier* : Influence des théories européanisées du XIXe siècle sur la notation et la pratique des modes de la musique arabe et d'autres musiques, à travers la mise en exergue du mythe du genre *ḥijāz* semi-tonal", *Near Eastern Musicology Online 2 3* |2014-11| [url: http://nemo-online.org/articles] p. 87–177.
21. Beyhom, Amine : *Théories et pratiques de l'échelle dans le chant byzantin arabe : Une approche comparative et analytique proposant une solution inédite pour le système théorique de Chrysanthos le Madyte*, Par l'auteur |Broummana (Liban), 2015a-9|.
22. Beyhom, Amine : *Théories de l'échelle et pratiques mélodiques chez les Arabes – Volume 1 : L'échelle générale et les genres – Tome 1 : Théories gréco-arabes de Kindī (IXe siècle) à Ṭūsī (XIIIe siècle) 1/4* (vols.), Librairie orientaliste Paul Geuthner & l'Auteur (Electronic version) |Beyrouth, 2015b-11-25| [url: http://foredofico.org/CERMAA/?attachment_id=482].
23. Beyhom, Amine : "*Dossier*: Hellenism as an Analytical tool for Occicentrism (in musicology)", *Near Eastern Musicology Online 3 5* |2016-11| [url: http://nemo-online.org/articles] p. 53–273.
24. Chailley, Jacques : "Essai sur les structures mélodiques", *Revue de Musicologie 44 120* |1959-12-1| [doi: 10.2307/927967. url: http://www.jstor.org/stable/927967] p. 139–175.
25. Chailley, Jacques : *Éléments de philologie musicale [Recherche des principes - Intervalles et Échelles]*, Alphonse Leduc |Paris, 1985|.
26. Chraibi, Said : *Souleimane*, CD |Morocco?, s.d.|.
27. Chraibi, Said : *Taquassim Aoud*, CD |Morocco?, s.d.|.
28. Cleonidès : *L'Introduction Harmonique de Cléonide*, editor Charles-Emmanuel Ruelle |Paris, 1884|.
29. Collectif, ouvrage : *Recueil des Travaux du Congrès de Musique Arabe qui s'est tenu au Caire en 1932 (Hég. 1350) sous le Haut Patronage de S. M. FOUAD 1er, ROI D'ÉGYPTE*, Imprimerie Nationale d'Egypte |Le Caire - Egypte, 1934|.
30. Crocker, Richard L. : "Pythagorean Mathematics and Music", *The Journal of Aesthetics and Art Criticism 22 2* |1963-12-1| [doi: 10.2307/427754. url: http://www.jstor.org/stable/427754] p. 189–198.

31. CROCKER, Richard L. : “Pythagorean Mathematics and Music”, *The Journal of Aesthetics and Art Criticism 22 3* |1964-4-1| [doi: 10. 2307/427236. url: http://www.jstor.org/stable/427236] p. 325–335.

32. ERLANGER, Rodolphe (d’) : *La musique arabe (5) – Essai de codification des règles usuelles de la musique arabe moderne. Échelle générale des sons, système modal 5/6* (vols.), Librairie Orientaliste Paul Geuthner |Paris, France, 1949|.

33. FĀRĀBĪ (AL-), Abū-n-Naṣr Muḥammad ibn Muḥammad ibn Tarkhān : *La musique arabe (1) – Al-Fārābī, Grand traité de la musique [*Kitāb al-Mūsīqī al-Kabīr*] (Livres I et II)*, editor Rodolphe d’Erlanger, translator Rodolphe (d’) Erlanger *1/6* (vols.), Librairie Orientaliste Paul Geuthner |Paris, France, 1930|.

34. FĀRĀBĪ (AL-), Abū-n-Naṣr Muḥammad ibn Muḥammad ibn Tarkhān : *La musique arabe (1) – Al-Fārābī, Grand traité de la musique [*Kitāb al-Mūsīqī al-Kabīr*] (Livres I et II)*, editor Christian Poché, translator Rodolphe (d’) Erlanger, ed. 2e en fac-similé, *Les Geuthner (Paris), ISSN 1294-6656 1/6* (vols.), Librairie Orientaliste Paul Geuthner |Paris, France, 2001|.

35. FĀRĀBĪ (AL-), Abū-n-Naṣr Muḥammad ibn Muḥammad ibn Tarkhān, al-Ḥusayn ibn ʿAbd-al-Lāh SĪNĀ (IBN) OU AVICENNE (0980?-1037), محمد ابن محمد أبو نصر الفرابي and الحسين ابن عبد الله ابن سينا (0980?-1037 : *La musique arabe (2) – Al-Fārābī [Grand traité de la musique] Livre III du* Kitāb al-Musīqī al-Kabīr*; Sīnā (ibn) ou Avicenne,* Kitāb a-sh-Shifāʾ – *Mathematiques*, editor Rodolphe d’Erlanger, translator Rodolphe (d’) Erlanger, *Les Geuthner (Paris), ISSN 1294-6656 2/6* (vols.), Librairie Orientaliste Paul Geuthner |Paris, 1935|.

36. FARMER, Henry George : “Greek Theorists of Music in Arabic Translation”, *Isis 13 2* |1930-2-1| [url: http://www.jstor.org/stable/224649] p. 325–333.

37. GIANNELOS, Dimitrios : *La musique byzantine : le chant ecclésiastique grec, sa notation et sa pratique actuelle, Collection Musique et musicologie, les Dialogues, ISSN 1272-1972 ; 1996*, L’Harmattan |1996|.

38. HELMHOLTZ, Hermann L. F. (von) : *On the sensations of tone as a physiological basis for the theory of music: Translated, rev. and corr. rendered conformable to the 4th (and last) German ed. of 1877*, Longmans, Green, and Co. |London, UK, 1895|.

39. MATHIESEN, Thomas J : *Apollo’s lyre: Greek music and music theory in antiquity and the Middle Ages*, University of Nebraska Press |Nebraska - EU, 1999|.

40. NELSON, David Lowell : *An Analysis of Olivier Messiaen’s Chant Paraphrases in two volumes*, Ph.D., university of Evanston |Evanston, Illinois, United-States, 1992|.

41. POWERS, Harold S. and Richard WIDDESS : “India, §III, 1: Theory and practice of classical music: Tonal systems in Oxford Music Online”, *Grove Music Online* |2001| [url: http://www.oxfordmusiconline.com/].

42. POWERS, Harold S., Frans WIERING, James PORTER, et al. : “Mode”, *The New Grove Dictionary of Music and Musicians 16/29* (vols.), Oxford University Press |Oxford, 2001|.

43. ṢABBĀGH (A-Ṣ-), Tuwfīq الأستاذ توفيق الصباغ : *الدليل الموسيقي العام في أطرب الأنغام* A-d-Dalīl al-Mūsīqī al-ʿĀm fī Aṭrab al-Anghām, مطبعة الإحسان لميتم الرّوم الكاثوليك *Maṭbaʿat al-Iḥsān li-Maytam a-r-Rūm al-Kāthūlīk* |Aleppo, 1950|.

44. SCHULTER, Margo : “Systematist Buzurg and its Relatives: Notes on a Zalzalian Modal Genre”, *Near Eastern Musicology Online 2 2* |2013-11| [url: http://nemo-online.org/articles] p. 25–49.

45. SIGNELL, K. : “Contemporary Turkish makam practice”, *Garland Encyclopedia of World Music 6* |2002| p. 47–58.

46. SĪNĀ (IBN) OU AVICENNE (0980?-1037) : “Kitāb] a-sh-Shifā’ - Riyādiyyāt 3 - Jawāmiʿ ʿIlm al-Mūsīqā”, Wizārat a-t-Tarbiya wa-t-Taʿlīm, Al-Maṭbaʿa al-Amīriyya |Cairo, 1956|.

47. URMAWĪ (D. 1294), Ṣafiyy-a-d-Dīn ʿAbd-al-Muʾmin ibn Yūsuf ibn (ab-ī-l-Ma)Fākhir (al-) صفي الدين الارموي and ʿAlī ibn Muḥammad [JURJĀNĪ (AL-)] : *La musique arabe (3) – I.* A-sh-Sharafiyya *ou Épître à Sharaf a-d-Dīn. II. (Commentaire anonyme du)* Kitāb al-Adwār *ou Livre des Cycles musicaux*, translator Rodolphe (d’) Erlanger, ed. orig., *La Musique Arabe 3/6* (vols.), Librairie Orientaliste Paul Geuthner |Paris, 1938|.

48. WRIGHT, Owen : *The modal system of Arab and Persian music, 1250-1300 : an interpretation of contemporary texts.* |1969|.

The Truth about Babylonian Music

Richard Dumbrill[*]

> *"In describing non-western music, be it oriental or primitive, one must strictly refrain from misusing incongruous concepts of western music. The terminology that has been learned in music school applies to the harmonic structure of music and is inappropriate, indeed misleading and distorting in descriptions of non-harmonic, non-western music"*
>
> [Curt Sachs – *The Wellsprings of Music*][1]

Introduction[2]

The title of this article was not meant to benefit from the current world trend of "untruths" with which we are saturated.[3] It is coincidental but nevertheless opportune. Truly, there has been a chain of "untruths" about the history of Babylonian music theory for the past fifty-seven years, and growing strong. I will address the matter, its causes, consequences and remedy.

The tablets examined in this article are the oldest texts of music theory ever found anywhere in the world. They were published from the early 1960s onward as the corpus increased when new texts were discovered[4] (mainly in the museums where they were kept). Authors approved each other's interpretations with meaningless addenda. According to their authors, the Babylonian scale could only be ascending, tense diatonic,[5] heptatonic and octavial because for them, "it could not be anything else".

Then, in 1994, a paper[6] fuelled by the new reading of a verb, turned the world upside-down and all, or most, agreed that the scales were descending.[7]

Another paper[8] claimed, extraordinarily, that the intervals listed on a tablet were to be played simultaneously, a view resting on no evidence, as there is, to my knowledge, no known comparable system, anywhere in the world, past and present. This dogma met with the

[*] Richard Dumbrill is the leading expert in Near-Eastern Archaeomusicology to which he has devoted all his working life. He is the Director of ICONEA, a research Group at the University of London, consultant to the British Museum and member of the scientific Board of MUSICOMED, a research team at the Université de la Sorbonne, Paris. His expertise is recognized among the highest institutions, from Oxford to Harvard and Yale, to China, to Iraq, Palestine, Lebanon, Syria, etc. He has published intensively and his "The Archaeomusicology of the Ancient Near East" is the textbook for universities worldwide. He is the editor of ICONEA, London; co-editor of NEMO-Online, Beirut and London; and co-editor of ARAM, Oxford.

[1] [Sachs, 1962, p. 49].

[2] This article is an edited version of the original draft temporarily published as a print on demand document.

[3] Barry, D., quoting adviser to president Trump, who used "alternative fact" to describe assertions by the White House: "In a Swirl of "untruths" and "falsehoods", calling a lie a lie. *The New York Times*, Jan 25, 2017, https://www.nytimes.com/2017/01/25/business/media/donald-trump-lie-media.html.

[4] *nabnītu* xxxii; CBS 10996; U.7/80; YBC 11381; CBS 1766; H6 (RS13.30 + 15.49 + 17.387). These references are well known to Assyriologists. They refer to various collections: CBS = Catalogue of Babylonian Section of the University Museum, Philadelphia, Pennsylvania; YBC stands for Yale Babylonian Collection; H refers to the tablets of Ras Shamra. *nabnītu* xxxii is the name of a series of tablets. The xxxii, is also known as UET VII 126, standing for Ur Excavation Texts, volume VII, Plate 126.

[5] It is clear that these authors did not know of other diatonisms. Obviously, they meant that it was "ditonic diatonism" to which they referred as it addresses the only type in Western theory. Beyhom, in his Hypothesis [Beyhom, 2017] uses "ditonic" to differentiate tense diatonism which has two Pythagorean tones in the Just fourth, from other types of diatonism.

[6] [Gurney, 1994, p. 101–106].

[7] Scales, or pitch sets can be read in an ascending manner: *c-d-e-f-g-a-b-c* or in a descending manner: *c-b-a-g-f-e-d-c*. These are simple changes of their polarity. The scale *b-a-g-f-e-d-c* is the reciprocal of f-g-a-b-c-d-e. Reciprocity is ruled by the cyclic construction of the scales. Descending *b-a-g-f-e-d-c* results from the alternation of descending fifths and ascending fourths (*b-e-a-d-g-c-f*) while, ascending *f-g-a-b-c-d-e* results from the alternation of ascending fifths and descending fourths (*f-c-g-d-a-e-b*). Therefore *b-a-g-f-e-d-c* is the reciprocal of *f-g-a-b-c-d-e*.

[8] [Duchesne-Guillemin, 1963].

horns of dilemma with Kilmer's interpretation of the Hurrian "hymn":[9] Which of the two notes to sing?

The problem was solved, laboriously, when Kilmer "spin-doctored" the matter and decreed that the paired pitches, were the accompaniment of the hymn, and that either bass or treble pitch of the dyad could be chosen to make up the melody, a rather bizarre method. It usually is the melody which commands the accompaniment, and not the contrary.[10]

Furthermore, the colophon does not mention any instrument, a fact dismissed by Kilmer.

Many assumptions laid unfounded, with their authors dismissing, and even censoring every article challenging their views.[11] Regardless, these flaws crept into encyclopedias and other publications.[12]

For their analysis of Ancient Near-Eastern musicology, these scholars, mostly had used Western musicological tools. Most systems can be explained by, and made to fit heptatonism, for example, by squeezing, metaphorically, pitches on and between the lines of the stave, by explaining scale constructions with elusive alternations of fourths and fifths. But none of these experts were willing to accept that other methods also do exist.

Their insistence at force-fitting a musical system into the Western model, and in this case with the "unconscious" aim at acculturating Semitic[13] musicology under the Occidental yoke, is nothing but a last breath, it is hoped, of supremacist musicology. It is one of the greatest oversights in the history of music. It came from the methodology (or rather of its absence) of certain Assyriologists and of their determination at spearheading "their discovery" by means of unsuitable Western models. A bit like translating Old-Babylonian with a grammar of Mandarin.

The manner in which systems are constructed, whether consciously or not,[14] are part of the culture of a people and must be unveiled with the utmost respect and without linkage to theories of later cultures as this would lead to colonialist unification.

This article is the consequence of my determined endeavor at academically fostering the proof of the evidence against unproven presumptive inference, and more significantly to assert, scientifically, that heptatonism[15] – which is not universal – is by no means engraved onto mankind's unconscious. It is a structure, among others, which eventually hatched in the Near-East, as part and consequence of another or other systems, but not as a new, independent and exclusive concept.

This work is intended for a general readership. Therefore, Assyriologists and musicologist may find some of my explanations facile. I have avoided diacritic signs for Akkadian and Arabic transliterations whenever possible. I have used the English language notation *c-d-e-f-g-a-b* so that readers may have an approximation of the musical sets and sub-sets described on the basis that Babylonian intonation, while different, is sufficiently close to our Western practice. I have avoided as often as possible mentioning musical ratios as while meaningless to many, they are subjectivist tools unsuited to the epistemology of Babylonian musicology.

[9] See Chapter VI, H6: The "proof of the pudding"?

[10] [Hagel, 2005]. Here, Hagel authoritatively writes that Babylonians only could notate accompaniment but not melody! I quote [p. 290]: "It is significant that this system was not orientated towards melody, as was Ancient Greek notation and music theory, but to instrumental practice".

[11] Madame le Docteur Marcelle Duchesne-Guillemin warned me, (in other diplomatic terms in a private correspondence) against publishing anything contradicting the current interpretations of Sumero-Babylonian music theory.

[12] See for example [Kilmer and Mirelman, 2001].

[13] I am using the term "Semitic" in its etymological meaning and not relating, exclusively to the Jewish people as it is nowadays.

[14] "Qu'il ait fallu en quelque sorte ce quelque chose qu'est l'analyse, et qui est venu nous annoncer qu'il y a du savoir qui ne se sait pas, et que c'est à proprement parler un savoir qui se supporte du signifiant comme tel […]" – Jacques Lacan, *Séminaire 20, Encore, séance du 20 mars 1973*, in [Lacan, 1975], available in audio as http://www.valas.fr/IMG/mp3/lacan-encore-20-mars-1973.mp3. This loosely translates as: "Analysis has come to announce that there is a sort of knowledge that is not known and which is based on the signifier as such […]" – [Lacan, 1999]. There is an on-going dispute between two schools of thought, the first conditioned by dogmatic *a prioricity* (see [Field, 1998]) which sustains the irrational belief in the universality of Western diatonism(s). This position finds reasonable, firstly to infer anything without any empirical evidence, infallibly, because in this case nothing can be taken as evidence against it, and that therefore (undefined) diatonism must be the consequence of "just intervals theory", or of the "theory of resonance", or for the reason that "it cannot be otherwise than it is". The second school of thought is animated by objective *a posterioricity* which opposes *in toto* the dogmatic *a prioricity*. Both schools are therefore mutually exclusive and therefore obsolete in the rhetorical discourse.

[15] There are various cultures where instruments sets are tuned in precise intervals without any construction and unconsciously memorized – [Sachs, 1962, p. 103] for a detailed tuning method.

Most obsolete musical terms are replaced with neologisms which will be explained whenever they appear or whenever necessary.

Whenever possible, I have avoided naming researchers in the body of the text. They are acknowledged in footnotes.

My usage of the following terms: dyads (2), triads (3), tetrads (4), pentads (5), hexads (6), heptads (7), octads (8), and enneads (9), etc., define "containing intervals" having pitches inside them, *i.e. C-d-e-f-G*, where *C* and *G* are the boundaries of the container and *d-e-f*, the infixed pitches.

They differ from seconds, thirds, fourths, fifths, sixths, sevenths (heptachords), eights (octaves), etc., which are empty cells used in heptatonic tuning constructions, or for general theoretical and practical purposes.

I use the terms "infix" to qualify pitches placed within intervals of triads and pentads. Intervals larger than pentads are made up of smaller intervals, for example a hexad is made of two conjunct intervals, a triad and a tetrad. Pitches placed before the principal infix or "nucleus", are called infrafixes, and those above are suprafixes.

It is the many possible locations of infixes, diverging from constructed pitches (*i.e.* such as pitches resulting from the alternation of just fifths and just fourths) which define the cultural source of a given set.

These structures erroneously became known as "modes", a term which only appeared during the Dark Ages of the Christian West and are only suitable for ecclesiastical types.

The theory of music is a science developed by, and made up for the amusement of the musicologist and is of little concern to the musician. However, Mesopotamian musicology is unique because its earliest reporters – the scribes – laid the fundaments of theory from their meticulous observation of the lyre, probably, and of its strings, and comments from the musician's mouth.

As such, it has drawn the most accurate portrait of pre- and early literate music, a feat never achieved before and since, in the long history of music.

I - *NABNĪTU*[16] XXXII: SETTING THE STRINGS

This text was excavated by Sir Leonard Wooley at Ur, Southern Iraq, in the late 1920s.[17] It dates from the middle of the first millennium BC and might be the copy of an older text, perhaps Old-Babylonian, from the early second millennium BC, and possibly earlier, I think, because of musicological and philological hints. It is a bilingual lexical text where the left column is written in Sumerian and the right, its translation, in Babylonian (Table 1). Most importantly, the text also reveals, in a second layer of meaning, an implied tuning pattern for a structure made of two conjunct pentads, amounting to an enneadic set or scale of nine pitches.

Line	Sumerian	Akkadian	Translation
1	sa.di	*qud-mu-u[m*	front string
2	sa.uš	*šá-mu-šu-um*	next string
3	sa.3.sa.sig	*šá-al-šu qa-a[t-nu*	third, thin string
4	sa.4.tur	*a-ba-nu-[ú*	fourth, small/Ea-created-string
5	sa.di. 5	*ḫa-am-[šu*	fifth string
6	sa.4.a.ga.gul	*ri-bi úḫ-ri-im*	fourth behind string
7	sa.3.a.ga.gul	*šal-ši úḫ-ri-im*	third behind string
8	sa.2.a.ga.gul	*ši-ni úḫ-ri-im*	second behind string
9	[sa.1].a.ga.gul	*úḫ-ru-um*	behind string
10	[9].sa.a	9 *pi-it-nu*	nine strings

Table 1 Transliteration and translation of Sumerian and Babylonian terms in *nabnītu* xxxii.

There are ten lines. The tenth says "nine strings". This indicates, I contend, inconspicuous indications for the harmonic interaction of nine strings. It has been advanced that the Sumerian word "sa = string", Akkadian "*pītnu*"[18] (with qualifiers such as "di", "2.a.ga.gul"[19], etc.) excluded the pitch to which a string was tuned.

I would find it illogical that a Babylonian theoretician segregated the pitch of a string from its name in his demonstration, which otherwise would be pointless. Therefore, the word "pitch" is a substitute for "string", and reciprocally. The practice remains today, as the "*e*" string of a violin is called the "chanterelle" in French.

[16] The word translates as either 1) offspring, progeny, product, living creature, 2) habitat, place of growth, 3) living creature, 4) appearance, stature, features. *Chicago Assyrian Dictionary* (see [Roth, 2012]), *CAD* henceforth, Vol. "n".

[17] [Gurney, 1974], Pl.74.

[18] *CAD*, Vol. "p". (See note 16 above)

[19] Sumerian sa.di; sa.2.a.ga.gul. "sa" = "string/pitch", "di" means "foremost, prime". "2.a.ga.gul" means "second of behind".

In the English language, the "*e*"; the "*a*"; the "*d*" and the "*g*" strings of the violin are tuned to "*e*", "*a*", "*d*", and "*g*" respectively. In Bach's "*g*"-string Air, it is the string and the piece which take the name of the pitch. May I remind the reader that the seven strings of the Greek lyre had names which became synonymous to the pitches of the scale, in descending order.[20] There is no reason why this would not have been inherited from a Babylonian precursor, but it is even more surprising that scholars did not make this parallel.

These nine strings (therefore pitches), are consistently mentioned in texts from the second to the first millennium BC. This means that for two thousand years, and perhaps more, a nine-pitch system was known. However, I do not suggest that a nine pitch or enneadic (bi-pentadic)[21] scale was the only one in practice during that period. I am of the opinion that there were concurrent structures. Sumer and Babylon, had different counting systems for different things and therefore it would not be dazing should music, too, have conformed to different ones. Additionally, there would have been various regional styles adding to the sound palette. These regionalisms persist to this day in rare countries which have not yet been polluted by equal temperament, or where regionalisms are protected.

For extrapolation, I will propose that the interval between strings 1 and 2 of the front has the same value as the interval between strings 2 and 1 of the back. The interval between strings 2 and 3 of the front has the same value as the interval between strings 3 and 2 of the back. The interval between strings 3 and 4 of the front has the same value as the interval between strings 4 and 3 of the back and finally, the interval between strings 4 and 5 of the front has the same value as the interval between strings 5 and 4 of the back. Therefore, the intervals between strings 1^f-3^f and 3^b-1^b are equal; between strings 1^f-4^f and 4^b-1^b are equal and between 1^f-5 and 5-1^b are also equal. This is probably why the strings were recorded in this palindromic manner.

The nine strings should be read as $1^{f(ront)}$-2^f-3^f-4^f-5-$4^{b(ack)}$-3^b-2^b-1^b but never 1-2-3-4-5-6-7-8-9, as most scholars did, because this would imply that the scale is heptatonic, with two added pitches, which it is not. The scale is made up of two conjunct pentads[22], such as: a-g-f-e-d/d-c-b-a-g.

The pattern can be simplified as:

1 2 3 4 5 4 3 2 1

with 5 in red, as pitch of conjunction.

Strings 3 and 4 (green) of the front have terms to qualify them. These Sumerian qualifications vary in their Akkadian version. The reason for this will be explained later as it is essential to Babylonian theory. Another important philological detail is that the first string is called "sa.di" in Sumerian and so is the fifth string called "sa.di.5", with added "5". If "di" means "prime" as well as "first", then "di" emphasizes the value (in the theory) of strings one and five (1-5-1) because they are the boundaries of the system. The Babylonian translation does not reflect this.

Modern Western music uses the equal temperament system (ET)[23] where tones and semi-tones measure 200 and 100 cents respectively.[24] They are ascending, heptatonic, octavial, and (tense) diatonic, for example: *c-d-e-f-g-a-b-c*, a scale of C major. They are made up of tones and semi-tones arranged in a strict sequential order. For the purpose of tonal appreciation, the symmetry in *nabnītu* xxxii, can be played with our modern scale extended to nine pitches, for example: *g-a-b-c-d-e-f-g-a*, or its descending form: *a-g-f-e-d-c-b-a-g*. But it must be borne in mind that this translation is only approximate because it is constructed from a different method. To the untrained ear, the scales played one after the other

[20] This will be evident to the Hellenist since the names of the strings were also the names of the notes. This fact is given in most books about Greek music, for example in [West, 1992], p. 64.

[21] As we shall see later, an ennead or set of nine contiguous pitches (tense diatonic) is made up of two pentadic subsets.

[22] The numbering of the strings from one to nine led to the conclusion that it was heptatonic, with strings eight and nine being at the octave of strings one and two, but since the set is made up of two conjunct pentads, neither pentad can accommodate octaves.

[23] Composers do not imagine their music in Equal Temperament. It is far removed from their creativity. However, in order to make their music playable, the transposition of the imagined music is written with it. My concern is that computer programs used by modern composers, have forced their creations into an ET infrastructure, not unlike composing "at the piano" has, in its time, contributed to the melodic enslavement to the harmonic master.

[24] The cent is a logarithmic unit used for measuring musical intervals. Twelve-tone equal temperament divides the octave into 12 semitones of 100 cents each. Cents are used to quantify or to compare intervals. Alexander J. Ellis based the measure on the acoustic logarithms decimal semi-tone system developed by the French mathematician Gaspard de Prony in the 1830s. See [Ellis, 1876] – notably p. 9-11 – and, for more information on Prony, [Anon. "Gaspard de Prony", 2016].

would sound very similar, but would reveal differences when played together.

In Fig. 1 below, columns in grey indicate tone[25] intervals; yellow, semi-tone intervals. The red column is the axis of symmetry of the system.

1		2		3		4		5		4		3		2		1
a		g		f		e		d		c		b		a		g
g		a		b		c		d		e		f		g		a
	tone		tone		1/2		tone		tone		1/2		tone		tone	

Fig. 1 Position of tones and semi-tones in the enneadic/bi-pentadic system of *nabnītu* xxxii.

Although they would have had the mathematical ability,[26] it is very improbable that Babylonians used the equal temperament. The size of their intervals would have differed slightly, but significantly, from our Western systems. It is my opinion that they used Just Intonation because it is the most natural manner to produce and appreciate intervals, at least in theoretical musicology, but it would certainly not have been an inflexible rule.[27]

A Just Intonation[28] fifth measures 702 cents, (expressed by the ratio of 3:2)[29] (=701.955001 cents); a Just Intonation fourth measures 498 cents, (expressed by the ratio 4:3) (=498.044999 cents), etc. In the Equal Temperament fifths measure 700 and fourths 500 cents, respectively.

From this basis, it is possible to build up an estimation of how the generative[30] Babylonian set might have sounded, but first, I shall describe the implied tuning process.

Firstly, the central string is tuned to an appropriate pitch. This will depend on the quality of the string. From my own experiments with sheep gut-strings, such a string sounds its best when stretched at about 80% of its breaking point. Therefore, it is possible to make an estimation of pitch in relation to the type of string used (gut of sheep, of fallow deer, of cow, of bull, etc.) and its length.

When the pitch of the central string is stable, (that is when it does not stretch any longer under a given tension) both the first string of the front and the last are tuned a just fifth away from the central string, the continuation of the process is explained in Fig. 2.

A calculation of strings parameters: length; tension; weight; section; mass, was made in order to find the most appropriate gages and tensions for stringing a lyre. I chose my 2008 replication of the silver lyre of Ur as model although it has eleven strings. I used Taylor's Equation: $T=M(2L\ F)^{2}$, where T is the tension of the string; M the linear mass; F is the Frequency and L the length of the string. The strings which came from the calculations were inharmonious to the organology of the lyre. They all sounded dull and could not possibly

[25] The word "tone" is a term used to designate an unqualified interval, *i.e.*, an interval which can be Just, Pythagorean, ET, etc. Sachs writes [1962, p. 60–61] that "tonic" has six different meanings. 1) As an adjective used as a noun, it is the main gravitational pole of a harmonized or harmonizable melody. The original Greek noun, *tonos* (and hence, via Latin and Old French, our "tone" is related to "tension" and means, 2) acoustically speaking, any regular sound as opposed to irregular noises; 3) the pitch, vibration number, or frequency of such a sound, say *C* or *C* sharp; 4) its colour or timbre, warm or cool; 5) a melody pattern (like "psalm-tone", and 6) the distance or interval of a major second.

[26] [Fowler and Robson, 1998] explain, in the abstract, [p. 366]: "We consider several aspects of the role and evaluation of the four-sexagesimal-place approximation to √2 on the well-known Old-Babylonian tablet YBC 7289. By referring to what is known about OB school texts, we show that this text is most probably a school exercise by a trainee scribe who got the approximation from a coefficient list. These coefficient lists are briefly described, with their use in geometrical problems. We consider other texts involving square roots and derive an algorithm for evaluating them, which complies with all known OB examples, from a simple geometrical construction of the type that seems to underlie many other OB procedures". Therefore, they would have been able to calculate an equal temperament scale. However, there must be a distinction between the ability as an unconscious knowledge, (unknown known) and the need to apply such a concept when the application is possible because of the ability. "Si, avec un si, on peut mettre Paris dans une bouteille, on doit pouvoir aussi, avec un si bémol ou naturel, mettre une contrebasse dans un porte-document ou un hélicon dans un carton à chapeau" – [Dac, 1981] (this quote is also available at http://dicocitations.lemonde.fr/citations/citation-29012.php).

[27] There is a great variety of musical intonations in World Music, all with different interval values although intervals of Just fifths, principally, and fourths appear to be constant factors, though often approximate. Some ethnomusicologists claim that the octave is the predominant interval. It is predominant, indeed, but only in systems in which it is predominant by design and not by chance. For further reading: [Beyhom, 2010b ; 2017].

[28] Just intonation is a musical tuning in which the frequencies of notes are related by ratios or quantifications of small whole numbers. Any interval tuned in this way is called a Just Interval. Pure intervals correspond to the vibrational patterns found in physical objects which correlate to human perception. The two notes in any just interval are members of the same harmonic series.

[29] Ratios of string length and ratios of frequency stand in reciprocal relationship to each other: 3/4= string length and 4/3 = frequency.

[30] A generative scale is the result of a construction from which other scales are derived. The descending scale *b-a-g-f-e-d-c-b* is constructed from the alternation of fifths and fourths.

have been used some five thousand years ago, or at any time, for that lyre. I rejected them and worked with some basic "intuitive" logic: eleven twisted strands of sheep gut for bass string 11; ten strands for string 10; nine strands for string 9, eight strands for string 8, seven strands for string 7; six strands for sting 6; five strands for string 5; four strands for string 5; 4 strands for string 4; 3 strands for string 3; 2 strands for string 2 and one strand for string 1.

This intuitive method proved to be the best for the lyre which now sounds at its best. Therefore, while Taylor's equation is correct for the calculation of strings for tense diatonic harps, it is totally unsuited to lyres.

The number 64.8 in Fig. 3 (line VIII: 81; 72; 64.8; 60, etc.), which came from my hypothetic tuning in fifths and fourths, presented a problem as it needs to be multiplied by ten to become a whole regular number (64.8x10 = 648).

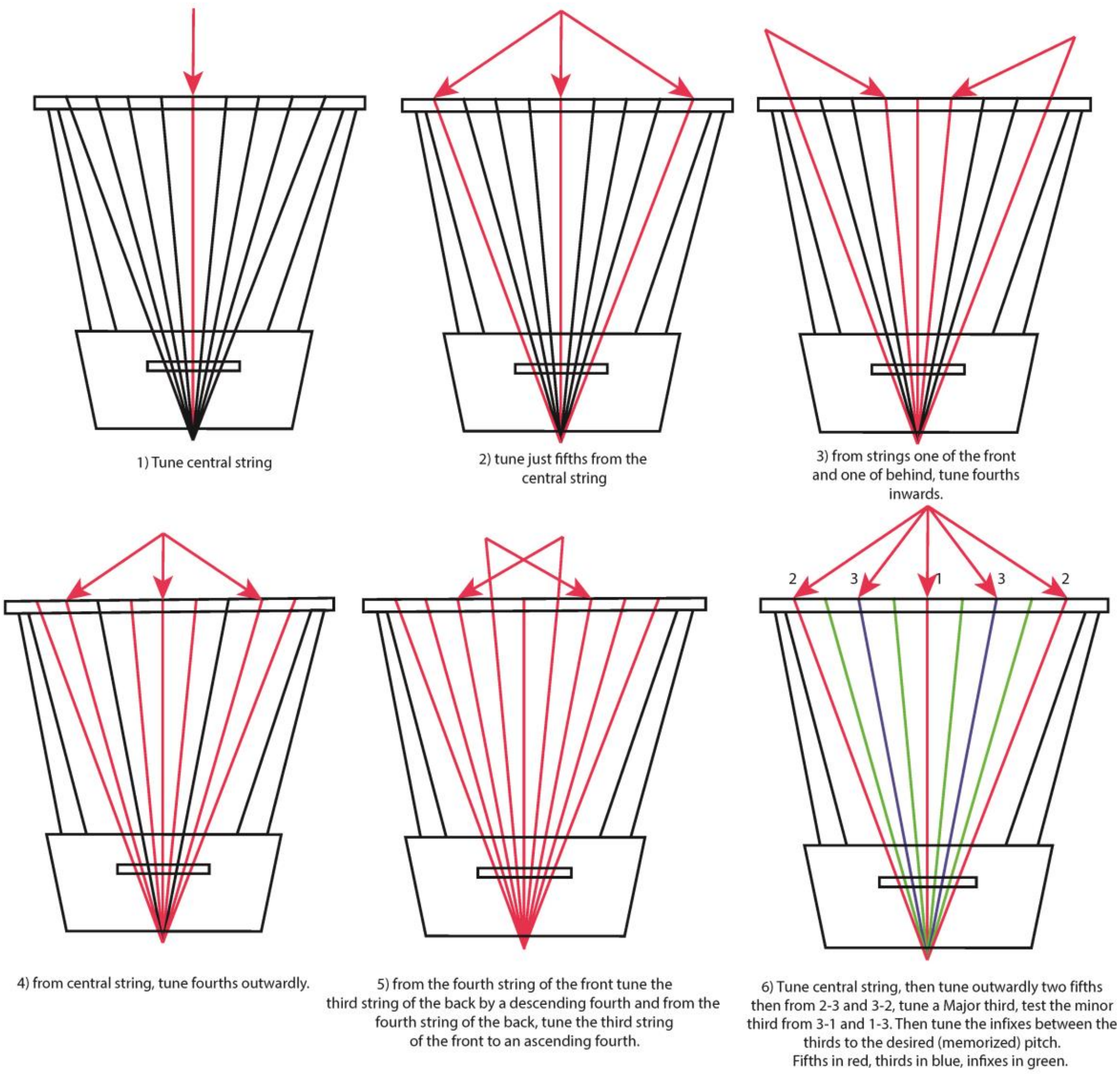


Fig. 2 (1-2-3-4-5-6). Illustrated tuning procedure derived from *nabnītu* xxxii. But it is also possible that they tuned with fifths and thirds only. In this case, after the second process when the central and two outer strings are tuned fifths apart, Just Major thirds are tuned from the outer strings. Then infixes are tuned from pitch memory. I would be in favor for this second type of tuning because it would be better suited to the interval list in the next tablet.

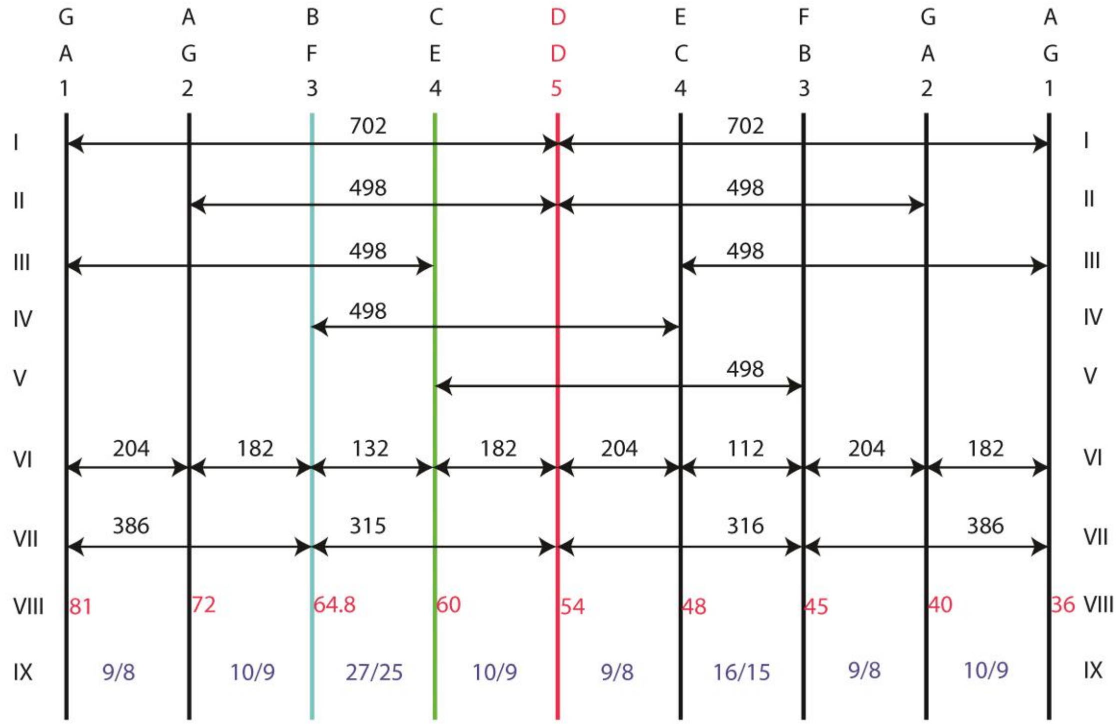


Fig. 3 Hypothetical construction of the generative Babylonian scale. I, location of fifths and value in cents; II, III, IV and V, location of fourths and size; VI, interval values of string-pitches in cents between each pitch and location; VII, interval values of major and minor thirds and location; VIII, location and pitch quantification of each string-pitch; IX, location and ratio values of each interval. Ratios are in blue; quantifications are in red.

It could be argued that they multiplied all of their regular numbers by ten (810; 720; 648; 600, etc.) as it was done later during the Western Renaissance, and later, but I do not think they did.[31]

However, 64.8 is the value for string 3 and therefore its qualification of "third thin string" hitherto obscure, is now explicit, due to its abnormality. It is rectified with 60, the fourth string, "corrected/created" by the god Ea/ENKI, the god of music, whose qualification is thereby understood.

64.8 in relation to 45 delineates a "dissonance"[32] of 631 cents (versus 612 cents, the Just Intonation "tritone" made of three just tones of 204 cents each).

It is this "dissonance", consequence of the introduction of the semi-tone, which off-balanced an otherwise perfect pentatonic system: *a-g-e-d-c-a-g/g-a-c-d-e-g-a* which became enneadic/bi-pentadic *a-g-**F**-e-d-c-**B**-a-g/g-a-**B**-c-d-e-**F**-g-a*. All figures, included 64.8 would either have been multiplied by ten, or 64.8 would have been adjusted to 64 with the consequences that the fifth 81:54 reduced to 80:54 would have produced a smaller fifth of 680 cents as shown in Fig. 4, line VIII. I am not in favour of the second proposition.

At present, my hypothesis is all we have to speculate about Babylonian intonation. I hoped that this

[31] I believe that they did not quantify their pitches beyond 81 (in their theory) because this is the last number in the Nippur tablets, with penultimate 80. Since 81-80 = 1 (81/80 = 1.0125; 80/81 = 0.98765432...) and that the ratio of 81:80 = 21.506290 cents. This is the comma of Didymus, also called syntonic comma, chromatic diesis, Ptolemaic comma, or the wrongly qualified as diatonic comma, which is a small interval between two musical notes, equal to the frequency ratio 81:80 (21.51 cents). In later Greek theory, this comma is referred to as the "comma of Didymus" because it is the amount by which Didymus would have corrected the Pythagorean major third (81:64, around 407.82 cents) to a just major third (5:4, around 386.31 cents). The quantification of 81 - 80 = 1, producing the smallest interval in the Nippur list, would have ended the series, logically.

[32] The term dissonance is inappropriate. Babylonians used the terms "*la zaku*" which roughly translates as "unclear", but unclear does not mean dissonant. Therefore, although Babylonians found that interval "strange" it had not reached the qualification of "dissonant".

would be useful as basis for more punctilious research. To that end, as I was looking for mathematical cuneiform texts with series of regular numbers.

About ten years ago, I "re-discovered" four tablets found in the early 1900s at the Temple Library of Nippur.[33] They date from 2300-2200 BC. They have a series of numbers from 1 to 81. They all are regular numbers taken from the Babylonian sexagesimal system, or base 60 arithmetics, and evenly divide powers of 60. For instance, $60^2 = 3600 = 48 \times 75$, so both 48 and 75 are divisors of a power of 60. They are numbers with only prime divisors 2, 3, and 5. In music theory, the Just intonation of the tense diatonic scale involves regular numbers: the pitches in a scale have frequencies proportional to the numbers in the sequence given above from 1 to 81.[34]

Thus, for an instrument tuned in this manner, all pitches are regular numbers, therefore, harmonics of a single fundamental frequency. This scale is called a 5-limit tuning, meaning that the interval between any two pitches can be described as a product $2^i3^j5^k$ of powers of the prime numbers up to 5, or equivalently as a ratio of regular numbers.

These numbers agree with my views. They are printed in red in Fig. 3 and Fig. 4. There is no formal evidence that they were used for musical purposes. However, they end with 80 and 81. This means that the interval between them, later named by the Greek word κόμμα (*kómma*) from κόπτω (*kóptō*, "I cut"), was already known in Babylon over 4000 years ago. This strongly reinforces my opinion that the Nippur Tablets were used as the basis for pitch quantification theory, although probably not exclusively. But the question is how they could have associated these numbers with the harmonic series is difficult to understand.

The Nippur regular numbers could also have been used as practical string length standards, essential to the instrument maker who would have used them as speaking lengths of string and lengths of air columns of wind instruments. (Fig. 5)

These measurements might suggest a standard "Babylonian relative tuning".[35] They can also be read as units of frequency, but the likelihood that they understood the concept is most improbable. However, we must never underestimate Babylonian scholarship. Frequency might not have been conceptualized as we understand it, but it might have been sensed. If a string is plucked and if the tip of a finger is lightly placed at about the middle of the string, its vibrations are felt.

It is probable that they would have noted that the higher the pitch, the faster the vibrations, and reciprocally, but they would not have been able to count them. However, from their expert usage of reciprocals, they might have perceived that the reciprocals of string lengths equated to the number of their vibrations.

Conclusion

This text describes a bi-pentadic (enneadic) set. Strings gave their names to pitches. Therefore, they could have notated a melody with them although there is no evidence that they did. The Babylonian set described in this tablet is a "Just Intonation enneadic diatonic" system made up of two symmetric conjunct pentads. But it is not a heptatonic set enlarged by two degrees.

33 [Hilprecht, 1906, p. 21, Pl. 10, 11, 12 and V].

34 Regular numbers are numbers that evenly divide powers of 60 (or, equivalently powers of 30). As an example, 602 = 3600 = 48 × 75, so both 48 and 75 are divisors of a power of 60. Thus, they are regular numbers. Equivalently, they are the numbers whose only prime divisors are 2, 3, and 5. Regular numbers from 1 to 81 are: 1; 2; 3; 4; 5; 6; 8; 9; 10; 12; 15; 16; 18; 20; 24; 25; 27; 30; 32; 36; 40; 45; 48; 50; 54; 60; 64; 72; 80; 81.

35 Relative tuning is when an instrument is tuned to itself. An absolute tuning is when the instrument is tuned to a pitch common to an orchestral, national or a 'tentative universal pitch'. See [Young, 1955], and [Lloyd and Fould, 1949, p. 84 sq.].

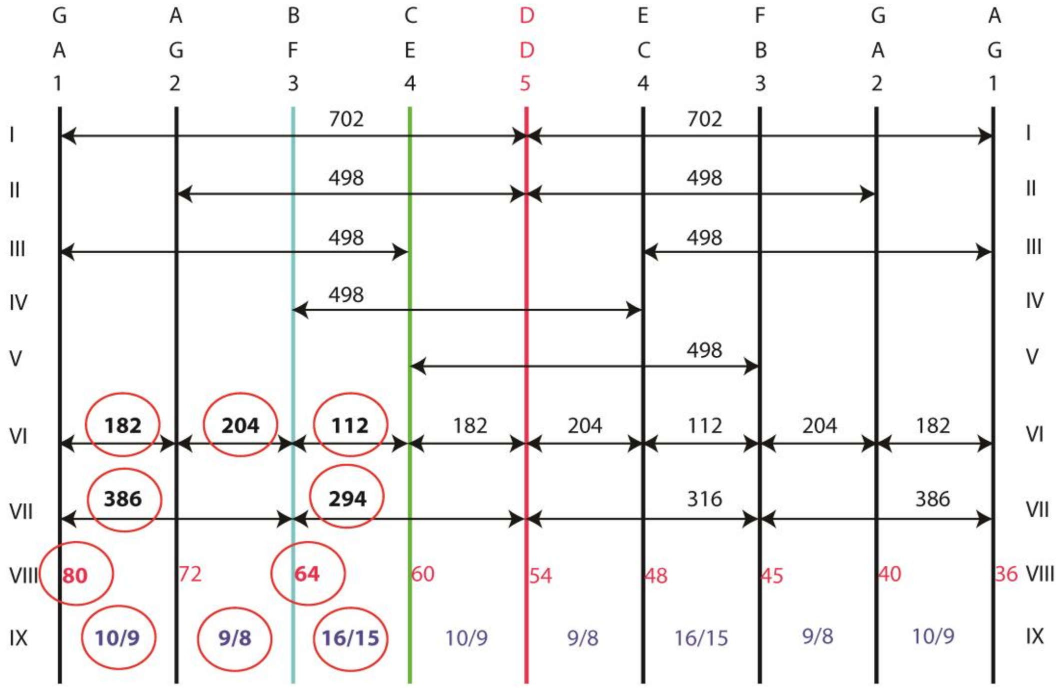


Fig. 4 Quantifications, ratios and cents in bold and underlined indicate changes due to the reformation when 64.8 was corrected to 64. This brought new quantifications in the first pentad (encircled in red). There, the tritone is 610, almost equal to 612, the tritone in Just Intonation.

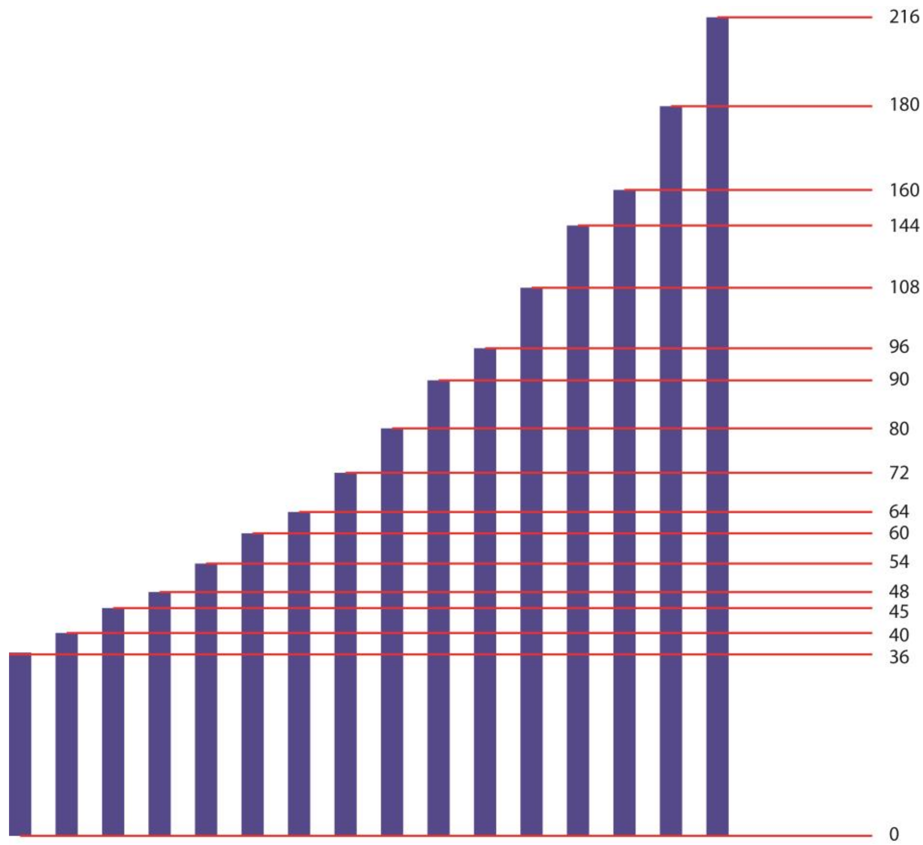


Fig. 5 Babylonian quantification as pattern for string lengths, (with identical sections and mass) or air column lengths, for instrument makers. Figures not to scale.

II - CBS 10996:[36] Occidental or Oriental?

This text is also Neo-Babylonian, perhaps a bit older than *nabnītu* xxxii. It was excavated at Nippur and first published in 1960.[37] It lists a series of names of intervals and numbers associated with them. Since numbers do not exceed seven, Kilmer and others thought that this was evidence of ascending heptatonism (Fig. 6).[38] However, it was later proven that the system is descending.[39]

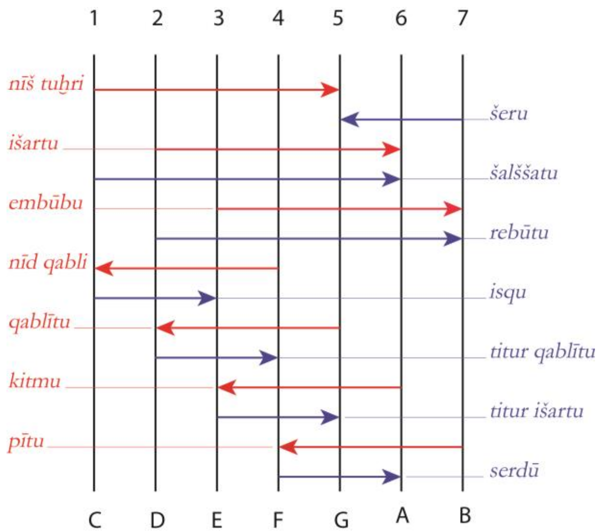


Fig. 6 Graphic representation of CBS 10996, Kilmer's version. Names in red indicate principal pentadic sets. The tetrads in this graphic are obviously inverted pentads. Names in blue are secondary (triadic, or inverted-triadic) subsets.

Fig. 7 is my graphic interpretation of the tablet. The top part (A) is Kilmer's erroneous reading of the text. It is, she claims, a pattern spanning seven steps numbered from the bottom, suggesting that "1" is the lowest pitch, and that therefore the structure is ascending. The bottom part (B) shows my reconstruction of an original and hypothetical tablet, forerunner of CBS 10996. It displays a regular pattern spanning thirteen steps starting with number "1" at the top, suggesting that "1" is the highest pitch. For the sake of clarity, let us agree that "1" = "c".

At the first line (I) of top part (A), Kilmer"s interpretation, 1↑5 (*nīš tuḫri*) is *c*↑*g*. (since Kilmer sees it ascending).

At the first line (I) of the bottom part (B) of my reconstruction, 1→5 = *c*→*f* is descending.

Line II in (A) is descending 7→5 = *b*→*g* with Kilmer.

Line II in (B) is ascending 7↑5 (*šeru*). It is "*d*↑*f*".

The rest of my graphic representation where part (B) is the reconstruction which would have been the triskaidecadic[40] source for part (A). The erratic arrangement of part (A), the original CBS 10996, was left unexplained even as recently as 2013.[41]

Obviously, the arrhythmic order of the intervals in CBS 10996 is the consequence of the adaptation of a larger system into a smaller one, of seven pitches, or for an instrument fitted with seven strings.

The scribe who wrote the text kept the original polarities[42] of the intervals as they were in the original text, in his adaptation. It explains the inconsistencies in the numbers. Obviously, the scribe knew about the larger span which he was adapting, (Fig. 8 and Fig. 4) probably as an exercise, to an instrument with seven string/pitches.

Such an instrument would have been designed exclusively for music composed from a heptatonic system, obviously.

[36] [Gurney, 1974, v. VII (1973), Pl. 126].

[37] [Kilmer, 1960]. In her paper, Kilmer does not write anything worth mentioning about music. In another article entitled "The Strings of Musical Instruments: their Names, Numbers and significance", [Kilmer, 1965], she makes interesting philological remarks but no progress with musicology. The article has an appendix written by Duchesne-Guillemin who wrongly confirms that the scale is ascending. Another article by David Wulstan, "The Earliest Musical Notation", [Wulstan, 1971], is also misguided. Another paper by Kilmer, "The Discovery of an Ancient Mesopotamian Theory of Music", [Kilmer, 1971], confirms that she has concocted a whole theory resting on the flawed interpretation of one text only.

[38] A scale of seven degrees as: *c-d-e-f-g-a-b*; *d-e-f-g-a-b-c*; *e-f-g-a-b-c-d*, etc.

[39] The rising or falling of a system is only relevant to the theoretical process but is irrelevant to praxis.

[40] From Ancient Greek τρεισκαίδεκα (*treiskaídeka*, "thirteen"), from τρεῖς (*treîs*, "three") + καί (*kaí*, "and") + δέκα (*déka*, "ten"). Hence triskaidecadic, adj.

[41] [Mirelman, 2013, p. 46, fn. 6]: "The order in which the dichord pairs are referred to here (e.g., '5-2' as opposed to '2-5') corresponds to the order in which they occur in the theory texts. The theory texts enumerate the dichords according to a pattern that is not consistently ascending or descending."

[42] The polarity of an interval is defined by which note comes first: c↘f (1↘5) suggests that c (1) is first played, followed by lower f (5). In CBS 10996, polarity is given in number and pitch order.

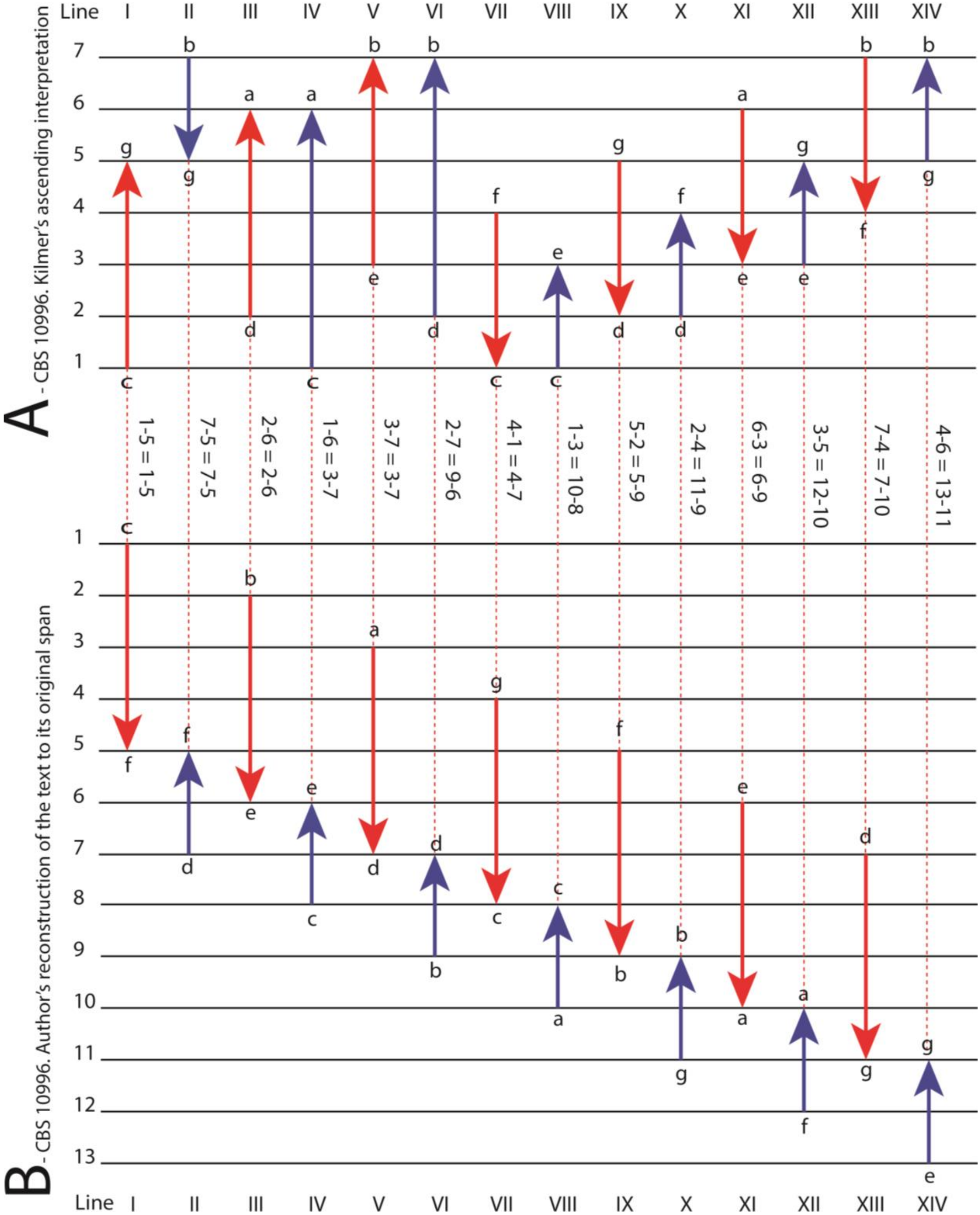


Fig. 7 The seven lines at the top are the transliteration of the original text in its descending polarity. Lines 1 to 13 of the lower graphic shows the reconstruction of what would have been the original span, in a descending order. Numbers between lines 1 of A and 1 of B give interval inversions when they appear.

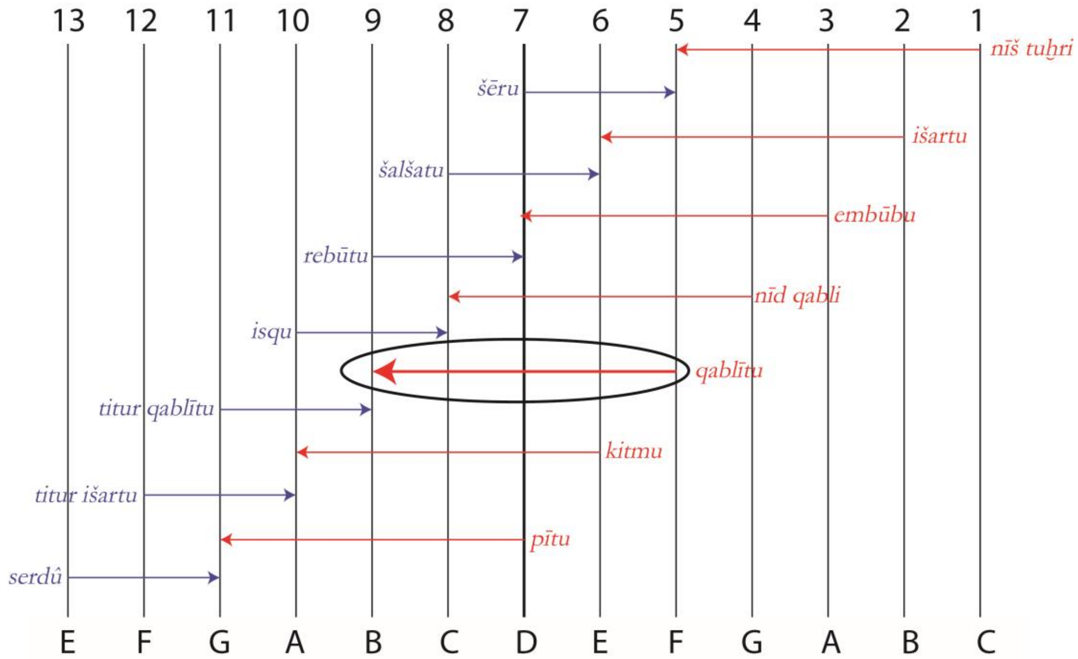


Fig. 8 Author's reconstruction of the Greater Babylonian System of descending pentads and ascending triads. The position of Babylonian pentads is extrapolated from text CBS 10996. Therefore, this is how they would have been located prior to their contraction into a heptatonic framework. I have inscribed *qablītu* in an ellipse because in Babylonian the term means 'middle' which in this case is perfectly suited. *qablītu* sits exactly in the middle of the grid, it is the only tritonic pentad in the system and is symmetrical with *D* as its axis: $B_{(\text{semitone})}C_{(\text{Tone})}D_{(\text{Tone})}E_{(\text{semitone})}F$.

But I would like to be clear in my opinion that it was certainly not a catalogue of intervals that musicians would have used for writing compositions or playing pieces.

The two most puzzling questions are, firstly, why eminently intelligent Babylonian theoreticians could have devised such an incredibly ill-conceived method? In any literate and illiterate culture[43] in the world, past and present, music is notated, or memorized from successions of pitches. That Babylonians would have been restricted to compose with dyads is inconceivable. Intervals of dyads cannot be used for melodic notation since the human voice can only sing one pitch at a time;[44] and secondly, why eminently intelligent contemporary scholars could not have seen that their interpretation of the Babylonian notation of melody was flawed,[45] is impossible to understand.

But what is even more difficult to understand is that while early Greek theory, which is built up from the same basic principles,[46] is undisputed, its Babylonian origins are deemed whimsical.

The numbers printed and encircled in red in Fig. 4 are speculative. The ennead or "nine pitch system" is perfectly symmetric in a Just Intonation construction made from the alternation of just fifths and just fourths.

[43] By literate I mean cultures which are musically literate/numerate. Musical literacy/numeracy is certainly not essential to music theory and practice. Oral usage of contiguous pitches is not the prerogative of the literate. Music existed a long time before the written language and it is obvious that the earliest attempts at writing down theory rested on orality.

[44] However, there is a form of "polyphonic overtone singing" by which the singer can produce overtones, one at a time above the fundamental pitch, as well as undertones. This is known in various cultures such as in Inner-Mongolia, Tibet, etc. It is also called "harmonic singing". But this technique would not allow to sing two unrelated pitches at a time as in Kilmer's hypothesis. YouTube has many examples of this polyphonic overtone singing. See [Anon. "Overtone singing", 2017].

[45] [Hagel, 2005]. This article must be read *in extenso* to judge for oneself the ways by which Hellenistic supremacists attempt at segregating knowingly and deviously Greek from Oriental theory and praxis, in order to majorize the one and pejorize the other, respectively. This is done despite the evidence under the form of cuneiform texts which, to the contrary, proves that it was the Greeks who "borrowed" all they could from Babylonian scholarship. It would be laborious to list these cuneiform texts but the essential ones are studied in the present paper.

[46] [West, 1994, p. 219–223].

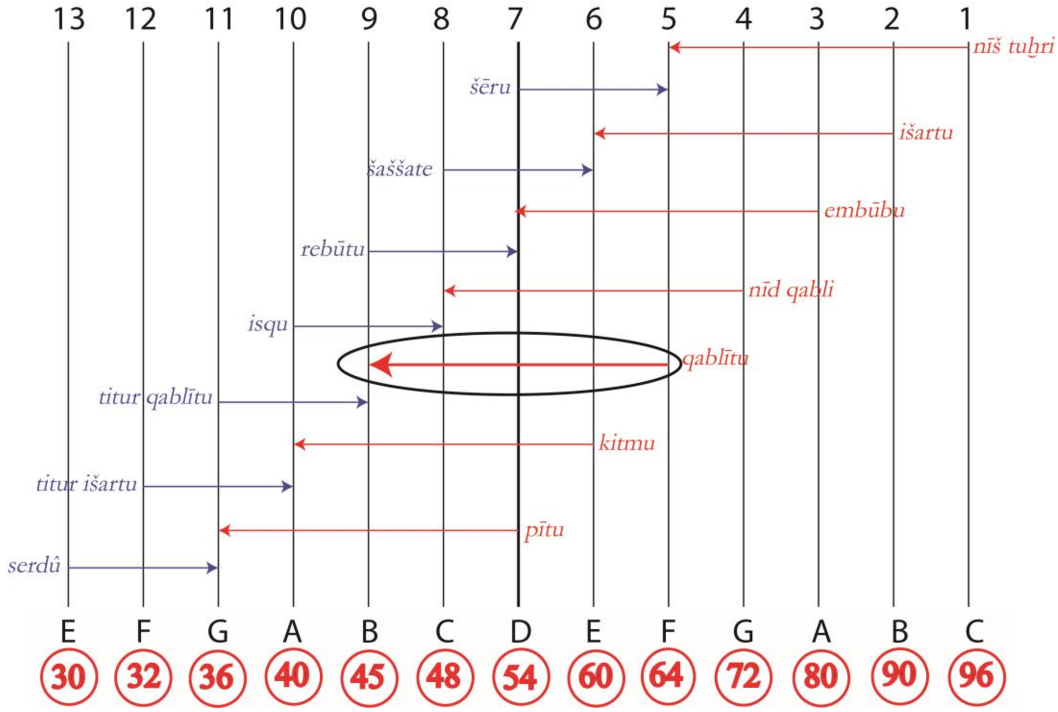


Fig. 9 Superimposition of quantifications to the original interval series. Quantification 64.8 has been reduced to 64.

My reconstruction of CBS10996 in its expanded version in Fig. 8 and Fig. 4 assumes that the central pitch in the interval *qablītu*, is the axis of symmetry for the whole system, in its original status.[47] This interval is made up of (27/25 [great limma] = 133.237 cents) + (10/9 [minor tone of just intonation] = 182.40 cents) + (9/8 [major tone] = 203.91 cents) + (16/15 [just semitone] = 111.73 cents) = 631.28 cents, which is an approximate acute diminished fifth.

In case of the adjustment of 64.8 to 64, the intervals of which *qablītu* is made are (16/15 [just semi-tone] = 111.73 cents) + (10/9 [minor tone of just intonation] = 182.40 cents) + (9/8 [major tone] = 203.91 cents) + (16/15 [just semi-tone] = 111.73 cents) = 609.78 cents, which is an approximate diminished fifth.

Both values which would be the Babylonian counterpart of the later Greek tritone are made up of the four different intervals with which the ennead is built and not of three just tones in the Greek system.

However, neither form of *qablītu* is tritonic as both are made up of four intervals. It is conceivable that both forms were considered as dissonant. This would explain the Babylonians term *la zaku*, meaning "unclear", *i.e.* "dissonant"[48] but it is not possible to determine its exact value as it was, as we shall see in the next text, based on tension and relaxation. I suggest that in Babylon the concept of dissonance was not clearly defined, or rather was not confined to a specific interval. In Babylonian theory, there is no known term for other forms of dissonance.

The aforementioned mathematical texts from the Nippur Temple Library have series of numbers from 1 to 81. They are all regular numbers taken from the Babylonian sexagesimal system, or base 60 arithmetics and evenly divide powers of 60.[49]

The Nippur numbers agree with my hypothesis. They are the numbers with only prime divisors 2, 3, and 5. In music theory, the Just intonation of the "diatonic" scale involves regular numbers: the pitches in a scale have frequencies proportional to the numbers in the sequence given above from (in our case) 36 to 81 or to 80.

81 is the first pitch of the generative descending scale (as derived from *nabnītu* xxxii). It is preceded by 80.

[47] "Original status" is the series of pitches resulting from a generative construction, in this case, as given in *nabnītu* xxxii.

[48] See also fn. 32, p. 97.

[49] For instance, $60^2 = 3600 = 48 \times 75$, so both 48 and 75 are divisors of a power of 60.

The ratio of 81:80 known as the aforementioned *comma* of Didymus,[50] which is of great importance in musicology, was already known at Babylon.

To conclude, the manner in which this scale is symmetrically built as 1-2-3-4-5 and 5-4-3-2-1, means that it was made up of two conjunct pentads, *i.e.* two pentads sharing a common pitch "D". Therefore, "two conjunct pentads" is a better description of what I call "enneadic set". This survived in Greece where "two conjunct tetrads" is a better description of heptatonism.

III - U.7/80 = UET VII, 74: *Not a tuning text!*

This text is further evidence, among many others, of the remarkable creative genius of Babylonian scholarship. The method explained in this system was never equalled in any other civilization, as it translates a dynamic disposition into its thetical[51] form.

This third tablet dates from the Old-Babylonian period, about 1800 BC. It was unearthed by Sir Leonard Woolley at Ur[52] and was published about forty years later, in 1968, by Professor Gurney.[53] At that time no one had yet hypothesised that the scale might be descending. Despite my attempts at promoting the idea on the basis of Greek and Oriental models, I was ignored. Consequently, and despite having asked advice from Oxford musicologist David Wulstan, Gurney's paper was published with the premise that the system was ascending.

Then in 1982, the Syrian Raoul Gregory Vitale[54] also attempted at promoting a descending system but was likewise ignored. At last, in 1990, Assyriologist friend Th.J.H. Krispijn perceived a new reading of line 12 as *nu-su-ḫ[um*, a form of the verb *nasāḫum*, "to tighten". This new term *nasāḫum*, Sumerian gíd-i, or *nussuḫum*, Sumerian zi-zi, is the technical verb for "to tighten" strings. Its antonym is *ne'ûm*, Sumerian tu-lu. Subsequently Gurney published another paper in 1994[55] where it was finally established that the Babylonian system was descending[56] on the basis that the strings must be tightened in part one of the text while it was assumed that strings were to be loosened in the previous publication of 1968. So, it was philology which won the case for musicology: Assyriologists did not trust musicologists.

The Text: restoration, translation and commentaries

Transliteration of U.7/80

[*šum-ma* $^{\text{giš}}$ZÀ.MÍ *pi-i-tum-ma*]
1 [*e-e*]*m-b*[*u-bu-um la za-ku*]
2 *ša-al-š*[*a-am qa-at-na-am tu-na-sà-aḫ-ma*]
3 *e-em bu-bu-u*[*m iz-za-ku*]

4 *šum-ma* $^{\text{giš}}$Z]À.MÍ *e-em-bu-bu-um-ma]*
5 *ki-it-mu-um* [*la za-ku*]
6 *re-bi úḫ-ri-im* [*tu-na-sà-aḫ-ma*]
7 *ki-it-mu-um i*[*z-za-ku*]

8 *šum-ma* $^{\text{giš}}$ZÀ.MÍ *k*[*i-it-mu-um-ma*]
9 *i-šar-tum la za-*[*ka-at*]
10 *ša-mu-ša-am ù-úḫ-ri-a-a*[*m tu-na-sà-aḫ-ma*]
11 *i-šar-tum iz-za-*[*ku*]

12 *nu-su-ḫ*[*u-um*]

13 *šum-ma* $^{\text{giš}}$Z]À.MÍ *i-šar-t*[*um-ma*]
14 *qa-ab-li-ta-am ta-al-pu-*[*ut*]
15 *ša-mu-ša-am ù-úḫ-ri-a-am te-*[*ni-e-ma*]
16 $^{[\text{giš}]}$ZÀ.MÍ *ki-it-mu-*[*um*]
17 [*šum*]*-ma* $^{\text{giš}}$ZÀ.MÍ *ki-it-m*[*u-um-ma*]
18 [*i-ša*]*r-ta-am la za-ku-ta-am t*[*a-al-pu-ut*]
19 [*re-bi*] *úḫ-ri-im te-ni-e!*[*-ma*]
20 $^{[\text{giš}}$ ZÀ.MÍ *e-em-bu-bu-um*]

Certain words in this transliteration have a final mimation, an 'm' following the case ending of a word, *i.e.* *išartum* instead of *išartu*. This practice is typical of the Old-Babylonian period.

[50] See fn. 31, p. 97.

[51] Thetic means "set down or stated positively or absolutely". From Greek "*thetikos*" = that can be placed < "*tithenei*" = to place. It describes sets translated from the dynamic layout in a disposition as is described with text U.7/80. It is another manner in which to notate a scale, from Greek "*dynamikos*", "powerful". It describes the layout of pitches as in the GBS (Greater Babylonian System). Dynamic *a-b-c-d-e-f-g-a* is thetic *c-d-e*$^{\flat}$*-f-g-a*$^{\flat}$*-b-c*, in case the thetic is set on the scale of "*c*" with accidentals added according to a given dynamic scale.

[52] [Gurney, 1974], Pl. 74.

[53] [Gurney, 1968].

[54] [Vitale, 1982].

[55] [Gurney, 1994].

[56] However, a descending system is not appropriate for lute types where the strings are "stopped". They require an ascending system because the system starts by an open string. Complementary pitches are produced by the position of finger tips along the neck of the instrument. This results in an ascending system.

It was on this basis that Gurney translated the text, and reconstructed it partially by extrapolation as follows:

"First part
1. If[57] the harp is *išartum*
the 'unclear interval' between strings 5 and 2 is *qablītum*
(should be 5-1^b)
tighten by a 'semi-tone'[58] string 5
the harp will be *qablītum*"

This first quatrain of the first part was reconstructed by Professor Gurney. My interpretation is that the set of *išartum* comes from the conjunction of pentads *nīš tuḫrim* and *qablītum* = *c-b-a-g-f* + *f-e-d-c-b* as explained in my reconstruction of CBS 10996. But the "unclear interval" is not between strings "5" and "2 of the front" (although in theory it exists as an "unclear" fourth at that position) but between "5" (*ḫa-am-šu*) and the "1 behind string" (*úḫ-ru-um*), an "unclear" fifth.

Now, that it was strings "5" and "2 of the front" which located the "unclear interval" would not have been written as such in the original text. It would have said that *qablītum* is *la zaku* which means, as mentioned before, "unclear", *i.e.* unpleasant.[59] The substitution of string "1 of the behind" to "2 of the front" is the consequence of the erroneous reading of CBS 10996, and is used to suggest heptatonism.

"2. If the harp is *qablītum*
the 'unclear interval' between strings 1 and 5 is *nīš tuḫrim* (correct)
tighten strings 1 and 8 (should be 1^f-2^b)
the harp will be *nīš tuḫrim*"

The set of *qablītum* comes from the conjunction of pentads *qablītum* and *išartum* = *f-e-d-c-b* + *b-a-g-f-e*. Therefore, the "unclear interval" is between strings "1 of the front" and "5". The reconstruction says that strings 1 and 8 should be tuned-up by a "semi-tone". But it should be written that it is string 1 of the front and string 2 of the back which should be tuned-up.

"3. If the harp is *nīš tuḫrim*
the 'unclear interval' between strings 4 and 1 is *nīd qablim*
(should be 4^f-2^b)
tighten string 4
the harp will be *nīd qablim*"

The set of *nīš tuḫrim* comes from the conjunction of pentads *išartum* and *kitmum* = *b-a-g-f-e* + *e-d-c-b-a*. The reconstructed text says that the "unclear interval" is between strings "4 of the front" and "1 of the front". Here again, it should be placed between strings "4 of the front" and string "2 of the back".

"4. If the harp is *nīd qablim*
the 'unclear interval' between strings 7 and 4 is *pītum*
(should be 7-11)
tighten string 7
the harp will be *pītum*"

The set *nīd qablim* comes from the conjunction of pentads *kitmum* and *embūbum* = *e-d-c-b-a* + *a-g-f-e-d*. Here, the limitation of the span for the set places the "unclear interval" *pītum* between strings "3 of the behind" and "4 of the front" and it is string "3 of the behind" which must be tuned-up.

"5. If the harp is *pītum*
the 'unclear interval' between strings 3 and 7 is *embūbum*
(should be 3^f-3^b)
tighten string 3
the harp will be *embūbum*"

The set of *pītum* comes from the conjunction of pentads *embūbum* and *pītum* = *a-g-f-e-d* + *d-c-b-a-g*. The transliteration of the tablet, since this is where the text U.7/80 starts, says that the "unclear interval" *embūbum* is placed between strings "3 of the front" and string "3 of the behind" and that string "3 of the front" should be tuned-up.

"6. If the harp is *embūbum*
the 'unclear interval' between strings 6 and 3 is *kitmum*
(should be 6-10)
tighten string 6
then the harp will be *kitmum*"

[57] The Akkadian term *šumma* has been consistently translated by "when" although it should be the conditional "if". It was argued that it meant the same thing. The Babylonians were keen on the usage of *protasis* (if) and *apodosis* (then): a protasis is the clause expressing the condition in a conditional sentence (e.g. *if you asked me* in *if you asked me I would agree*). The apodosis is the main clause of a conditional sentence (*e.g. I would agree* in *if you asked me I would agree*).

[58] The text does not say "semi-tone". It is an amount by which the "unclear interval" is corrected. This quantity is unknown as the system does not rely on ratios and therefore is left to the appreciation of the musician's tonal memory. I shall replace the term by "tighten".

[59] See also fn. 32, p. 97.

The set of *embūbum* comes from the conjunction of pentads *pītum* and *nīd qablim* = *d-c-b-a-g* + *g-f-e-d-c*. The "unclear interval" is *kitmum*. It should be placed on strings 9-10 of the Greater System.

"7. If the harp is *kitmum*
the 'unclear interval' between strings 2 and 6 is *išartum* (should be 2^{f}-4^{b})
tighten strings 2 and 9
the harp will be *išartum*"

The set of *kitmum* comes from the conjunction of *nīd qablim* and *nīš tuḫrim* = *g-f-e-d-c* + *c-b-a-g-f*. The "unclear interval" *išartum* is located between strings 2 and 6, while it should be string "2 of the front" and string "4 of the back".

The second part is the reverse of the first part.

Musical Quantification of U.7/80

Although incomplete, this fragmentary text holds a wealth of knowledge which coincides with the information extracted from the previous texts, *nabnītu* xxxii and CBS 10996.

The method given in U.7/80 places seven sets on a bi-pentadic span, or on an instrument with nine strings by simple tuning of one or two of its strings. This gives the following enneadic sets:

Part 1

išartum (1):	*c-b-a-g-f-e-d-c-b*
qablītum:	*c-b-a-c-f#-e-d-c-b*
nīš tuḫrim:	*c#-b-a-g-f#-e-d-c-b*
nīd qablim:	*c#-b-a-g#-f#-e-d-c#-b*
pītum:	*c#-b-a-g#-f#-e-d#-c#-b*
embūbum:	*c#-b-a#-g#-f#-e-d#-c#-b*
kitmum:	*c#-b-a#-g#-f#-e#-d#-c#-b*
išartum (2):	*c#-b#-a#-g#-f#-e#-d#-c#-b#*

12 *nu-su-ḫ[u-um]*

Part 2

išartum (2):	*c#-b#-a#-g#-f#-e#-d#-c#-b#*
kitmum:	*c#-b-a#-g#-f#-e#-d#-c#-b*
embūbum:	*c#-b-a#-g#-f#-e-d#-c#-b*
pītum:	*c#-b-a-g#-f#-e-d#-c#-b*
nīd qablim:	*c#-b-a-g#-f#-e-d-c#-b*
nīš tuḫrim:	*c#-b-a-g-f#-e-d-c-b*
qablītum:	*c-b-a-c-f#-e-d-c-b*
išartum (1):	*c-b-a-g-f-e-d-c-b*

The strings which are tuned up are printed red. Note that the last *išartum* is not at the octave of the first *išartum*. It is a "semi-tone" (of an undetermined value) higher. Therefore *išartum* (1) is not equal to *išartum* (2).

The indications in the text are "to tighten" and "to loosen" the strings. The quantity by which it should be is not given. This means that while theoretically we should have a Just Intonation system, in practice it might have been quite different in function of mood and other factors, such as location, time of day, season, but also and most importantly on tonal memory. Had they insisted on precise pitches, they would have indicated them in ratios with which they were fully conversant.

However, ratios are meaningless on harps or lyres, and this is probably why they were not used. They are only effective when a string is divided with frets or fret-marks as guides, on lute types.

For the sake of demonstration, should we hypothesize that this structure was intended for Just Intonation, then Fig. 10 gives such quantifications.

The recital in U.7/80 is an exceptional narrative for the history and transmission of the earliest musical construction, from its pre-literate form onward. Then, with the advent of literacy, musicology over-flowed its banks to grow into the most sophisticated form ever achieved in any civilization – four thousand years ago. The reliability of the Sumero-Babylonian scribal discipline was such that even with the few tablets which have reached us by luck – and not by design – it was nevertheless possible to decipher some of the unique intricacies of Mesopotamian music making.

Text CBS 10996 describes the reduction to a heptachord of a triskaidecadic forerunner. It suggests a foundation pitch around which other pitches agglutinate in a manner not dissimilar to the development of language. They agglutinate as sets and subsets, pentadic and triadic, respectively.

Two conjunct triads (Fig. 11) make a pentad: *serdû* + *titur qablītu* = *išartu* (*E-F-G/G-A-B* rising); *titur išartu* + *isqu* = *niš tuḫri* (*F-G-A/A-B-C* rising); *titur qablītu* + *rebūtu* = *pītu* (*G-A-B/B-C-D* rising); *isqu* + *šalšatu* = *kitmu* (*A-B-C/C-D-E* rising); *rebūtu* + *šeru* = *qablītu* (B-C-D/D-E-F rising).

Tune up									
	I	II	III	IV	V	IV	III	II	I
išartum	1290	1200	996	792	588	498	294	90	0
qablītum	1290	1200	996	792	680	498	294	90	0
nīš tuḫrim	1382	1200	996	792	680	498	294	182	0
nīd qablim	1382	1200	996	884	680	498	294	182	0
pītum	1382	1200	996	884	680	498	386	182	0
embūbum	1382	1200	1088	884	680	498	386	182	0
kitmum	1382	1200	1088	884	680	590	386	182	0
išartum	1382	1292	1088	884	680	590	386	182	92
Tune down									
išartum	1382	1292	1088	884	680	590	386	182	92
kitmum	1382	1200	1088	884	680	590	386	182	0
embūbum	1382	1200	1088	884	680	498	386	182	0
pītum	1382	1200	996	884	680	498	386	182	0
nīd qablim	1382	1200	996	884	680	498	294	182	0
nīš tuḫrim	1382	1200	996	792	680	498	294	182	0
qablītum	1290	1200	996	792	680	498	294	90	0
išartum	1290	1200	996	792	588	498	294	90	0

Fig. 10 Analysis of values of sets in cents showing that the last *išartum* of the first chapter is not at the octave of the first set. The same applies to the second chapter. The two sets differ by 92 cents throughout. 92 cents is the larger *limma* which is the defect of a fourth, 498 cents, increased by an *apotome*, 112 cents (total 610 cents) from a fifth, 702 cents, and hence the interval by which the fourth must be sharpened to be an *apotome* below (*i.e.* the 'leading note' to) the fifth and hence the interval by which the fourth is sharpened on modulating into the dominant.

D 1
C D E 3
B C D E F 5
A B C D E F G 7
G A B C D E F G A 9
F G A B C D E F G A B 11
E F G A B C D E F G A B C 13
D E F G A B C D E F G A B C D 15
C D E F G A B C D E F G A B C D E 17

Fig. 11 Pyramid of systems. This pyramid shows the gradual structure from an initial pitch, to a triad, then the conjunction of two triads amounting to a pentad, then of two conjunct pentads amounting to an ennead, then of four conjunct pentads amounting to the Greater Babylonian System or heptadecade.

The reason for their position in my reconstruction of the Greater Babylonian System is not yet understood. However, their integration in my interpretation of the Hurrian song H6 corroborates their presence, complementing descending fifth, logically and aesthetically.

As they stand, these triads are an essential part of the Babylonian sound-scape. The Greater Babylonian System spreads onto 17 pitches with smaller spans of 15, 13, 11, 9, 7, 5 and 3, (Fig. 11) all based on the same principle of the sharing of a common axis of symmetry. This is supported by the iconography where the number of strings vary with periods coinciding with organological trends.

Pitch sets are composed of two conjunct pentads where the last pentad of a given ennead is also the first pentad of the ennead which follows (Fig. 12, Fig. 13 and Fig. 14):

- Pentads *nīš tuḫri* + *qablītu* = set of *išartu* = ***c-b-a-g-f-e-d-c-b***
- Pentads *qablītu* + *išartu* = set of *qablītu* = ***f-e-d-c-b-a-g-f-e***
- Pentads *išartu* + *kitmu* = set of *nīš tuḫri* = ***b-a-g-f-e-d-c-b-a***
- Pentads *kitmu* +*embūbu* = set of *nīd qabli* = ***e-d-c-b-a-g-f-e-d***
- Pentads *embūbu* + *pītu* = set of *pītu* = ***a-g-f-e-d-c-b-a-g***
- Pentads *pītu* + *nīd qabli* = set of *embūbu* =***d-c-b-a-g-f-e-d-c***
- Pentads *nīd qabli* + *nīš tuḫri* = set of *kitmu* = ***g-f-e-d-c-b-a-g-f***

or are composed of two conjunct pentads which also follow each other, conjunctly, where the last pitch of a set is the first pitch of the next and results in an order of descending contiguous pitches:

- Pentads *nīš tuḫri* + *qablītu* = set of *išartu* = ***c-b-a-g-f-e-d-c-b***
- Pentads *išartu* + *kitmu* = set of *nīš tuḫri* = ***b-a-g-f-e-d-c-b-a***
- Pentads *embūbu* + *pītu* = set of *pītu* = ***a-g-f-e-d-c-b-a-g***
- Pentads *nīd qabli* + *nīš tuḫri* = set of *kitmu* = ***g-f-e-d-c-b-a-g-f***
- Pentads *qablītu* + *išartu* = set of *qablītu* = ***f-e-d-c-b-a-g-f-e***
- Pentads *kitmu* +*embūbu* = set of *nīd qabli* = ***e-d-c-b-a-g-f-e-d***
- Pentads *pītu* + *nīd qabli* = set of *embūbu* = ***d-c-b-a-g-f-e-d-c***

Unequivocally, this system, whether of 17, 15, 13, 11, 9, 7, 5 or 3 pitches, is built from pentads and triads and can also integrate a set of seven pitches.

The "unclear intervals" are located at the following positions:

- In *išartu*, ***c-b-a-g-f-e-d-c-b***=1-2-3-4-5-4-3-2-1, the "unclear interval" is *qablītu* and is placed on 5-1b = ***f-b***
- In *qablītu*, ***f-e-d-c-b-a-g-f-e*** = 1-2-3-4-5-4-3-2-1, the "unclear interval" is *nīš tuḫri* and is placed on 1f-5 = ***f-b***
- In *nīš tuḫri*, ***b-a-g-f-e-d-c-b-a*** = 1-2-3-4-5-4-3-2-1, the "unclear interval" is *nīd qabli* and is placed on 4f-2b = ***f-b***
- In *nīd qabli*, ***e-d-c-b-a-g-f-e-d*** = 1-2-3-4-5-4-3-2-1, the "unclear interval" is *pītu* and is placed on 3b-4f (7-11) = ***f-b***
- In *pītu*, ***a-g-f-e-d-c-b-a-g***=1-2-3-4-5-4-3-2-1, the "unclear interval" is *embūbu* and is placed on 3f-3b = ***f-b***
- In *embūbu*, ***d-c-b-a-g-f-e-d-c*** = 1-2-3-4-5-4-3-2-1, the "unclear interval" is *kitmu* and is placed on 4b-3f (6-10) = ***f-g***
- In *kitmu*, ***g-f-e-d-c-b-a-g-f***=1-2-3-4-5-4-3-2-1, the "unclear interval" is *išartu* and is placed on 2f-4b = ***f-b***

The "unclear interval" in each set gives its name to the set which follows: in *išartu*, the "unclear interval" is *qablītu*. It gives its name to the second ennead: *qablītu*. In this set the "unclear interval" is *nīš tuḫri*. It gives its name to the next ennead: *nīš tuḫri*, and so forth.

All "unclear interval" are pentadic (***f→b***) when the span has seventeen pitches (when the span is restricted, some "unclear intervals" are tetradic, because of inversion) but have different names according to where they are placed. This shows that the enneadic set is a reduction of the Greater Babylonian System (GBS), as CBS 10996 is the reduction of the GBS for a pitch set of seven, or heptad.

Should we take "unclear interval" location numbers as Gurney located them in 1992, where he follows the order of intervals in CBS 10996, they would be either pentads or tetrads. The location of the "unclear interval" in the first part of the text is: 5-2; 1-5; 4-1; 7-4; 3-7; 6-3; 2-6, or (5-1-4-7-3-6). The second part is the inversion of the first part: 5-2; 2-6; 6-3; 3-7; 7-4; 4-1; 1-5, or (2-6-3-7-4-1).

Nomenclature	Approximative pitch	Quantification
1. *niš tuḫrim*	E^4-D^4-C^4-B^3-A^3	$24^{(9:8)}27^{(10:9)}30^{(16:15)}32^{(9:8)}36$
2. *išartum*	D^4-C^4-B^3-A^3-G^3	$27^{(10:9)}30^{(16:15)}32^{(9:8)}36^{(10:9)}40$
3. *embūbum*	C^4-B^3-A^3-G^3-F^3	$30^{(16:15)}32^{(9:8)}36^{(10:9)}40^{(9:8)}45$
4. *nīd qablim*	B^3-A^3-G^3-F^3-E^3	$32^{(9:8)}36^{(10:9)}40^{(9:8)}45^{(16:15)}48$
5. *qablītum*	A^3-G^3-F^3-E^3-D^3	$36^{(10:9)}40^{(9:8)}45^{(16:15)}48^{(9:8)}54$
6. *kitmum*	G^3-F^3-E^3-D^3-C^3	$40^{(9:8)}45^{(16:15)}48^{(9:8)}54^{(10:9)}60$
7. *pītum*	F^3-E^3-D^3-C^3-$B^{3(\flat?)}$	$45^{(16:15)}48^{(9:8)}54^{(10:9)}60^{(16:15)}64$

Fig. 12 Quantification of pentads showing that they all differ in content. Quantifications are given in regular numbers and in ratios.

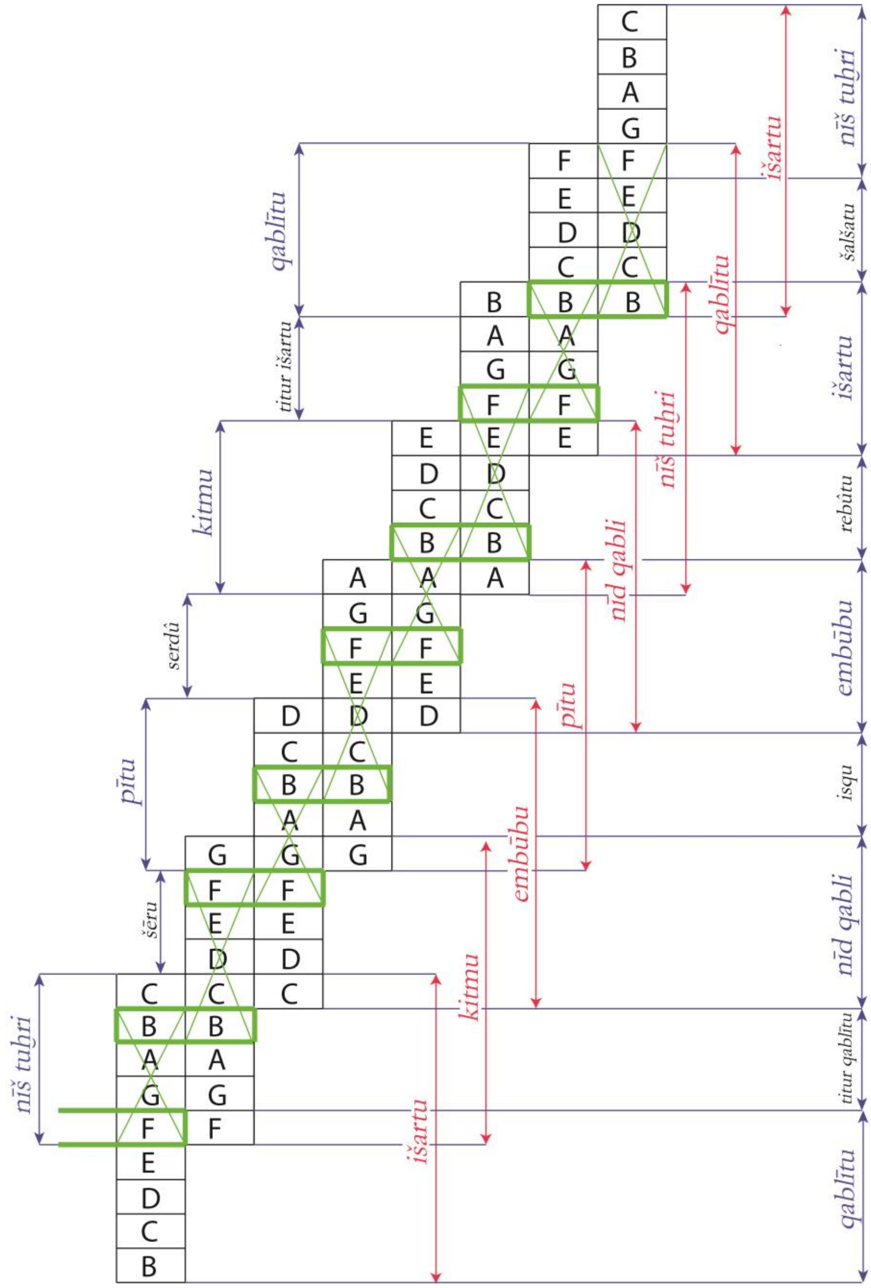


Fig. 13 Set construction with superimposition of pentads (last pentad of a set being the first pentad of the following set). Pentads (principal intervals) are in blue; triads (secondary intervals) are in black; sets are in red. Tritones are crossed with green lines with their conjunction pitch framed in thick green lines.

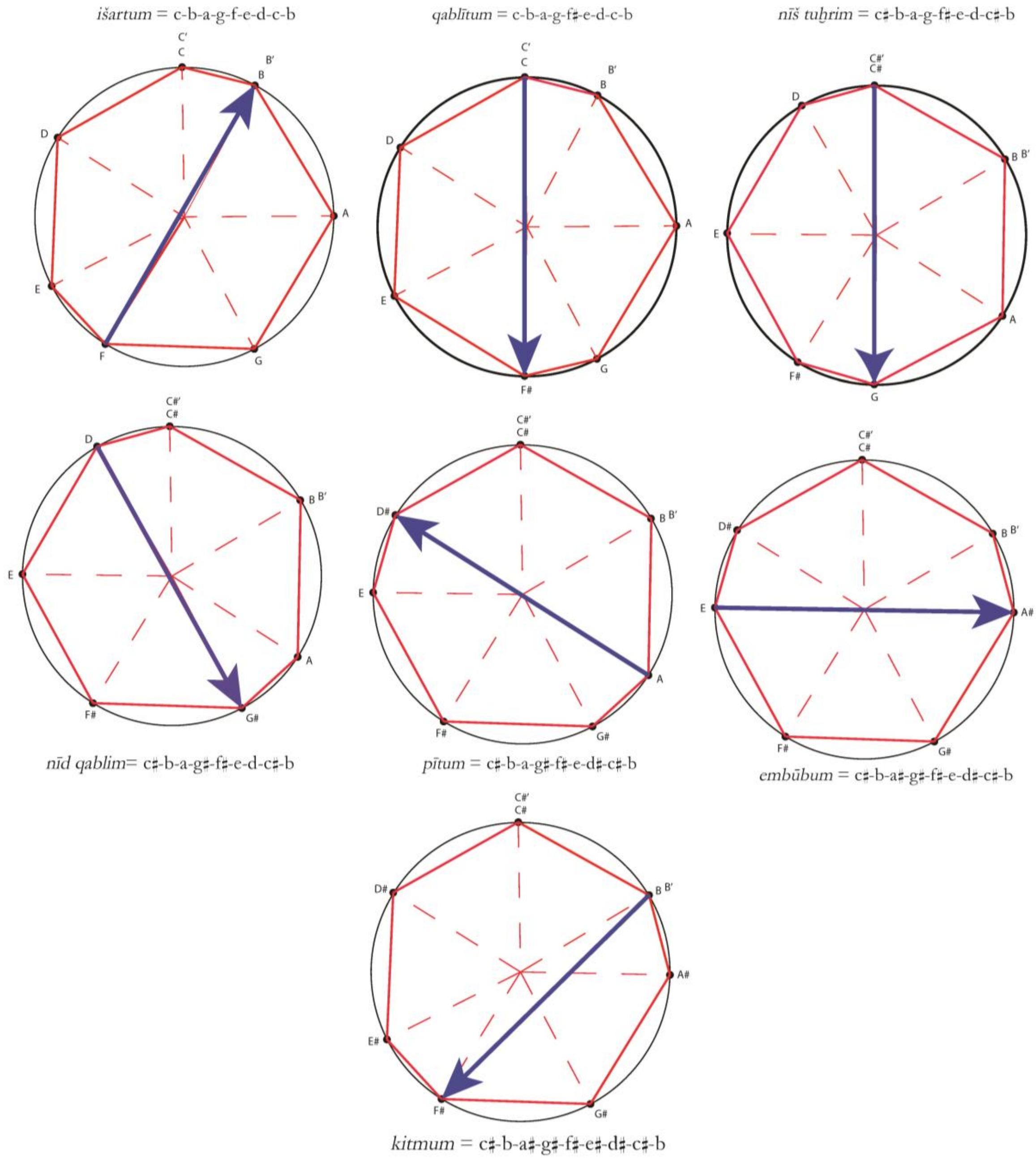


Fig. 14 Circular representation of the sets generated in U.7/80. There is no evidence that Babylonians used this form of representation of their sets mainly because their system was enneatonic. Only heptatonism is suited for its representation in an encircled heptagram. (In my representation, note that I have doubled *C*s and *B*s to fit enneatonism within a heptagram): 1. *išartum*; 2. *qablītu*; 3. *nīš tuḫrim*; 4. *nīd qablim*; 5. *pītum*; 6. *embūbum*; 7. *kitmum*. Blue arrows indicate the tritones and their polarity.

This sequence is exactly the same that we find later with text CBS 1766, (Fig. 16: 114) which, without any doubt is a heptatonic construction. This is how lack of meticulousness and hasty assumptions always lead to wrong conclusions.

If the enneadic sets, which constitute the basis for Babylonian music theory are composed of two conjunct pentadic intervals, then their description and purpose in CBS 10996 has been wrongly interpreted. Therefore, all postulations built from this assumption are consequently flawed.

Philology is only partially understood. My reconstruction of CBS 10996 has correctly positioned the "unclear interval" interval *qablītu* perfectly in the middle of the grid. *pītu* means "opening" and *kitmu* perhaps "closing"; *išartu* means "erect, straight".

All these terms would have had their meanings which at present remain obscure. Usually, various cultures use toponyms to name their scales. Greek theory has Ionian, Dorian, Phrygian, Lydian, Locrian, etc. Babylonian sets also use particular names though not toponymic.

For advocates of heptatonism, I must insist that to prove its existence, there must be evidence for its construction. Without it, the term may not be used. U.7/80 has no evidence of it. The tuning of octaves does not prove that the system is octavial heptatonic. There is incompatibility between the heptatonic system and the octave.[60] A heptatonic set is made up of 6 just tones (5 just tones and 2 semi-tones). A Just tone equals slightly less than 204 cents (9:8) and six of them amount to 1223 (1223.46) cents. The octave measures exactly 1200 cents. In the context of U.7/80, the octave exists as an interval shared between two conjunct pentads but it is not and interval contained within a pentad. Furthermore, a distinction must be made between the octave as an interval and the octave as a concept. These are two very different things. The octave as a concept is a sampling standard within which a certain number of intervals can be fitted for the purpose of measurement. It is a container of smaller intervals[61] as first coined by friend and scholar Amine Beyhom.

A problem remains. How enneadic sets where distinguished from pentadic sets since they have the same names? In 1977, Aaron Schaffer found a small fragment at the University Museum, Philadelphia which he thought might be part of the reverse of *nabnītu* xxxii. The word *siḫpu*, was found associated with each of the enneadic, or pentadic sets:

išartu /siḫip išartu
kitmu/siḫip kitmu
embūbu/siḫip embūbu
pītu/siḫip pītu
nīd qablim/siḫip nīd qablim
nīš tuḫrim/siḫip nīš tuḫrim
qablītum/siḫip qablītum

The order of the sets above corresponds to the second part of the text.

Line 11 of *nabnītu* xxxii is the header of a new list: [sa.]du.a! *pismu*. There, the word *siḫip* precedes sets. Would *pismu* or *siḫip* denominate pentadic or enneadic sets is not possible to say at present.

IV - YBC 11381: *9 sets?*

A recently published Neo-Babylonian text[62] in the Yale Babylonian Collection, this is one of the most significant additions to the corpus of music theory for the past fifty years.

The text lists nine strings. Each string number is followed by an incipit[63]. The nine strings are known from *nabnītu* xxxii and mentioned in U.7/80. Unlike their disposition in *nabnītu* xxxii where the nine strings are listed palindromically/symmetrically: 1-2-3-4-5-4-3-2-1, YBC 11381, has them listed continuously: 1-2-3-4-5-6-7-8-9, significantly.

Each line start with the Sumerian sign "sa", meaning "string", followed by a number. I believe the nine "sa" with their numbers are no longer used only for listing strings, as with *nabnītu* xxxii, but would also be used for naming nine enneatonic/bi-pentadic sets generated from the system described in text U.7/80.

Interestingly, this new text might be a precursor for Plato's quantification of his nine Muses. In a notoriously difficult passage of *Republic,* (545c-546d)[64] the Muses speak about two harmonies,[65] two Pythagorean heptachords superimposed, Dorian and Phrygian, in such a way that their combination aggregates into an enead/bi-pentad with pitch quantifications which would have come from the Babylonian model. Clio is *a"* 2400; Euterpe is *g'* 2700; Thaleia, is *f'*, 3000; Melpomene is *e'* 3200; Terpsichore is *d'* 3600; Erato is *c'* 4050; Polyhymnia is *b* 4320; Urania is *a* 4800 and Caliope is *g* 5400. Apart from Erato and Polyhymnia with typical Greek numbers, the other muses have Babylonian quantifications.

[60] The term "octave" has been borrowed from Mediaeval Western Christianity. It means a series of eight days preceding a festival. It is contended that by giving the same name to a series of eight notes, it would "Christianize" it thus making of music a religious act. A more appropriate term should be "octade".

[61] [Beyhom, 2003 ; 2010a ; 2013 ; 2017].

[62] [Payne, 2010]. As stated by Payne this tablet can be approximately placed as Neo-Babylonian based on its orthography.

[63] In music, an *incipit* (from the Latin, meaning "it begins") is an initial sequence of notes or words used in catalogues of musical texts.

[64] *e.g.* [Cornford, 1997] omits the description" of Socrates" "sovereign number". In [Plato and Waterfield, 1993] the latter notes "scholars nowadays largely ignore the passage" – see [Crickmore, 2009]: "Hesiod's 'races' and 'political degeneration' in Plato", p. 56-57.

[65] See notes in [Plato and Adam, 1909, v. 2, p. 202–203].

The way instructions are given in U.7/80 imply that they would have left room for local, regional, or, and national tone inflections in Old-Babylonian systems allowing for specific intervals to be tuned slightly wider, or slightly smaller than the Just paradigms. They were tuned by ear only, from a master's teachings through metaphors, and metonymy, and not with ratio theories.

Aristoxenos would have preferred speaking in terms of tension (ἐπίτασις) and relaxation (ἄνεσις), but how much of Aristoxenos' works are really his and not Western Mediaeval transpositions of Eastern theories, into Western ones, during and after the crusades, is conjectural.

Al-Fārābī, Latinised as Alfarabius, because of the complete disappearance of the Babylonian cuneiform script would have assumed that most he knew of the past would have mainly come from the Greek: He would have thus lost all knowledge of any Babylonian antecedence, and the Greeks were not eager at giving Babylon any credit.

Since U.7/80 relies only on tension and relaxation of strings, and not with ratios, it follows that the ratio of 2/1, the octave, is irrelevant. Although the "Gurney/Wulstan theory", is interpreted as octavial, tense diatonic heptatonism, all seem to ignore that the first extrapolated scale of *išartum*, is not at the octave of the last *išartum* in both chapters.

It is either higher, or lower, by an unqualified semitone. It would appear logical that the Babylonians, after having adopted an enneatonic generative model, would have had nine subsets. These sets would have stemmed from their fundamental or generative model, as shown below, for the first chapter of U.7/80 with the second chapter relaxing the tension in each set as a reverse process of chapter one.

Note that because we are certain, from the reading of U.7/80, that the last quatrain of the first part and the first of the second was *išartum*, it would be reasonable to assume that the series started with *kitmum*.

Tension (part one)

1	*kitmum:*	*c-b*$^{\flat}$*-a-g-f-e-d-c-b*$^{\flat}$
2	*išartum:*	*c-b-a-g-f-e-d-c-b*
3	*qablītum:*	*c-b-a-g-f*$^{\#}$*-e-d-c-b*
4	*nīš tuḫrim:*	*c*$^{\#}$*-b-a-g-f*$^{\#}$*-e-d-c*$^{\#}$*-b*
5	*nīd qablim:*	*c*$^{\#}$*-b-a-g*$^{\#}$*-f*$^{\#}$*-e-d-c*$^{\#}$*-b*
6	*pītum:*	*c*$^{\#}$*-b-a-g*$^{\#}$*-f*$^{\#}$*-e-d*$^{\#}$*-c*$^{\#}$*-b*
7	*embūbum:*	*c*$^{\#}$*-b-a*$^{\#}$*-g*$^{\#}$*-f*$^{\#}$*-e-d*$^{\#}$*-c*$^{\#}$*-b*
8	*kitmum":*	*c*$^{\#}$*-b-a*$^{\#}$*-g*$^{\#}$*-f*$^{\#}$*-e*$^{\#}$*-d*$^{\#}$*-c*$^{\#}$*-b*
9	*išartum":*	*c*$^{\#}$*-b*$^{\#}$*-a*$^{\#}$*-g*$^{\#}$*-f*$^{\#}$*-e*$^{\#}$*-d*$^{\#}$*-c*$^{\#}$*-b*$^{\#}$

Relaxation (part 2)

9	*išartum":*	*c*$^{\#}$*-b*$^{\#}$*-a*$^{\#}$*-g*$^{\#}$*-f*$^{\#}$*-e*$^{\#}$*-d*$^{\#}$*-c*$^{\#}$*-b*$^{\#}$
8	*kitmum":*	*c*$^{\#}$*-b-a*$^{\#}$*-g*$^{\#}$*-f*$^{\#}$*-e*$^{\#}$*-d*$^{\#}$*-c*$^{\#}$*-b*
7	*embūbum:*	*c*$^{\#}$*-b-a*$^{\#}$*-g*$^{\#}$*-f*$^{\#}$*-e-d*$^{\#}$*-c*$^{\#}$*-b*
6	*pītum:*	*c*$^{\#}$*-b-a-g*$^{\#}$*-f*$^{\#}$*-e-d*$^{\#}$*-c*$^{\#}$*-b*
5	*nīd qablim:*	*c*$^{\#}$*-b-a-g*$^{\#}$*-f*$^{\#}$*-e-d-c*$^{\#}$*-b*
4	*nīš tuḫrim:*	*c*$^{\#}$*-b-a-g-f*$^{\#}$*-e-d-c*$^{\#}$*-b*
3	*qablītum:*	*c-b-a-g-f*$^{\#}$*-e-d-c-b*
2	*išartum:*	*c-b-a-g-f-e-d-c-b*
1	*kitmum:*	*c-b*$^{\flat}$*-a-g-f-e-d-c-b*$^{\flat}$

It will be noted that these sets proceed in fifths: *c-g-d-a-e-b-f*$^{\#}$*-c*$^{\#}$*-g*$^{\#}$, therefore in the thetic disposition. However, the sets are here in the dynamic disposition (Fig. 15) and that therefore, the eighth set is not the repetition of the first one and the ninth is not the repetition of the second one, one octave higher.

Had the system been octavial, then the first and eighth sets would have been identical and so would have been the second and the ninth.

It is possible that the nine chants listed in the text would have been sung to the following scales:

sa 1 May *Aššur*, the king of the gods, improve your dominion for you.
c-b^{b}*-a-g-f-e-d-c-b*^{b} = *g-f-e-d-c-b-a-g-f* = *kitmum*

sa 2 May *Ištar*, who created mankind, grant you well-being and longevity.
c-b-a-g-f-e-d-c-b = *išartum*

sa 3 May *Daragal* make you rival the fierce weapon (s and) the raging storm.
c-b-a-g-f$^{\#}$*-e-d-c-b* = *f-e-d-c-b-a-g-f-e* = *qablītum*

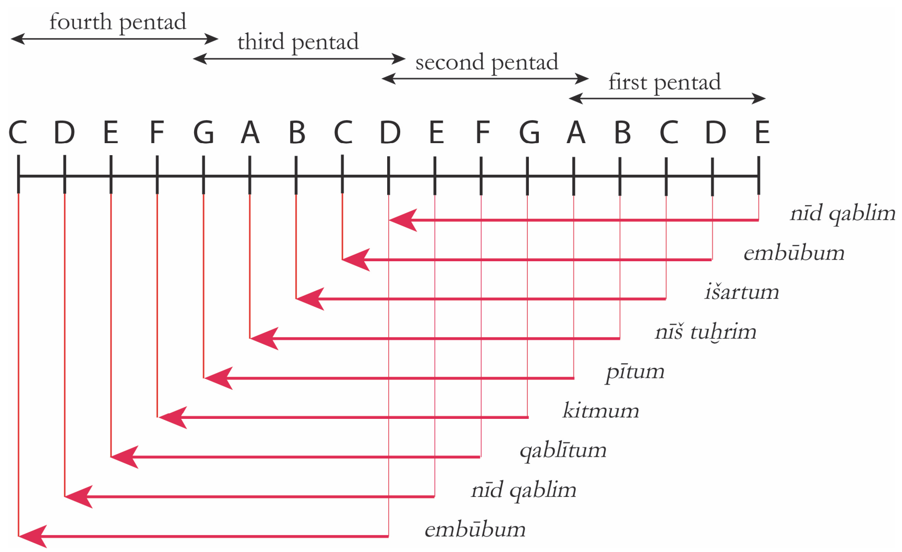


Fig. 15 Placement of the nine sets on the greater Babylonian System of 17 pitches in a dynamic disposition.

sa 4 *Enkidu*, treat kindly the Lady, the protective spirit who created good things, the *lamassu*.
c#-b-a-g-f#-e-d-c#-b = *b-a-g-f-e-d-c-b-a* = *nīš tuḫrim*

sa 5 May *Damkianna* make your appeal, your prayers, and the stroke of your nose always pleasing to the lord of lords. *c#-b-a-g#-f#-e-d-c#-b* = *e-d-c-b-a-g-f-e-d* = *nīd qablīm*

sa 6 May *Endašurimma* present your artful advice and your precious words daily.
c#-b-a-g#-f#-e-d#-c#-b = *a-g-f-e-d-c-b-a-g* = *pītum*

sa 7 May *Endukuga* always let your footstep fall on a prosperous road and a smooth path.
c#-b-a#-g#-f#-e-d#-c#-b = *d-c-b-a-g-f-e-d-c* = *embūbum*

sa 8 May *Enudtila* constantly establish abundance, plenty, and prosperity for the pastures of your people.
c#-b-a#-g#-f#-e#-d#-c#-b = *g-f-e-d-c-b-a-g-f* = *kitmum*

sa 9 May *Enmešarra* crush the forces of those who wrong you and of your enemies. May he scatter the weapons of your adversaries. *c#-b#-a#-g#-f#-e#-d#-c#-b#* = *c-b-a-g-f-e-d-c-b* = *išartum* + undefined quantity

Thus, it is possible that the nine sets were known, at some point during the late Neo-Babylonian period, no longer by their names but by their numbers. There is a parallel in the text which follows (CBS1766) where the names of sets are also substituted by numbers. This also applies, much later to Ecclesiastical Modes such as "mode of the first tone", "mode of the second tone",[66] etc., and no longer by their original Greek names.

V - CBS 1766:[67] Or first evidence of heptatonism

This unusual rectangular tablet dates from the late Neo-Babylonian period, early last half of the first millennium. It has the drawing of an irregular heptagram[68] etched within two concentric circles, at the top left corner, with annotations both lexical and numeral. Under the heptagram, there are eleven columns spreading onto the whole width of the tablet. Columns two and three have seven numbers each. Column four is empty. Columns five, six and seven are inscribed with only one line of numbers. A header spreads along the entire length of the columns but at present resists interpretation.

[66] The seven ecclesiastical modes: Mode of the first tone (Ionian) (mode of *c*) *c-d-e-f-g-a-b-c* = 1 1 ½ 1 1 1 ½. Mode of the second tone (Dorian) (mode of *d*) *d-e-f-g-a-b-c-d* = 1 ½ 1 1 1 ½ 1. Mode of the third tone (Phrygian) (mode of *e*) *e-f-g-a-b-c-d-e* = ½ 1 1 1 ½ 1 1. Mode of the fourth tone (Lydian) (mode of *f*) *f-g-a-b-c-d-e-f* = 1 1 1 ½ 1 1 ½. Mode of the fifth tone (Mixolydian) (mode of *g*) *g-a-b-c-d-e-f-g* = 1 1 ½ 1 1 ½ 1. Mode of the sixth tone (Eolian) (mode of *a*) *a-b-c-d-e-f-g-a* = 1 ½ 1 1 ½ 1 1. Mode of the seventh tone (Locrian) (mode of *b*) *b-c-d-e-f-g-a-b* = ½ 1 1 ½ 1 1 1.

[67] [Waerzeggers and Siebes, 2007].

[68] In general, a heptagram is any self-intersecting heptagon, a seven-sided polygon. It is the 7/3 heptagram which is depicted in CBS1766. This is the smallest star polygon which can be drawn in two forms, 7/2 and 7/3, as irreducible fractions.

The heptagram and the column two represented in Fig. 16 constitute the first evidence of a heptatonic construction, and therefore of conceptual, if not practical heptatonism. This is based on the names of seven strings inscribed on each point of the heptagram. The names of the strings are given in the same order as they were in *nabnītu* xxxii, without the two last strings (second behind and behind string).

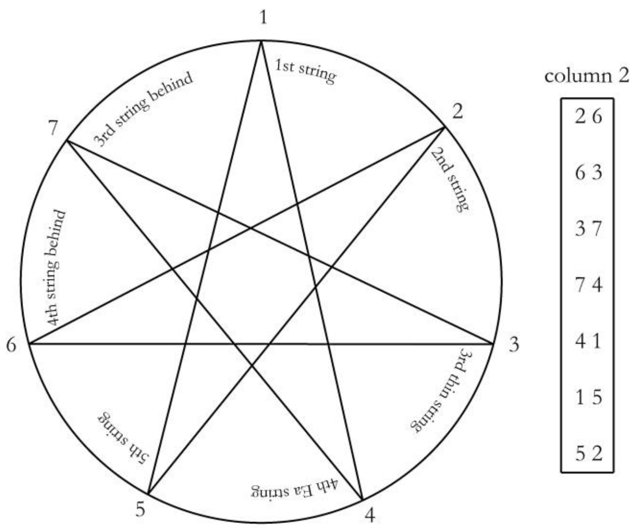


Fig. 16 CBS 1766, selective lexical and numeral translation.

Another significant matter is that the strings are also described with numbers from one to seven. The intersecting lines link the points of the heptagram in a pattern generated by the numbers in column 2: 2-6 = *b-e*; 6-3 = *e-a*; 3-7 = *a-d*; 7-4 = *d-g*; 4-1 = *g-c*; 1-5 = *c-f*; 5-2 = *f-b*. This heptatonic construction consists in the alternation of descending fifths and ascending fourths until the last ascending fourth reaches 5-2 = which should be *f-b*♭, a just fourth. However, the *b*♭ would be conflicting with the initial “natural”[69] “*b*”. Therefore, to suit the heptagram, the *b*♭ is made “natural” so that it equates to the initial “*b*”.

This system is radically different in its construction from all previous systems. It indicates, if not a change, but at least an addition to Babylonian theory. While the older system is of linear construction, CBS 1766 is of cyclical expression, two very different concepts. The names of the strings/pitches described in earlier texts are replaced by numbers from 1 to 7.

The system relies only on just fourths and fifths for its construction, and no longer on fifths, fourths and, or thirds. This was a remarkable innovation, typical of Babylonian scholarship that the Greeks would have adopted.

However, it could also be surmised that this innovation was originally Greek and adopted by Babylonian theory during the Orientalizing period, fertile in exchanges between both cultures, but this is highly conjectural as there is no reliable chronological (or other) evidence from the Greek side of the coin. Furthermore, there is no evidence of any heptatonic representation with circumscribed heptagrams in the history of Ancient Greek theory. This theory has always been linear, conceptually and transposed as a tangible monochord on which ratios of string-lengths were applied.

This *modus faciendi* will remain with Boethius, and later theoreticians. It is highly probable that Near-Eastern scholarship adopted the cyclical model which perdured into Islamic theory but was never adopted in the West until much later. Therefore, CBS 1766 might be Babylonian, or perhaps a Babylonian interpretation of a Greek linear model, a hypothesis which I would advance with little conviction.

The Near-East never wilfully adopted the octavial concept and remained attached to smaller intervals known as *ajnās* which agglutinated to one another forming scales. Later, probably with the indoctrination from the crusades, tetrads were added to pentads and triads. There would have been further influence from crusaders who remained in the Levant and probably Westernised local trends. There was further contamination during the French Mandate, in Syria and Lebanon where *Maqām* musicians and teachers were instilled with Western heptatonism.

The belief persists and has greatly contributed to the degeneration of Oriental intonation. But I would advance with conviction that the *Maqām* and other musical forms practiced in the Near-East are direct inheritors of the Babylonian models.

[69] I use the term “natural” reluctantly, as it conveys an impression of normality for the Western tense diatonic scale.

VI - H6: The "proof of the pudding"?

The Hurrian songs[70] are well documented.[71] Tablet H6 comes from a collection of about thirty which could be restored from three fragments: (RS13.30 + 15.49 + 17.387). The other texts were mostly broken in small fragments which could not be joined. They date from about 1400 BC and were excavated at the site of Ugarit, modern-day Ras-al-Shamrah in North West Syria. The tablets were written in the agglutinative Hurrian language. Fortuitously, musical terms were written in "Hurrianized" Babylonian making it reasonably easy to read. There were hitherto unknown terms the meaning of which remaining obscure. The writing runs parallel to the longest side. It is divided in three. The first part generally spreads onto the obverse. A double line with two winkelhaken[72] is drawn at about the middle of the tablet. Musical notation is written under the double lines.

The musical notation can be segmented in sets and numbers associated with them:

According to Kilmer, the colophon says: [*an-n*]*û za-am-ma-rum ša nid-qib-li za-l*[*u*]*-z*[*i ša* DINGIR.MEŠ TA m*Urḫiya*] ŠU m*Am-mu-ra-bi.* This roughly translates as: This is a song in the set of *nid qibli*, a *zaluzi* for the gods, composed by *Urḫiya* and written by the scribe *Am-mu-ra-bi.*

The Chicago Assyrian dictionary says that a *zamāru* is "a song with or without instrumental accom-paniment". However, I think that the word "song" is inappropriate because there are instances where the word is used for an *adapu*-instrument. Since an instrument does not sing, I prefer the use of the term melody: "a sung melody", or an "instrumental melody", to avoid confusions. For instance, there is a *za-ma-rum šá pít-ni* which the *CAD* translates as "to sing to the accompaniment of the *pitnu*-instrument". However, this could also translate as "a melody played on the *pitnu*-instrument". In most cases, it is the *ḫalḫallatu*-drum which is mentioned as accompaniment to the voice, but percussion is rhythmical rather than melodic. However, we have instances where *šušqqûssu ina sammî li-iz-za-mir-ma* translates as: "let her (Babylon's) exaltation be sung to the accompaniment of the harp". The only instruments of which we are certain that they accompanied the voice were the *ḫalḫallatu* and the *alû* which are drums; the *balaggu* and the *sammû* are string instruments. My view is that popular instruments such as the pastoral *inu*, a type of primitive lute, would have provided some basic accompaniment to a song. On the other hand, I would think that ritual singing, mostly, would have been "a cappella". The more solemn cultic chants would have had percussion accompaniment.

It took centuries for the Christian Church to adopt the organ. Plain-Chant should have remained unaccompanied because a well-tempered tuned instrument is anathema to ecclesiastic modality. The Babylonian clergy might have had similar views, although not for the same reasons, but it is usually for reasons of spirituality that religious singing mostly remains unaccompanied, in most cultures.

With regard H6, I believe the song did not have any instrumental accompaniment. Had there been, it would have been written down. They certainly could do so. Kilmer's hypothetical accompaniment has been forced-fitted as justification for her belief in simultaneous dyads. The notion of instrumental accompaniment is not a simple matter as it introduces the concept of "absolute" tuning in a world where tuning was "relative".

In the absence of a standard pitch, instrumental accompaniment would have been problematic unless one specific instrument accompanied one specific voice, exclusively. On the other hand, a street or a folk musician could have accompanied him- or herself should the tuning fit with their own "tonal" register, but this certainly would have been exceptional rather than habitual. This problem is of no concern to us, in the West, or at least since the seventeenth century AD, as equal temperament tuning allows for transposition which would certainly not have been possible at Ur or Babylon.

Additionally, the principle of accompaniment, thousands of years ago, was one which would have involved conceptual understandings for which there is certainly no evidence at that period.

Some of the terms and numbers in Fig. 17 are difficult to read and therefore, the number of beats in the

[70] I write "songs" in reaction to the sempiternal denomination of any ancient music as "hymn", with a religious connotation. The term "song" means that the melody can be either secular or religious.

[71] [Nougayrol, 1955], [Schaeffer, 1962], [Nougayrol et al., 1968].

[72] The Winkelhaken (from German "angular hook"), also simply called a hook, is one of five basic wedge elements appearing in the composition of signs in Akkadian cuneiform.

last column to the right reflect these problems. My experience, shouldered by logic, tells me that there must have been a regular infrastructure in this melody. It is written on six lines; it has six intervals per line.

I would confidently guess that the four lines at the centre (2, 3, 4 and 5) amount to thirty-six beats. Therefore, six times six intervals are thirty-six.

I can only but assume that the first and the sixth lines being introductive and conclusive would have twice thirty-six beats, therefore seventy-two beats. However, the rhythmical values of the sets are irregular. This is probably because music had to fit the text and not the contrary.

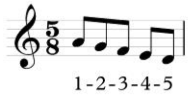
This suggests that a single melody, whether a song or a hymn, might have different sets of lyrics to accompany and that inevitable metrical variations of the lyrics would be echoed in the time signature for each segment.

The colophon in the text says that this song is in the set of *natqabli*, Babylonian *nīd qablim*, which is: *e-d-c-b-a-g-f-e-d*.

My methodology in this interpretation is as follows (Fig. 17):

- Each set is followed by a number.
- Each line has sets and subsets amounting to six.
- The numbers are rhythmical notation.The numbers following the intervals prolong the last beat.
- One number beat equals to two interval beats.
  This is the process:

The first cell of the first line is *qablite*. (*qablītu*).
qablite in the set of *nīd qablītu* equals five beats:



...*qablite* followed by 3 equals 5 + (6-1) = 10 beats (5 = beat in the interval. (6-1) 6 is double 3 and -1 is subtracting the last beat of the interval:

My interpretation of the song (Fig. 18) lends itself to analysis. This is a critical point as there is no music without structure.

Here, it is built on the A B C formula. There is an ***introduction*** at the first line (A), and a ***coda*** at the last (C).

The ***refrain*** of the song (B) is composed of four lines of six bars each with a total of 36(?) beats each amounting to six (irregular bars) amounting to a 36/8 time signature, per line split in six bars.

No	I	II	III	IV	V	VI	Beats
1	*qablite 3*	*irbute 1*	*qablite 3*	*šaḫri (?)1(?)*	*titimišarte 10*	*uštamari (?)*	70 (?)
2	*titimišarte 2*	*zirte 1*	*šaḫri 2 (?)*	*šaššate (?) 2*	*irbute 3 (?)*	*šaššate 2 (?)*	38 (?)
3	*umbube 1*	*šaššate 2*	*irbute 3(?)*	*natqabli (?) 1*	*titarqabli 1*	*titimišarte 2 (?)*	38 (?)
4	*zirte 1*	*šaḫri 2*	*šaššate 4*	*irbute 1*	*natqabli 1*	*šaḫri 2*	38 (?)
5	*šaššate 2(?)*	*šaḫri 1*	*šaššate 2*	*šaḫri 1*	*šaššate 2*	*irbute 4(?)*	38 (?)
6	*kitme 2*	*qablite 3*	*kitme 1*	*qablite 4*	*kitme 4 (?)*	*qablite (?) 4(?)*	60 (?)

Fig. 17 H6 notation reconstructed.

Fig. 18 Author's interpretation of Hurrian song of H6. Near-Eastern intonation according to advice from Damascus and implementation with the collaboration of Rosy Azar Beyhom and Amine Beyhom from Beirut. The first bar of the introduction is the fourth bar of the conclusion. It is the musical version of well-known catch-lines often used in Mesopotamian texts. Numbers after accidentals indicate: #1 = 1 comma sharper = 22.64 cents; #2 = 2 commas sharper = 45.28 cents; #3 = 3 commas sharper = 67.92 cents; #5 = 5 commas sharper = 113.2 cents; b1 = 1 comma flat = - 22.64 cents; b2 = 2 commas flat = - 45.28 cents; b3 = 3 comma flat = - 67.92 cents; b4 = 4 comma flat = - 90.57 cents.

The *coda* leads back to the *introduction* to repeat the whole song, as indicated on the tablet with a double winkelhaken on the double bar separating lyrics from music.

However, I am not suggesting that my interpretation is how the piece sounded in 1400 BC. The subsets which I have interpreted, in tense diatonic scale, would have been played with intonations similar to *Maqāmian ajnās*.[73] The Babylonian or Hurrian musicians were unable to write down particular intonations for each of their pentads and triads the inflexions of which being as refined as they were complex, and therefore impossible to notate. They still are. However, they were and are inscribed in the memory of the genetic unconscious. Therefore, they had different names. Their recalling, as conditioned reflexes, would immediately suggest how they sounded. Similarly, the accordion evokes Paris; the *ādhān* evokes Cairo; the shofar evokes Jerusalem; pipes evoke Edinburgh, etc. *Maqāmian ajnās*, like Babylonian pentads and triads, are called *ʿajam*, *jahārkā*, *mustaʿār*, *bayātī*, *būsalīk*, *ḥijāz*, *kurd*, etc., as Babylonian pentads and triads are called *išartum*, *qablītum*, *šaššate*, *isqu*, etc.

Coranic declamation uses *ajnās* but it must be reminded that these intonations are not specifically Islamic. They were shared by most if not all cultures in the Ancient-East, and continuously throughout history to our days. I am inclined to think that Babylonian music would not have been very different. Hebraic cantillation in Synagogues of Morocco, and Christian music

[73] A mixed score (Tonogram reproduction of the intonations in parallel with the score) accompanies this article (pdf version available at http://nemo-online.org/wp-content/uploads/2017/08/Hurrian-H6-intonation-120902-12-mixed-scoreS.pdf), together with a midi reproduction of the intended intonations (http://nemo-online.org/wp-content/uploads/2017/08/H6-intonated-Dumbrill-Beyhom-Azar-Beyhom.mp3) and an mp3 version of the recording from 2012 with Lara Jokhadar-Aro (http://nemo-online.org/wp-content/uploads/2017/08/H6-Lara-Jokhadar-121021-04-Dumbrill-Beyhom-Azar-Beyhom.mp3).

in the Levant, also share these intonations, certainly not as a conscious adoption, or association with Islamic declamation, but as the reminiscence of an unconscious knowledge.

In Damascus, during the 2011 Oriental Landscapes Conference, I submitted my interpretation of H6 to leading *Maqām* musicians at the Dar al-Assad Opera House. They hummed along my interpretation as it was played. After my presentation, they corrected the melody which I was playing electronically (in the tense diatonic scale), to its proper intonation, and suggested how to play it as it should. These musicians, after over 3000 years, recognized H6 as part of their heritage.[74]

This anecdote is certainly not an academic proof for the authenticity of my interpretation, but it is, certainly, as far as I am concerned, a proof much more significant than any other.

I have titivated the title of this last chapter with the addendum *"proof in the pudding"*. The reason is that my view of Babylonian theory, which clearly diverges from the established version, is consistent throughout, contrarily to Kilmer's. There are no points in this little work which are not fully tested, no more than there are points which do not fit in with the general description of the theory in all texts available to us. The intervals of pentads and triads are the most obvious origins for the *Maqāmian ajnās*, and suggest a continuous usage of Babylonian theory from its origins to our days. It is Babylonian music which shaped Early Greek music which in time slowly evolved away from its original model; it is Babylonian music, probably, which shaped some part of Byzantine music;[75] It is Babylonian music which gave the early Mediterranean world musicological tools with which it could, in turn, develop its own concepts.

Music theory was born in Mesopotamia, it was the earliest theory ever developed and is at the source of all other Mediterranean systems and perhaps others.

All music theories of the Ancient Western and Oriental Worlds carry the Babylonian gene and it is therefore not surprising that Plain-Chant modality is so close to it.

[74] A video of this text translated by the author with Oriental adaptation by Rosy Azar Beyhom and Amine Beyhom is available at https://www.youtube.com/watch?v=gynhfxQ1IO4. It must be noted that the singer because of her Western operatic training was unable to give an appropriate Oriental intonation to the piece.

[75] For a rational and comprehensive introspection into Byzantine Music, see [Beyhom, 2015].

Musicological Conclusions

Babylonian music rests on a series of descending pentads and ascending triads with infixes. Two conjunct triads make a pentad and two conjunct pentads make an ennead. The system is essentially descending enneadic, or preferably descending bi-pentadic. Triads, pentads and enneads make up the elements of music similarly to the *ajnās* of the *Maqām* form, of which they are likely to be the source. The sets are organised in systems of enneads, either conjunct when the last pitch of an ennead is the first pitch of the next one, or in organised pentadic conjunction where the last pentad of an ennead is the first pentad of the next one. This is the dynamic arrangement of the system. There is evidence that as early as the Old-Babylonian period the thetic system was also used. It allowed for all sets of a system being contained within a fundamental enneatonic set.

Numbers following pentads and triads indicate the time by which the last pitch of a set should be prolonged. There were other forms which might have been embryonic, and others complementing the system, such as pentatonism and heptatonism, respectively. The ambitus or span of the Greater Babylonian System could expand to 11, 13, 15 and 17 pitches, always arranged in symmetry from the central common pitch, or axis of symmetry. There were nine enneatonic sets as we know from a Neo-Babylonian text, and also from an Old Babylonian tablet which suggests seven enneatonic, but also possibly nine sets. It is probable as with *Maqāmian ajnās*, that infixes of pentads were played in any order to suit a composition. Infixes in pentads, while initially diatonic in construction, would have been modified to express mood as with *ajnās*, and like *ajnās*, their names would reflect these variations in intonation.

My exposition of Babylonian music theory radically differs from the established interpretation. However, it is so closely related to Oriental forms, such as the *Maqām*, that it is difficult to ignore this relationship. Ἀπόδοτε οὖν τὰ Καίσαρος Καίσαρι καὶ τὰ τοῦ Θεοῦ τῷ Θεῷ.[76]

[76] "Render unto Caesar" is the beginning of a phrase attributed to Jesus in the synoptic gospels, which reads in full, "Render unto Caesar the things that are Caesar's, and unto God the things that are God's" – [Matthew 22:21].

Ultimate Remarks

The following gems are lifted from Sach's *The Well-springs of Music*. In his *General History of the Science and Practice of Music*,[77] Sir John Hawkins wrote[78] that "the music of the Barbarians [Orientals] was said to be hideous". Although he studied Greek music he did not realize that the *chroai*, were Oriental. He scorned Oriental music not because it was hideous, but because it was said to be hideous. As for his chapters on the Greeks and the Hebrews, on the contrary, there was no danger of unfavourable reports: conceivably, there were no ear-witnesses.

The two sections of the book were easily filled with learned quotations from literary sources well-known to all the erudite contemporaries. The music itself was absent, to be sure; but being Biblical or Greek, it must have been perfect by definition.

In K.C.F. Krause's unremarkable *Darstellungen aus der Geschichte der Musik*,[79] we read with astonishment that

> "'in Antiquity, which was the childhood of music (!), only simple unadorned melody was known, as is the case today with such peoples as the Hindus, Chinese, Persians, and Arabs, who have not yet progressed beyond the childhood age' (!). This is true Hegelian progressivism: how far have we come in our mature age (or is it senility, if not worse?) (!). Not to mention the profound ignorance behind the notions of Hindus, Persians, and Arabs singing in 'simple unadorned melody' – they who are unrivalled masters in the art of highly adorned singing, and leave simplicity to the lower forms of children's songs – and to the West",[80]

while

> "The reader who reaches for the monumental *Geschichte der Musik* by August Wilhelm Ambros[81] finds a whole *Buch* on the *Kulturvölker des Orients*, indeed on the Primitives. But on these pages, he also finds the most bewildering *pronunciamientos* such as: 'Assyrian music seems never to have risen above the level of a mere sensual stimulus', or: the music of Babylon 'was quite certainly voluptuous, noisy, and far from simple beauty and noble form'; and Phoenician music was mainly meant to drown 'the cries of the victims who burned in the glowing arms of Moloch'".[82]

More recently, Stefan Hagel, in his "Is *nīd qabli* Dorian? – Tuning and modality in Greek and Hurrian music",[83] says:

> "A comparison with Ancient Greek music suggests a largely independent development of musical form at least as early as the first half of the second millennium on".[84]

How could Greeks having borrowed mathematics, astrology, medicine, mythology, religion, divination, literature, law, etc., from the Orient, would have, by some extraordinary phenomenon, forgot all about Babylonian music on their way home?

Further:

> "It is significant that this system was not orientated towards melody, as was Ancient Greek notation and music theory, but to instrumental practice".

What an amazing statement!

Later:

> "For that reason it [the Babylonian system] will survive for a considerable period of time only in a mainly traditional if not backward-orientated musical culture. But in Greek music history the melodic possibilities had soon become too rich to be contained within such a reduced harmonic framework".

What an extraordinary feat of Hellenic supremacism well in keeping with Krause and Ambros. *Plus ça change, plus c'est la même chose.*

[77] [Hawkins, 1776].

[78] For this paragraph: [Sachs, 1962, p. 6].

[79] [Krause, 1827].

[80] Quote and commentary from [Sachs, 1962, p. 7].

[81] [Ambros, 1862].

[82] [Sachs, 1962, p. 7–8].

[83] [Hagel, 2005]: the title is already biased as should it not be: "Is Dorian *nīd qabli*" rather than the contrary?

[84] For this quote and the following: [Hagel, 2005], Abstract, [p. 287].

References

1. AMBROS, August Wilhelm : *Geschichte der Musik 1/*, F.E.C. Leuckart |1862|.
2. Anon. "Gaspard de Prony", *Wikipedia* |2016-10-23| [url: https://en.wikipedia.org/w/index.php?title=Gaspard_de_Prony&oldid=745774476].
3. Anon. "Overtone singing", *Wikipedia* |2017-3-30| [url: https://en.wikipedia.org/w/index.php?title=Overtone_singing&oldid=772916752].
4. BEYHOM, Amine : *Systématique modale – En 3 volumes*, PhD Thesis, Université Paris Sorbonne |2003-9-17| [url: http://www.sudoc.fr/075767538, http://foredofico.org/CERMAA/publications/publications-on-the-site/publications-amine-beyhom].
5. BEYHOM, Amine : "A new hypothesis on the elaboration of heptatonic scales and their origins", *ICONEA 2008*, Lulu on behalf of ICONEA PUBLICATIONS, LONDON-UK |London, 2010a| [url: http://foredofico.org/CERMAA/publications/publications-on-the-site/publications-amine-beyhom] p. 151–209.
6. BEYHOM, Amine : *Théories de l'échelle et pratiques mélodiques chez les Arabes – Volume 1 : L'échelle générale et les genres – Tome 1 : Théories gréco-arabes de Kindī (IX^e^ siècle) à Ṭūsī (XIII^e^ siècle) 1/4* (vols.), Librairie orientaliste Paul Geuthner |Paris, 2010b-11|.
7. BEYHOM, Amine : "Un lexique de la modalité", *Near Eastern Musicology Online 2 2* |2013-11| [url: http://nemo-online.org/articles] p. 5–24.
8. BEYHOM, Amine : *Théories et pratiques de l'échelle dans le chant byzantin arabe : Une approche comparative et analytique proposant une solution inédite pour le système théorique de Chrysanthos le Madyte*, Par l'auteur |Broummana (Liban), 2015-9|.
9. BEYHOM, Amine : "A Hypothesis for the Elaboration of Heptatonic Scales", *Near Eastern Musicology Online 4 6* |2017-11| [url: http://nemo-online.org/articles] p. 5–90.
10. CORNFORD, Francis Macdonald : *Plato's Cosmology: The Timaeus of Plato*, Hackett |London, 1997|.
11. CRICKMORE, Leon : "Harmonic Mythology", *Arane I* |2009| p. 53–68.
12. DAC, Pierre : *Les pensées*, Le cherche midi |1981|. (See also http://dicocitations.lemonde.fr/citations/citation-29012.php)
13. DUCHESNE-GUILLEMIN, M. : "Découverte d'une gamme babylonienne", *Revue de Musicologie 49 126* |1963-7-1| [doi: 10.2307/927207. url: http://www.jstor.org/stable/927207] p. 3–17.
14. ELLIS, Alexander John : "On the Sensitiveness of the Ear to Pitch and Change of Pitch in Music", *Proceedings of the Musical Association 3* |1876-1-1| [url: http://www.jstor.org/stable/765234] p. 1–32.
15. FIELD, Hartry : "Epistemological Nonfactualism and the a Prioricity of Logic", *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition 92 1–2* |1998-10-1| [doi: 10.1023/A:1017147216094. url: https://link.springer.com/article/10.1023/A:1017147216094] p. 1–24.
16. FOWLER, David and Eleanor ROBSON : "Square Root Approximations in Old Babylonian Mathematics: YBC 7289 in Context", *Historia Mathematica 25 4* |1998-11-1| [doi: 10.1006/hmat.1998.2209. url: http://www.sciencedirect.com/science/article/pii/S0315086098922091] p. 366–378.
17. GURNEY, Oliver Robert : "An Old Babylonian Treatise on the Tuning of the Harp", *Iraq 30 2* |1968| [doi: 10.2307/4199853] p. 229–233.
18. GURNEY, Oliver Robert : *Middle Babylonian Legal Documents and other Texts, Publications of the joint expedition of the British Museum and of the University Museum of the University of Pennsylvania, to Mesopotamia VII (1973)/*, British Museum Publications |London, 1974|.
19. GURNEY, Oliver Robert : "Babylonian Music Again", *Iraq 56* |1994| [doi: 10.2307/4200387] p. 101–106.
20. HAGEL, Stefan : "Is *nīd qabli* Dorian? Tuning and Modality in Greek and Hurrian Music", *BaM 36* |2005| p. 287–348.
21. HAWKINS, John : *A General History of the Science and Practice of Music*, Payne and Son |1776|.
22. HILPRECHT, Hermann Volrath : *Mathematical Metrological and Chronological Tablets from the Temple Library of Nippur*, Department of Archaeology, University of Pennsylvania |Philadelphia, 1906|.
23. KILMER, Anne Draffkorn : "Two New Lists for Mathematical Operations", *Orientalia 29* |1960| p. 273–308 & Tab. LXXXIII.
24. KILMER, Anne Draffkorn : "The Strings of Musical Instruments: Their Names, Numbers, and Significance", *Studies in honor of Benno Landsberger on his seventy-fifth birthday, April 21, 1965*, ed. University of Chicago - Oriental Institute and Benno LANDSBERGER, *Assyriological studies* 16, University of Chicago Press |Chicago, 1965|.
25. KILMER, Anne Draffkorn : "The Discovery of an Ancient Mesopotamian Theory of Music", *PAPS (Proceedings of the American Philological Society) 115 2* |1971| p. 131–149.
26. KILMER, Anne and Sam MIRELMAN : "Mesopotamia", *Grove Music Online* |2001|.
27. KRAUSE, Karl Christian Friedrich : *Darstellungen aus der Geschichte der Musik: nebst vorbereitenden Lehren aus der Theorie der Musik*, Zentralantiquariat d. DDR |1827|.
28. LACAN, Jacques : *Le Séminaire. Encore*, Seuil |Paris, 1975-1-1|. (See also the audio file http://www.valas.fr/IMG/mp3/lacan-encore-20-mars-1973.mp3)
29. LACAN, Jacques : *The Seminar of Jacques Lacan: On Feminine Sexuality, the Limits of Love and Knowledge (Encore) 20/*, Norton &Company |New York, 1999|.
30. LLOYD, Llewelyn S. and Achille FOULD : "International Standard Musical Pitch", *Journal of the Royal Society of Arts 98 4810* |1949| [url: http://www.jstor.org/stable/41364475] p. 74–89.
31. MIRELMAN, Sam : "Tuning Procedures in Ancient Iraq", *Analytical Approaches to World Music 2 2* |2013| [url: http://www.aawmjournal.com/articles/2013b/Mirelman_AAWM_Vol_2_2.pdf] p. 43–56.
32. NOUGAYROL, Jean : "Le Palais Royal d'Ugarit III et Planches", *Mission de Ras Shamra, Tome VI, LE PALAIS ROYAL D'UGARIT III Textes accadiens et hourrites des archives est, ouest et centrales*, ed. Claude Schaeffer |Paris, 1955|.
33. NOUGAYROL, Jean, Claude Frédéric Armand SCHAEFFER, Emmanuel LAROCHE and Charles VIROLLEAUD : *Ugaritica. V: nouveaux textes accadiens, hourrites et ugaritiques des archives et bibliothèques privées d'Ugarit, commentaires des textes historiques (première partie)*, Impr. nationale |1968|.
34. PAYNE, E. : "A New Addition To The Musical Corpus", *Opening the Tablet Box, Near Eastern Studies in Honor of Benjamin R. Foster, Culture and History of the Ancient Near East*, Brill |Leiden, Boston, 2010| [url: http://booksandjournals.brillonline.com/] p. 291–300.

35. PLATO and James ADAM : *The Republic 2/2* (vols.), Cambridge : University Press |1909| [url: http://archive.org/details/republicplat02plat].
36. PLATO and R. WATERFIELD : *Republic*, OUP Oxford |1993|.
37. ROTH, Martha T. : "Oriental Institute | The Assyrian Dictionary of the Oriental Institute of the University of Chicago (CAD)" |2012| [url: http://oi.uchicago.edu/research/pubs/catalog/cad/].
38. SACHS, Curt : *The wellsprings of music*, Martinus Nijhoff |The Hague, 1962|.
39. SCHAEFFER, Claude, ed. : *Nougayrol, Jean, Laroche Emmanuel, Virolleaud, Charles, Schaeffer, Claude, F.A., in Mission de Ras Shamra, Schaeffer, Claude, F.A., Membre de l'Institut, ed. Tome XVI, UGARITICA V, Nouveaux textes accadiens, houssites, et ugaritiques des archives et bibliotheques privees d'ugarit commentaires des textes historiques (Premiere partie) avec la collaboration de Herdner, Andree, Yoyotte, Jean, Aynard, Jean-Marie, Courtois, Leon Chalon-Shaeffer, Isidore de, Szycer, Maurice et de Courtois, Jean-Claude, Secretaire General de l'Edition. Paris, Imprimerie Narionale, Librarie Orientaliste Paul Geuthner, 1868*, *UGARITICA* VI *XV/*, Librairie Orientaliste Paul Geuthner |Paris, 1962|.
40. VITALE, Raoul : "La musique suméro-accadienne, gamme et notation musicale", *Ugarit-Forschungen 9* |1982| p. 241–263.
41. WAERZEGGERS, Caroline and Ronny SIEBES : "An Alternative Interpretation of the Seven-Pointed Star on CBS 1766, NABU 2007/40", *NABU 40 2* |2007-6| [url: https://www.academia.edu/1045063/C._Waerzeggers_and_R._Siebes_An_Alternative_Interpretation_of_the_Seven-Pointed_Star_on_CBS_1766_NABU_2007_40] p. 43–45.
42. WEST, M. L. : *Ancient Greek Music*, Clarendon Press |1992-10-1|.
43. WEST, Martin Litchfield : *Ancient Greek music*, Oxford University Press |1994|.
44. WULSTAN, David : "The Earliest Musical Notation", *Music & Letters 52 4* |1971-10-1| [url: http://www.jstor.org/stable/734711] p. 365–382.
45. YOUNG, Robert W. : "Why an international standard tuning frequency", *The Journal of the Acoustical Society of America 27 2* |1955| [url: http://scitation.aip.org/content/asa/journal/jasa/27/2/10.1121/1.1907908?crawler=true] p. 379–380.

A preliminary approach to the analysis of honkyoku*, the solo repertoire of the Japanese* shakuhachi

Bruno Deschênes[*]

Introduction

Up until the opening of its borders at the end of the Edo period (1603-1868), the Japanese had not developed any clear means for analytical art discourse. The majority of Japanese arts were influenced by Zen Buddhism, which asserts that the intellectual and analytical mind should not be "trusted". Consequently, artists were not prompted to develop an analytical understanding of their art. With traditional artists, the same remains true today.

One of the aims of the Meiji (1868-1912) government in Japan at the end of the 19th century was to bring Japan up to an equal footing with the West. This specifically involved sending groups of intellectuals, politicians, etc., to study abroad, and inviting Western scholars to come to Japan. The former were to learn, and the latter were to teach Western theoretical, philosophical and political principles, among other things. Japanese scholars and students had to deal with new fields of study as well as with unfamiliar ways of understanding the world. Several European concepts were not known in Japan at the time; words and expressions had to be created and adapted to the Japanese way of thinking.[1] As for music, Japanese musicologists relied on European analytical methodology to make sense of their music, which traditional musicians did not feel the need to theorize.

Since the end of the 19th century, and even more so after WWII, a number of books and articles have been published concerning the theoretical background of traditional Japanese music. Two main theories have been put forward: the first is that their music is based on modes, the second that it is based on motivic patterns of three notes within the interval of a fourth, *i.e.*, a triad(4). The debate over the best framework for understanding traditional Japanese music continues through the present. As a non-Japanese *shakuhachi*[2] player, I am neither a musicologist nor an ethnomusicologist. I am more of a musician deeply involved in performance and aesthetic study of *shakuhachi* (尺八) music.

The *shakuhachi* is an upright bamboo flute whose playing was restricted to monks belonging to a Zen Buddhist sect during the Edo period. Even without any clearly defined theoretical framework, musicians over the centuries have been able to compose music that follows basic rules from which modern musicologists have been able to extrapolate these two theoretical viewpoints.

In this paper, I submit my personal understanding of these theories as a musician, and seek a means of applying them to the solo pieces of *honkyoku* (本曲, lit. original piece), the name given to classical repertoires of *shakuhachi* music. To accomplish this, I begin by succinctly presenting the conclusions of six authors (four Japanese and two non-Japanese) who have studied and analyzed traditional Japanese music. Although the four Japanese authors do not analyze *honkyoku* as such, they do provide important clues on the melodic structure of the music. The second section gives an overview of the

[*] Bruno Deschênes is a trained *shakuhachi* player. He received his *shihan* (師範), master title, in August of 2016, alongside with an artist name, *Chikushin*. As an ethnomusicologist, his two main fields of study are the aesthetic of traditional Japanese music, and the phenomenon of transmusicality, the musicians who become performer of a music from a culture of which they are not native. He recently published the first book in French dedicated to the *shakuhachi*: "*Le* shakuhachi *japonais, Une tradition réinventée*" (*The Japanese* shakuhachi*, A Reinvented Tradition*) [Deschênes, 2017]. His two most recent articles on the subject of transmusicality are [Deschênes, 2007 ; 2011].

[1] For a good example of this problematic of European aesthetic concepts, see [Marra, 2001, p. 1–22 ("Introduction")]. In most instances, these newly created terms were not translated directly from the European concepts, but adapted them to the Japanese way of thinking. These Japanese terms have usually a meaning wider than their European counterparts do.

[2] More generally on *shakuhachi*, see [Berger and Hughes, 2001 ; Keister, 2004b].

traits that distinguish the melodic structure of *honkyoku* pieces from other forms of Japanese music. I next provide an analysis of pieces from two distinct *honkyoku* repertoires: first, a piece written in the traditional style at the beginning of the 20th century by *shakuhachi* master Jin Nyōdo (1892-1965), and second, a well-known traditional piece in its modern version, adapted by Katsuya Yokayama (1934-2010). In order to propose another model for understanding this unique music, I expand on the six aforementioned authors' proposals. In the final section, I show that some of these six authors' conclusions do apply to *honkyoku* music, while others do not. I show that, although the authors present a relevant understanding of the melodic structure of *honkyoku*, there is more to it than they suggest, specifically highlighting two important aspects of this music that they miss.

In this article, I put forth not a typical methodological analysis of this music, but an understanding of it from the perspective of the musician and performer rather than the musicologist or ethnomusicologist. For example, an article entitled "*Shakuhachi Honkyoku*: Motivic Analysis of *Sokaku Reibo*"[3] was recently published by clarinetist and musicologist Amy Simon on the AAWM Journal on-line. Her analysis is basically about pitch and rhythm cells. She provides a methodological sound analysis of the piece from a typically Western musicological standpoint. Although she refers to the work of two of the Japanese musicologists and of two non-Japanese ones I will be presenting below, her analysis does not take into consideration the fact that traditional music, and more so *honkyoku* music, is not based on the notions of pitch and rhythm current in musicology, as I will try to show in this paper, but more on tone-colors and variation in them. In this article, I opted to follow the approaches of Japanese musicologists.

Finally, what I am proposing below cannot be applied to all repertoires of *shakuhachi honkyoku* pieces. Still, I hope it sets forth a preliminary framework for understanding how the music was composed.[4]

Theoretical Background

Although the pieces of *honkyoku*[5] solo repertoires for *shakuhachi* can be considered as having melodies, they do not have melodic lines as defined in Western music, *i.e.*, a pleasing succession of musical tones. The rhythmic structure of most of these pieces is not measured, although some may have a pulse that is played without clear respect to rhythm. According to Swiss *shakuhachi* player Andreas B. Gutzwiller, the pieces of the *honkyoku* repertoire were originally composed based not on theoretical concepts or abstract rules, but on playing rules.[6] The monks of the Fuke sect who composed them considered their flute a *hōki* (法器), a spiritual tool to reach enlightenment, rather than a *gakki* (楽器), a musical instrument, a fact that influenced how the pieces were composed. The central figure in Japanese music is not the composer or the theoretician but the player.[7] Moreover, as Allison McQueen Tokita indicates, very few genres of music in Japan have any basic theoretical discourse, the main being *gagaku* (雅楽, Japanese court music); the majority do not. She indicates that although the modal terminology of that particular music was applied to other genres, it did not really give insight about them. Consequently, over the centuries, no relevant theories have been developed that would give us today an historical understanding of the theoretical evolution of traditional Japanese music. As mentioned earlier, it is at the end of the 19th century, with influence of Western scholarship, that we see an analytical outlook on Japanese music begin to develop. However, Japanese musicologists have mainly been using Western terms, without thoroughly pondering if and how they apply to their

[3] [Simon, 2017].

[4] Most composers writing for the *shakuhachi* today show a clear influence of Western music in their style. Using Western notation software, they transcribe afterward their pieces mainly into the notation system of the Tozan School, a notation that has been influenced by Western notation.

[5] Today, the term *honkyoku* refers to all styles of solo pieces for the *shakuhachi*, including the modern ones composed in the spirit of the original repertoire. Since 1970, the expression *koten honkyoku* (古典本曲, classical *honkyoku*) is used to refer to the traditional pieces from the Edo period.

[6] Gutzwiller uses the term "performing" rules, instead of "playing". Because these monks were not giving concerts or performances of any kind during the Edo period, his use of "performing" is misleading – see [Gutzwiller, 1974, p. 86–89].

[7] This applies as well to the *kabuki* theater, for example, in which the actor is the central figure. For a long time, the author of a play was not even advertised, only the actors were.

traditional music. For example, they have not been consistent in their use of terms such as scale (*onkai*, 音階) or mode (*senpō*, 旋法).

Most of these researchers have been using them interchangeably as if they are the same, though scale appears to be the preferred term. As Tokita suggests, the reason is that a mode is not conceived of as a tonal system within which scales can be defined, as in European music or other music such as the music of the Arabic or Persian worlds.[8] For example, the view of the two known Japanese musicologists I review below appears to be that modes are more of a grouping of notes from which a pattern or motive can be created, rather than a scale with a differentiated internal structure (*i.e.*, a modal scale as defined by Amine Beyhom).[9] The most important characteristic of Japanese modes is not the internal structure of the tones but the intervallic relationship between them, as we will see below.

Stemming from the above understanding of a mode as a grouping of notes from which patterns or motives are created, Japanese traditional music does not appear to be based on tones, notes or pitches, but on tone-colors and their relationships. In fact, the authors I cite here do not clearly define what they mean when they use the terms "tone" and "note". I am somehow forced to propose a definition that might be unsatisfactory for musicologists. As I suggest in the final section, Japanese music is based on tone-colors. Tones in a melody are not tones as we currently define them in the field of musicology – as a steady periodic sound considered with reference to its duration, pitch, intensity, tone-color, source, etc., for example. By analogy, the concept of a musical tone follows the Buddhist notion of dependent origination, *i.e.* that just as the flame on a candle cannot exist without the wick and wax, things in themselves are devoid of their own, independent existence, existing only in relation to one another. Likewise, a musical tone is understood not as having its own, independent (objective) existence, but in relationship to other tones. More precisely, it is understood in terms of its intervallic relation to another tone. A tone is musical because of the presence of other tones. But more specifically, under the influence of Zen Buddhism with its distrust of the analytical mind, modes and tones in Japanese music should not viewed as concepts but as percepts. This is, in all probability, one of the primary reasons why Japanese musicians have not developed a theoretical discourse, as Tokita indicates.

A major figure in the study of traditional Japanese music is Uehara Rokushirō (1848-1913), who was also a *shakuhachi* player known as Uehara Kyodō. He studied the music of the Edo period, which he called urban music, *miyako bushi* (都節, song of the urbanite), distinguishing it from country or folk music, *min'yō* (民謡, folksong), which he did not study. He was influenced by the Western distinction between minor and major mode, considering that urban music was using the *in* (陰) scale (or *miyakobushi* 都節), and folk music outside of urban centers used the *yō* (陽) scale (or *ritsu* 律) (Fig. 1). According to Gutzwiller, Uehara's usage of the terms *in* and *yō* is also based on a tradition that relates phenomena in opposing principles, largely influenced by the Chinese principle of *yin* and *yang*, terms which are translated as *in* and *yō* in Japanese.[10] Uehara considered Japanese music to be based on modes that are built on what he calls two conjoint "tetrachords," or triad(4)[11]. The main particularity of these two modes is that the upper triad(4) differs between its ascending and its descending forms, something which is of course not unique to Japanese music. For Uehara, these modes are structured not around a tonic but around two nuclear notes, the interval of which form a tetrachord, *i.e.* an interval of fourth. The single intermediary note within this triad(4) does not have a fixed tone, for this reason it cannot be defined with a clearly structured scale or mode.

[8] See [Alison McQueen Tokita, 1996, p. 1–3].

[9] See [Beyhom, 2013].

[10] See [Gutzwiller, 1974, p. 42].

[11] Uehara is the first musicologist to use this term to designate a trichord or a triad on the fourth (triad(4)). Other Japanese musicologists, following Uehara, have been also using "tetrachord". This is an example of the use of a non-Japanese term employed without validating it with respect to European terminology. While triad(4) refers to the number of pitches, this use of the term "tetrachord" pertains to the interval of a fourth that is constant, while the pitch of the intermediary note within it is movable. A musician might not always play exactly in tune as specified by a triad(4); that is, for the intermediary note, a half-tone can be played as a full tone without any contradiction. To be in line with the current musicological European terminology, I use triad(4). I still have to use the Japanese terms on some occasions since it is used by the four Japanese authors I refer to.

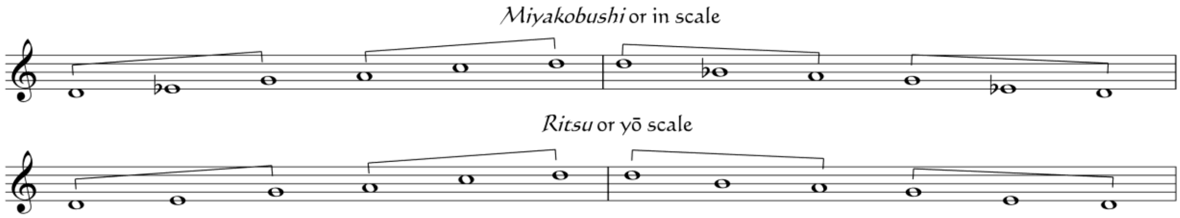


Fig. 1 The *ritsu* scale is recognizable by the presence of tones, while the *miyakobushi* uses half-tones. Each scale is made of a "tetrachord repeated" twice, a tone apart.

The most important figure in the study of traditional Japanese music is Koizumi Fumio (1927-1983). According to Tokita, Koizumi was analyzing music more from an ethnomusicological, emic perspective rather than a musicological one; his theory came to supplant Uehara's. Yet, following up on Uehara's footsteps, he also viewed Japanese music as being constructed on "tetrachords," *i.e.*, triad(4). According to him, traditional Japanese music is based on four triad(4) that form four different scales which are not based on the octave or forming a tonal center (Fig. 2). The notes are defined relatively to what he calls *kakuon* (核音, nuclear notes),[12] each triad(4) containing two nuclear notes, which give 4 *kakuon* of equal importance within each mode. For Koizumi, the nuclear notes form a stable framework of pitches upon which melodies and phrases can be composed.[13]

Among the articles and books analyzing some aspects of the traditional Japanese music by Western ethnomusicologists, only a few are dedicated to the *honkyoku* repertoire for *shakuhachi*. There is an article by Elliott Weisgarber[14] who has studied *shakuhachi* in Japan. He suggests that the pieces of the *honkyoku* repertoire have been composed based on melodic patterns and cells. His article presents a pattern analysis of three pieces. Without making any references to Uehara's work, he suggests that what distinguishes the music of the *shakuhachi* is the *in/miyakobushi* scale and its half-tones, but he does not analyze the melodic structure of these cells. He also uses terms such as "leading tonic" and "dominant tones," terms used in Western music which cannot be applied directly to Japanese music. Although this point might suggest a possible link with the notion of *kakuon*, Weisgarber does not say anything about Koizumi's work. His reference to a series of predefined common patterns or cells from which these pieces are composed is valid. For example, the main songs in *kabuki* (歌舞伎) theater, called *nagauta* (長唄, long song), or in *shōmyō* (声明, Buddhist chant) chanting, are composed in such a manner. The dance movements of *nihon buyō* (日本舞踊) are similarly based on formulaic patterns.[15] Weisgarber is one of the rare to suggest that the melodies of *honkyoku* music are formulaic.

The melodies of the *honkyoku* pieces have not been composed as melodic lines per se, as in *min'yo music*, for example. They sound, at times, more like a "patchwork" of predefined motives and patterns than a melody *per se*. In particular, obligatory breathing marks fragment the flow of the melody into well-defined and clear-cut phrases, so the player can take his or her breath, the length of which is not rhythmically determined. However, Weisgarber did not develop his theory well enough to give a relevant understanding of how these motives are melodically structured internally and in relation to each other.

[12] Even the translation of *kakuon* as "nuclear note" is misleading since it refers not to pitch but to sound, *on* meaning sound or noise.
[13] One reviewer suggested that the term "phrases" can be problematical in the context of the unpitched melodies found in *shakuhachi* music. As will be shown in the analysis of the two pieces below, the pieces of the *honkyoku* repertoire are based on phrases clearly delineated by breath marks.
[14] See [Weisgarber, 1968].
[15] For *nagauta*, see [Alison McQueen Tokita, 1996 ; Keister, 2004a ; Tokumaru, 2000]. For *shōmyō*, see [Alison McQueen Tokita, 1996]. For *nihon buyō*, see [Hahn, 2007].

Fig. 2 Each scale is formed by combining the same triad(4) twice, a tone apart. Whole notes indicate the *kakuon*. (See [Koizumi, 1977, p. 76])

In his 1974 Ph.D. thesis, *shakuhachi* player Andreas B. Gutzwiller discusses the question of the breathing marks that delineate the phrases of *honkyoku* pieces. According to him, these phrases form indivisible and clearly defined musical units. The player must take a breath at each of these marks, playing each phrase within a single breath. However, he does not say anything about the possible formulaic character of the music. He pays closer attention to the melodic structure of these phrases that are based, according to him, on a central note around which gravitates what he calls “moving notes” that are not tonally or modally defined, and are thus constantly fluctuating. However, he does not make any reference to Koizumi’s theory of “tetrachords” and *kakuon*, or that there could be more than one central note in a phrase, although he did study with this musicologist.[16]

Two Japanese researchers who have recently been debating the issue of modes *vs.* “tetrachords,” in French, are composer and historian Akira Tamba[17] and musicologist Yosihiko Tokumaru.[18] Tamba’s work is in line with Uehara’s views, and the bulk of his analyses are on modes, although he says just few words about him. As well, he mentions Koizumi’s name on two occasions without presenting his work, though he states that Japanese music is based on the “tetrachord”. In his book, Tamba presents first the theory of Chinese music (chapters 1 & 2),[19] and the extent of its influence on Japanese music.[20] According to him, *gagaku* music from China brought the notion of modes and fixed pitch to Japan. However, sometime between the 10th and the 13th centuries, Japanese musicians started to show a strong preference for one particular mode, the *in* mode, using it in particular in *biwa* music (琵琶, the Japanese lute), *nō* (能) theater, *shōmyō* Buddhist chanting, and *kagura* (神楽) *shintō* singing and ceremonial dancing. The use of modes as a fixed pitch scale did not have much influence on the music of the commoners. Before the advent of *gagaku* in the 8th century, Japanese music was already based on the triad(4), though they were conjoined (as the example shows in Fig. 3). It would only be around the 13th century that disjoint triad(4) would be brought together to form octavial scales, as Uehara and Koizumi are suggesting (see Fig. 1 and Fig. 2). Tamba even suggests that although a melody could be based on a mode, when a transposition occurs, it is based on the triad(4). Although a melody appears to be related to a fixed pitch mode, because of the importance of the triad(4), the “weight” of the triad(4) is stronger, thus attenuating the role of the mode in that melody.[21]

Fig. 3 Example of conjoint triad(4), in Tamba’s analysis of a *nō* theater song titled *Kagekiyo*.[22]

Yosihiko Tokumaru is a clear advocate of Koizumi’s “tetrachordal” theory. He analyzes the melodic structure of *shamisen* (三味線) music, particularly *nagauta* songs, beginning his analyses with Koizumi’s theory. We

[16] [Gutzwiller, 1974, p. 98–126].

[17] See [Tamba, 1988].

[18] See [Tokumaru, 2000].

[19] Interestingly, chapter 3 is dedicated to Greek music in regards to Chinese and Japanese music.

[20] Tamba mentions that Chinese mathematicians calculated the tempered scale around 1596, while it was calculated in Europe in 1692 {see also [Beyhom, 2016]: “Equal temperament was already mathematically established by Chu Tsai-yü in 1584 in China, and for the first time in Western musical theory by Flemish mathematician Simon Stevin roughly (and, most probably, independently though inaccurately […]) at the same time; the latter’s division of the octave remained however unpublished (and unknown) until 1884”}. The Chinese found that scale musically unpleasant (see [Tamba, 1988, p. 60–63]). In Japan it was also calculated in 1692 (see [Tamba, 1988, p. 90–94]).

[21] For example, in an analysis of the well-known classical piece *Rokudan no shirabe* (composed sometimes in the 18th century), Tamba shows that, although this piece is based on the *in* mode, the transpositions of its melodic patterns are based on the first or last note of the main triad(4), not the mode as such. See [Tamba, 1988, p. 167].

[22] See [Tamba, 1988, p. 143–144].

learn that the tuning of the *shamisen* is based on the *in* mode. Interestingly, however, he indicates that *shamisen* players believe these melodies to be based neither on that mode nor on the triad(4). According to him and to Tokita,[23] the melodies of these songs are based on predefined patterns that are ordered and reordered for the needs of the song being created, thus lending credit to Weisgarber's suggestion that it might be the same with *honkyoku* music. Tokumaru dedicates a full chapter to how *nagauta* melodies are composed from predefined melodic patterns, idioms or motives which are within the triad(4). Furthermore, reordering these motives to create a new melody also involves rearranging the links of the Koizumi's *kakuon* between patterns. In this sense, according to Tokumaru, melodies are formed not according to a mode or a scale, but according to the structural ties between their *kakuon*.[24]

Melodic Structure of the Music of the *Shakuhachi*

The *shakuhachi honkyoku* repertoire is distinguished from all other genres of Japanese music in that it is possibly the sole genre not composed for voice, particularly narratives or storytelling, that holds significant historical value with respect to Japanese arts. When the *biwa* found its way out of the *gagaku* ensemble, it was used to accompany the recitation of Buddhist *sutras* or the narration of legends, myths or tales.[25] When the *shamisen* reached mainland Japan in the 17th century from the Ryūkyū kingdom (Okinawa), it was primarily used as an accompanying instrument for entertainment in pleasure quarters and the newly developed *kabuki* theater, as well as the *bunraku* (文楽) puppet theater, among others. The only other instrument for which there was a solo repertoire during the Edo period is the *koto* (琴), the Japanese table zither, which was still used mainly for accompanying the voice.

As for the *shakuhachi* (Fig. 4), the flute was originally part of the *gagaku* ensemble; of Chinese origins, it had 6 holes. However, at the end of the 9th century, it was removed in an effort to streamline the ensemble.[26] Around the 11th century, a small straight flute appeared, the *hitoyogiri* (一節切) (length: approx. 33,6 cm); it had 5 holes and was played by wandering monks. This flute is considered the ancestor of the *shakuhachi*.[27]

Fig. 4 Illustration of a *shakuhachi*. This flute has 4 holes in front and 1 in the back. © Jean Laplante.

These *shakuhachi* players were a hodgepodge of monks from different religious backgrounds, some being considered "half-monks". Some among them were called *komosō* (薦僧, straw mat monks). They carried straw mats on their backs. Later, from the 14th century onward, they came to be known as *komusō* (虚無僧, monks of emptiness), a name with more religious overtones. However, it is not known precisely when the change of name occurred. Documents from the 17th century mention that these *komusō* were monks of a Zen sect called Fuke, considered a subject of the Rinzai sect, and that they played the *shakuhachi* to attain enlightenment, although they were independent of Rinzai authority.[28] They did not meditate, nor did they chant the Buddhist sutras; they did not even shave their heads, as did all other Buddhist monks. Thanks to an edict from the *shōgun* (将軍), they could travel freely all throughout Japan.

[23] See [Alison McQueen Tokita, 1996].
[24] See [Tokumaru, 2000, Chapter IV].
[25] See [Ferranti, 2009].
[26] See [Tamba, 2015, p. 27–28].
[27] In [Tukitani et al., 1993] it is indicated that the "mode" of the melodies played on that small flute was the *ritsu* mode, the mode mainly used in folksongs, and that the rhythmic structure of these songs was regular. While the *shakuhachi* as we know it today appeared at the beginning of the Edo period, the aesthetic quality of the *in* mode was preferred by the monks of Fuke sect, with a free rhythmic structure (also cited in [Lee, 1993, p. 59]).
[28] [Sanford, 1977, p. 412].

The edict stipulated that the members of the Fuke sect had to be from the samurai class, most of them being *rōnin* (浪人, masterless samurai), and that they were the only ones granted permission to play that flute. Many of these *rōnin,* disguised as *komusō,* were in fact gangsters and crooks, some of whom served as spies for the *shōgun*, travelling and playing the *shakuhachi* with a straw basket on their head, thus hiding their identities.[29]

The Fuke sect had a number of temples around Japan where the *komusō* could stay, with two head temples around Tōkyō and one in Kyōto. The role of the Tōkyō temples was more political than anything else, while the Kyōto temple, Myoan-ji, was for the more spiritually inclined of these *rōnin*-monks. Being despised, the sect was abolished in the Fall of 1871, following the collapse of the Tokugawa *shogunate* in 1868. The monks then began teaching *shakuhachi* to the general population and giving concerts to survive, which was something entirely new for most of them, though some, mainly around Tōkyō, had already been teaching for a number of years outside of their ranks. A few of them created their own schools with their own styles, writing new pieces or rearranging existing ones. Their temples were either destroyed or moved to other locations, taking different names, and losing any links with the Fuke sect. Myoan-ji in Kyōto was not destroyed and is still active today. Musicians, Buddhist monks and amateur *shakuhachi* players have been gathering at the temple twice a year since 1952 to perform traditional *honkyoku* pieces. A group of practitioners still maintains the temple's traditional repertoire.[30]

In the *shōgun* edict, it was stipulated that the *komusō* of the Fuke sect were not allowed to play popular songs or *min'yō* (民謡, folksong), but only their own music, although this rule was not always strictly enforced. It is only after that sect was banished in the Fall of 1871 that the *shakuhachi* started to find its way into other genres of music, including *min'yō*. Though these mendicant monks were playing in front of people while begging, these were not performances. They were not constrained by having to compose melodies to please a public, though they were obviously influenced by the music they were hearing at the time, including the ones they heard in the pleasure quarters.

The *shakuhachi* as it is known today appeared sometime within the 17th century or perhaps the beginning of the 18th century. It is made of young *madake* bamboo. It is unclear who decided to start making it with that particular type and size of bamboo, and when. One anecdote suggests that a *rōnin* thought that a bigger and heavier flute could be used as a club to fight when needed.[31]

With regard to the structure of the *honkyoku* pieces, we find in traditional Japanese music an important aesthetic and structural principle called *jo-ha-kyū* (序破急),[32] which has been used since the 7th century when *gagaku* came to Japan from China. *jo* can be translated as "introduction," *ha* as "breaking apart" or "exposition," and *kyū* as "rushing to the finish" or "denouement".[33] All forms of Japanese music and theatre (including the martial arts) use it as an aesthetic structure not only for an entire song or a full play, but also for an act, a single scene, and even for each individual movement the actors perform on stage. In *honkyoku* music, entire pieces as well as the phrases that comprise them follow this structure; in a phrase, the *ha* might take more the form of a culmination than an exposition. This structure does not divide each piece into equal parts. The *ha* might occur early in a piece, or toward the end. As for each phrase of a piece, it is up to the player to place it where he feels it fits during a piece's performance, though he must make clear that the phrase unfolds out of silence (from the *jo*) and return to it (with the *kyū*).

In modern musicology, a "musical phrase" is most commonly defined as the division of a melodic line. The pieces of the *honkyoku* repertoire obviously have musical phrases, but with a major difference both from other genres of Japanese music as well as from those of other cultures: the phrases are separated by silence defined by breath marks clearly indicated on the score. The player must obligatorily play each phrase within a single breath, followed by silence.

[29] See [Lee, 1993], [Johnson, 2014], [Deschênes, 2017].

[30] There is a particular school in the town of Hirosaki, in the northern prefecture of Aomori which developed a unique style of *shakuhachi* playing. Its practitioners were not monks or *rōnin*, but active samurais. The banishment of the Fuke sect had no influence on them.

[31] For a detailed history of the *shakuhachi*, *cf*. [Lee, 1993] and [Johnson, 2014].

[32] See [Tamba, 1988] and [Malm, 2000].

[33] See [Malm, 2000, p. 115].

In Japanese music, silence is not some sort of void; it can be viewed as the "seedbed" of sound.[34] Silence in these pieces do not mean an absence or an interruption of sound, but that sound unfolds from silence and returns to it. From that point of view, this silence is as important as the sounds themselves. Breathing becomes an integral part of the piece's performance, as it prepares the phrase to come, thus becoming part of its aesthetic character. The aim of these pieces is to express a state of mind that can be spiritual; the silence must express it as much as the notes played. The duration of these silences will differ from phrase to phrase, musician to musician, school to school, and even between a musician's performances.

Although the *honkyoku* repertoires are obviously influenced by the *in* mode, with its extensive use of the half-tone,[35] their melodic lines are not based on that mode. One reason for this is that, since they were not composed with the voice in mind or with an aim to create pleasing melodies, it may have been deemed unnecessary to compose them with a sustained melodic line. It must be added that this flute is extremely difficult to play, requiring the player to take long, deep breaths. The pieces were composed with that particular constraint in mind, forcing them to incorporate clear pauses and silences between phrases. The monks that crafted these pieces had a flexibility that they would not have had were they composing regular melodies. A phrase does not necessarily follow the preceding ones on the basis of a sustained melodic line. At times, a phrase might drastically break the flow of a possible melodic line by inserting a motive that does not express any obvious continuity with the preceding one(s).

It is quite common in *honkyoku* music to hear phrases with a single note, suggesting that there is no *kakuon*. Let's take for an example the first few phrases of *Daiwa gaku* (Fig. 5 & Fig. 6), the first of the two pieces I analyze in the next section. As can be seen in Fig. 5, the first two phrases have only a single note, while the third phrase has 2 notes, which are the same as the previous ones. In both cases, the interval is a fourth. In these first 2 phrases, it can be suggested that the *kakuon* are not within a phrase, but between them. In Fig. 6, phrases 4, 5 and 7 have 2 *kakuon*, while phrase 6 has only one. The *kakuon* of phrases 4 and 6 lead to phrases 5 and 7. Although phrases can be independent from one another, split by breathing marks, there can be a grouping of *kakuon* between them.

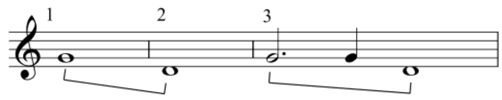


Fig. 5 *Daiwa gaku*: phrases 1 to 3

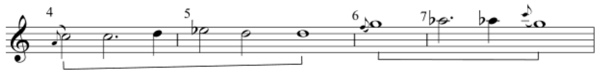


Fig. 6 *Daiwa gaku*: phrases 4 to 7

The notion of *kakuon* as proposed by Koizumi is, I believe, most pertinent in analyzing the *honkyoku* repertoire. However, his emphasis on the fourth and of having two or more *kakuon* within a phrase is somewhat too restrictive.

As I hope to show in my analysis in the next section, the melodic motives of the phrases in the *honkyoku* repertoire are based more on the intervals linking the *kakuon* together than on the *kakuon* themselves. These linking intervals occur between phrases as well as within them.[36]

Analysis of two *honkyoku* pieces

The background for my analysis of the melodic structure of the phrases in *honkyoku* music is twofold.

Firstly, it is based on the points raised in the two previous sections, particularly Koizumi's notion of *kakuon*.

Secondly, it relies on my personal study of the music from a *shakuhachi* player's point of view.

My primary aim is to understand these pieces so to better perform them.

We will begin with the following corollaries:

[34] Similarly to Japanese painting in which a space or a background is purposefully left blank. That empty space has as much meaning as everything else on the canvas.

[35] I am using "half-tone" for the sake of clarity for the reader. It is not at all the tempered half-tone or even the natural one. Being difficult to produce because of the use of partial opening of holes on the *shakuhachi*, the player is never really able to play it the same each and every time. From one performance to another, a half-tone within a piece will never be exactly the same interval.

[36] Japanese *shakuhachi* masters do not say anything about the structure of the melodic lines of the pieces they teach their students, nor do they discuss the *kakuon* or any other theoretical constructs. They usually elude such questions.

1. Phrases in *honkyoku* pieces usually have 2 nuclear notes, although on many occasions there is only a single note, thus a single *kakuon*. Some pieces composed or rearranged by 20th-century musicians may have phrases with more than 3 *kakuon*, while the ones in traditional pieces generally have 1 or 2 *kakuon*.
2. The *kakuon* within a phrase form an interval within a triad(4), while intermediary notes can have intervals whose span sometimes exceeds an octave.
3. *kakuon* are never simply 2 notes that structure a phrase. Their relation forms what I call *nuclear intervals* (which would become in Japanese *kakuontei* (核音程), *ontei* being a musical interval). These intervals give a melodic form to each phrase. Though Koizumi and Tokumaru acknowledge the importance of intervals, they do not develop that point.
4. The most common *kakuontei* are: the fourth, the half-tone, the major second and the minor third. The major third appears, but not as frequently as the other intervals.
5. A phrase should be viewed as a melodic "trajectory". The intervals are not simply a distance of some sort between tones or two *kakuon*, but a motion from one to another, a motion that musically structures each phrase. This intervallic motion between *kakuon* forms the melody structure of a phrase or a motive, not the *kakuon* as such.
6. As Weisgarber suggests, phrases are formed of motives. In traditional pieces, a phrase has usually a single motive. However, in modern pieces there can be more than one within a phrase.
7. A phrase must be performed within a single breath. The silences between phrases are an integral part of the aesthetic character of *honkyoku* music.
8. Lastly, the two pieces I am analyzing in this section are from two different schools, or *ryū* (流), and styles of *honkyoku* music. The first one, *Daiwa gaku* (大和楽, "The Great Peace"), is a piece from the repertoire assembled from different areas throughout Japan at the beginning of the 20th century by *shakuhachi* master Jin Nyōdo (1891-1965).[37] The second piece, *Shika no Tōne* (鹿の遠音, "The Distant Cry of the Deer")[38] is among the most known pieces of the *honkyoku* repertoire, and one of the few pieces originally written for two *shakuhachi.*[39] Most *shakuhachi* schools perform this piece, arranging it to their respective style while maintaining its overall structure, so as to allow *shakuhachi* players from different *ryū* to perform it together. The version I am analyzing here is from the *dokyoku ryū*, the *shakuhachi* school and style of the late Katsuya Yokayama (1934-2010).[40]

Daiwa gaku

Daiwa gaku is a beginner's piece and is the first *honkyoku* piece taught to students of the Jin Nyōdo school. The following points can be observed (see Fig. 9):

- As we saw above (Fig. 5 & Fig. 6), the notes of the first three phrases introduce two fourths. A third fourth, with the same notes, does not appear until phrase 17, toward the end of the piece.
- 8 phrases out of 19 have a single *kakuon* (1, 2, 6, 11, 13, 15, 18, 19).
- 2 of the single note phrases have the note repeated (13, 19).

[37] I learned part of this repertoire with Ronnie Nyogetsu Reishin Seldin (1947-2017), an American *shakuhachi* master based in New York, as well as with Kurahashi Yōdo II, a *shakuhachi* master from Kyōto, whose father, Kurahashi Yōdo I (1909-1980), was a disciple of Jin Nyōdo. Seldin was a student of Kurahashi Yōdo I.

[38] This is possibly the most recorded piece of the entire *honkyoku* repertoire, especially by non-Japanese *shakuhachi* players.

[39] The original piece is much simpler than the one we hear today. In the 20th century, the piece was adapted to a more virtuoso style of playing. There also exist a number of different versions that cannot be played together.

[40] We find today three major schools of *shakuhachi*. The Kinko School is considered the traditional school, which has a number of affiliated schools. The Tozan School was created at the end of the 19th century, the style of which has been modeled in part on Western music. It has few branches. This is the most popular school among Japanese students. A third school is the *dokyoku* school established by *shakuhachi* master Katsuya Yokoyama in the 1960s. It is popular among non-Japanese players. There are also other lesser known or popular schools.

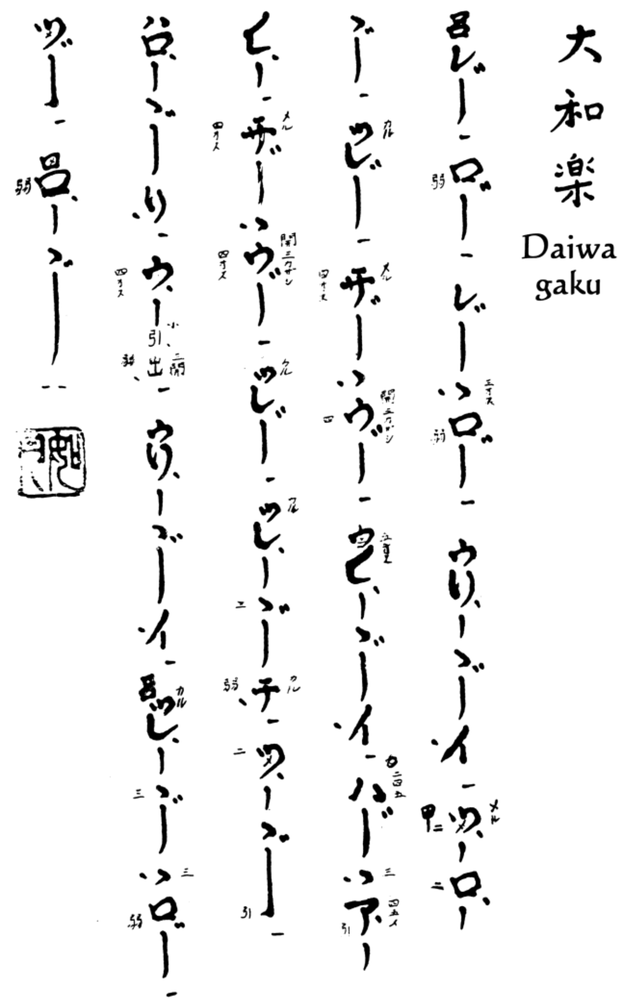


Fig. 7 Score of *Daiwa Gaku* in Japanese notation, calligraphy by Kurahashi Yōdo I. Used by permission, Kurahashi Yōdo II.[41]

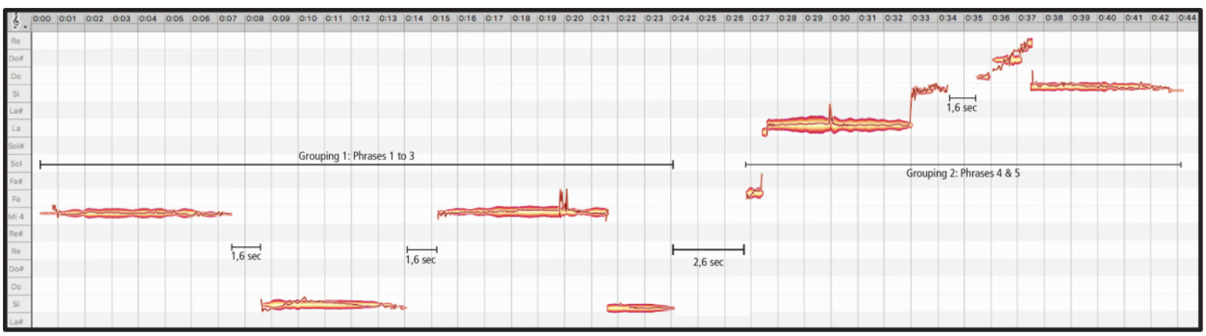


Fig. 8 Annotated (and modified) image of phrase 1 to the first note of phrase 5 of *Daiwa gaku* (see Fig. 9 and Fig. 9), showing lengths of silences between phrases for the recording accompanying this article. Analysis using MELODYNE software.

[41] The characters used in the *shakuhachi* notation do not refer to tones but fingerings. Some tones can be produced with different fingerings, thus giving different tone colors. These characters are from the *katakana* syllabary (one of three writing systems) and are used for foreign words and onomatopoeia. Each school has its own notation based on this common set of characters. Some notations can be very sparse, while others are quite detailed, though not to the extent of European notation.

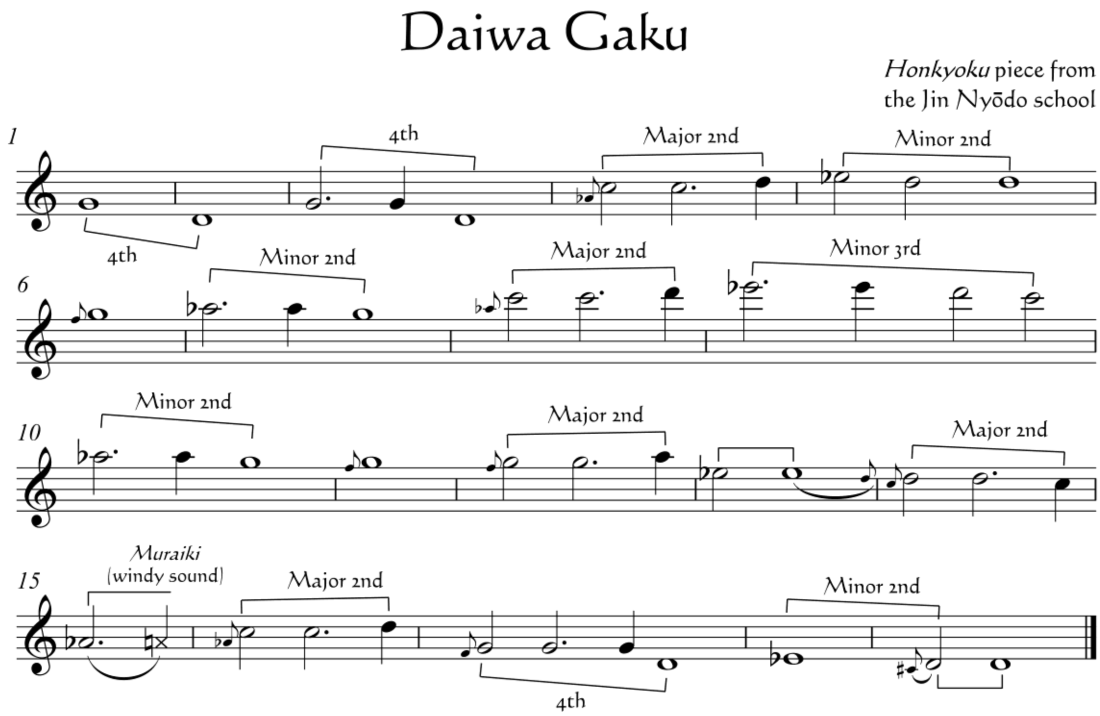


Fig. 9 Transcription in Western notation of *Daiwa Gaku*. The breath marks are represented by short bar lines. The numbers at the beginning of each staff indicate phrase numbers. The brackets indicate the *kakuontei*. This piece is performed on a 2.1 *shakuhachi*,[42] while the transcription is based on a 1.8 *shakuhachi*, the standard and most common length for the flute. The transcription is mine.[43]

Fig. 10 This example shows the groupings I use for my performance of *Daiwa gaku*. It can be grouped differently depending on the musician.

[42] The name *shakuhachi* refers to the length of the standard flute: 1 *shaku* 8, *shaku* being a unit of measurement and *hachi* being the number 8. The length of these flutes can be between 1.2 and 4.0 *shaku*, though the ones from 3 *shaku* on are extremely difficult to play.

[43] To hear my performance of the piece, see http://nemo-online.org/wp-content/uploads/2017/08/Daiwa-gaku-For-the-article-honkyoku-shakuhachi-Bruno-Deschênes.mp3 (duration: 2:34).

- 5 of them have a single intermediary note (6, 11, 13, 19) thus 2 *kakuon*, and one with a windy sound (15), called *muraiki* (ムラ息, a type of windy sound).
- 7 phrases use either a minor 2nd (5, 7, 10) or a major 2nd (4, 8, 12, 16) as *kakuontei*. There are no minor or major third *kakuon* in this piece.[44]
- Only one phrase has three *kakuon* (9).
- Phrases 4, 8, and 16 are the same, except for phrase 8, which is an octave higher than the two others.
- The piece begins and ends with nuclear intervals of a fourth. The minor second of the last two phrases (18 & 19) is, I would suggest, a "collapse" of the final fourth into a minor second.
- No two successive phrases have the same nuclear intervals.
- Phrases 4-5 and 8-9: a major second in ascending motion is followed by a minor second in a descending motion.
- As the culminating point of the piece, 8-9 is a recurrence of 4-5 an octave higher, with an extra note at the end of phrase 9.
- Phrases 6-7 and 10-11 express the same pattern, but in reverse order.
- Melodic structures are formed by groupings of 2 or 3 phrases such as: 1-2-3; 4-5; 6-7; 8-9; 10-13; 14-15; 16-17; 18-19, as shown in Fig. 10.
- The *jo-ha-kyū* structure of the piece is as follows: *jo*, phrases 1-5, *ha*, phrases 8-9, and *kyū*, phrases 10 to 19.

One obvious particularity of this piece is its simple, unsophisticated melody. Except for phrase 9 which has 3 *kakuon*, the melodic structures of all the other phrases are unadorned, having only 1 or 2 *kakuon*. This type of melody is common among traditional pieces with a melodic line that is not continuous in character.

One aspect of this melody that Weisgarber and Gutzwiller do not mention in their analyses of *honkyoku* music is that phrases can be *grouped*. These larger phrases exert an influence on the flow of the piece, the duration of breathing between phrases, and the performance of a piece.[45] These groupings are neither structural nor theoretical. *Shakuhachi* players do not simply play the phrases of a piece one after the other, interspaced with silent breathing; they create larger melodic structures by grouping phrases together, with groupings that could differ from one musician to another.

The concepts of nuclear intervals (*kakuontei*) and groupings that I propose here provide a new avenue in the analysis of the *honkyoku* repertoire, one that has not been proposed up to the present, at least not by the authors I reference in this article. As the article is intended as a preliminary discussion, I will not go into any further detail than putting forward these two proposals. My aim is to raise an issue that has not been previously proposed and still needs to be comprehensively studied.

A follow-up would be to extend my analysis of these two new concepts to a number of pieces from different repertoires and styles, and, in particular, to see how they are applied by different musicians, both Japanese and non-Japanese, in their performance of these pieces.

Shika no Tōne

Before presenting my analysis of this piece, I need to provide a few comments about both transcriptions.

For *Daiwa gaku*, I transcribed the original Japanese score precisely as-is.

For this second piece, I added in red some unwritten stylistic devices that can be optionally played, depending on the player or the school. Also, the *dokyoku* notation uses jagged lines that produce notes with up and down movements of the head. I transcribed these notes with smaller note heads, as in the *G* following the A^b in phrase three.

The note values of all the pitches (in both pieces) are relative, not fixed. Their duration and even the pitches themselves will differ between the two musicians playing that piece.

The following points can be observed about *Shika no Tōne* (see Fig. 13 & Fig. 14).

[44] My use of minor and major has no direct reference to these concepts in European music. I use it for the sake of clarity in presenting these *kakuontei*, knowing that these intervals will differ from one player to another.

[45] The breaths between the phrases within a group might be shorter than between two groups.

Structure

Shika no Tōne appears to have the following structure: A'-B'-C'-D'-E'-A''-F'.[46]

- Section A' includes phrases 1-7; section B', phrases 8-16; section C', phrases 17-26; section D', phrases 27-32 ; section E', phrases 33-9; section A'', phrases 40 to 45; and section F', phrases 46 to 57.
- In section A', the players play similar phrases, except for the first phrase that is played by the first player.
- B' and C' are two sections where both players repeat the same phrases alternatively.
- Section D' is the only section where both players play dissimilar phrases.
- In section E', we hear 2 short phrases played alternatively in ascending and descending order. A'' is similar to A', except that the second phrase is missing. The players have been switched.
- In the last section F', phrases are alternated between the players, except that at the end, phrases 53-56 appear as the only ones where both players play together.
- The *jo-ha-kyū* structure could be as follows: *jo*, sections A' and B', *ha*, C', D' and E', and *kyū*, A'' and F'. C', D' and E' could also be viewed as being structured according to this tripartite structure.[47]

Phrases

This piece clearly comprises groups of phrases (between two and five phrases) that are played alternatingly by the two players. At times the second player repeats what the first one played; at other times, it is reversed. Section D is the only one in which they do not play the same phrases. Phrase grouping plays a crucial role in the performance of the piece.

- The phrases of section A' are played by the first player, and those in A'' by the second.
- There is only one phrase that is not repeated (phrase 12).
- There is a group of phrases (section E') that are played alternatingly, but in reverse melodic order (33 to 39).
- There is only one phrase that is played by the same player when repeated, that being phrase 1 of section A' which recurs as phrase 40 of section A''.

Kakuon and *kakuontei*

The melodic structure of *Shika no Tōne* differs greatly from that of *Daiwa gaku*. The former has much greater complexity, and is composed for two *shakuhachi*.

The brackets on the Western transcription show the nuclear notes only for the first occurrences of phrase groups.

- This piece makes use of *kakuontei* that are constrained within a triad(4), supporting Koizumi's theory of *kakuon*.
- Numerous phrases have three *kakuon*, thus two *kakuontei* (phrases 1, 3, 5-6, 21-23, 27-29, 31, 33-41,43-44,48,53); and sometimes more.
- The phrases with two *kakuon* employ only three intervals: the fourth, the minor second and the major second.
- When there are three *kakuon*, the most frequently recurring interval is the major third. The first and third *kakuon* form what I consider to be a primary *kakuontei*, with the nuclear intervals between the first and second, and the second and third *kakuon* being secondary *kakuontei*.
- The first phrase of *Shika no Tōne* is a case in point, having three *kakuon* and two *kakuontei*. It starts with an E^{b}, ascends to a *G*, making a major third, and ends with a fourth on *D*. The primary nuclear interval between the first and third *kakuon* is a minor second.
- Although the major third is clearly stated, its structural importance as a nuclear interval is diminished due to the phrase's trajectory towards the fourth. The fourth and the minor second are melodically and structurally more important as both intervals end on the third *kakuon*.

Exceptions

- Phrases 5 and 30 have melodic structures distinct from all other phrases. Phrase 5 (repeated at phrase 43) starts with a major third, followed by another major third, and then a major second, giving the

[46] The reason why I say "appears" is that this structure is debatable, being dependent on how the player views and makes sense of the piece. Again, it can differ from one school to another. For example, a single phrase in one school could be divided in two distinct phrases in other schools.

[47] This too is debatable.

impression that we have three *kakuontei* and four *kakuon*. When listening to the piece, we get a different impression. We hear two distinct *kakuontei*, *i.e.* the first major third and the major second. The second major third is more of a repetitive "echo" of the first one than a distinct nuclear interval. Further, this phrase can be performed inserting a short silence right after the first nuclear interval, suggesting that it might be considered as two separate phrases.

- Phrase 30 starts on a B^b in the upper octave, followed by a *muraiki* (windy sound) on *C* in the lower octave, then returns to the original B^b. This structure is unique to this phrase. All other occurrences of *muraiki* occur at the beginning of phrases.

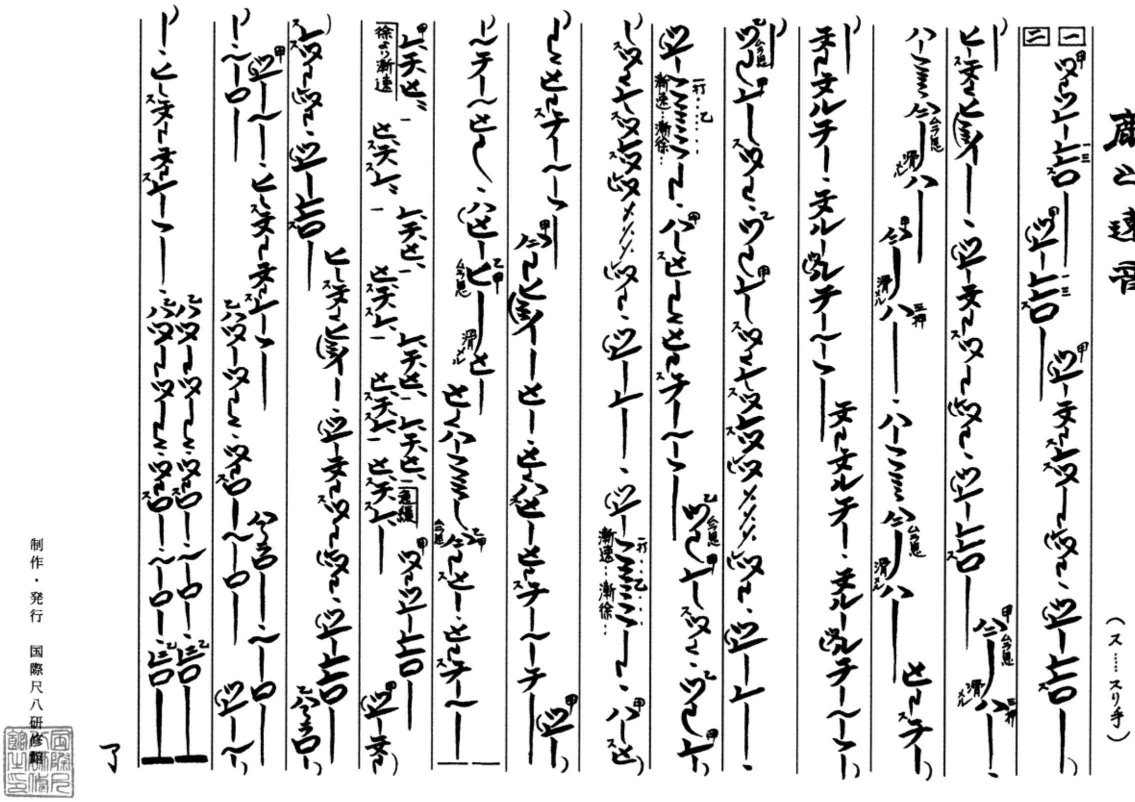


Fig. 11 Score of *Shika no Tōne* for two *shakuhachi*, calligraphy by Furuya Teruo, master *shakuhachi* player of the *dokyoku* school. Used by permission.

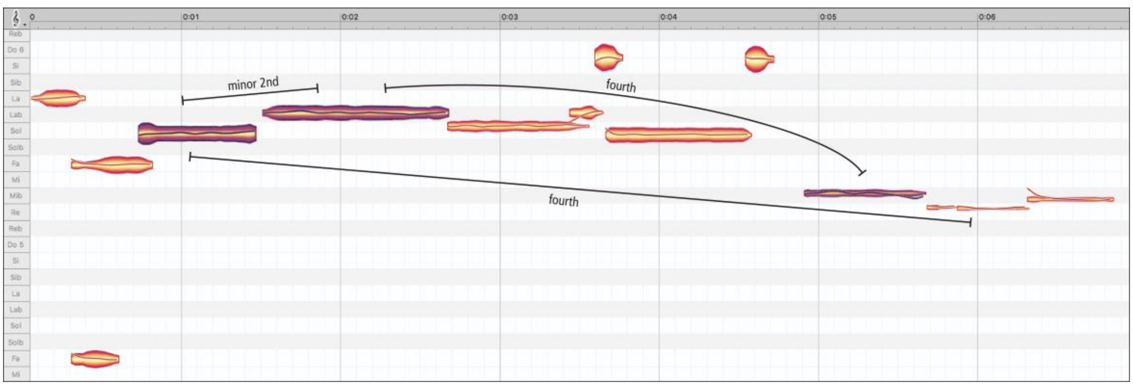


Fig. 12 Annotated image of phrase 3 of *Shika no Tōne*, showing the 3 *kakuon* (in a darker red) and their *kakuontei*. I do not consider the consecutive repetition of a note a new *kakuon*. Although the last intermediary note is not a *kakuon*, it could be considered a secondary interval with the first *kakuon*. Analysis using MELODYNE software.

(*) The bar lines refer to the breathing marks on the original score.

Fig. 13 Page 1 of the transcription in Western notation of *Shika no Tōne*, for two *shakuhachi*. The breath marks are indicated by shortened bar lines between the staves. The annotations, such as 22… and ...22, indicate that these phrases start at the end of a system and continue on to the next system. This piece is played with two standard (*i.e.* 1.8) *shakuhachi* of the same length.[48]

[48] To hear a performance of the piece, see http://nemo-online.org/wp-content/uploads/2017/08/Shika-no-tone-For-the-article-honkyoku-shakuhachi-Bruno-Deschênes.mp3 (duration: 7:20). Recording taken from the CD [Matsu Také Ensemble, 2017], by a Japanese music ensemble based in Montreal of which I am the artistic director. The second player is Michel *Zenchiku* Dubeau.

Fig. 14 *Shika no Tōne*: page 2 in Western notation of *Shika no Tōne*. The transcription is mine.

- Phrases 17 and 18 (repeated as phrases 23 and 24) are worth mentioning, too. Phrase 18 can be viewed as an extended variation of phrase 17, which presents a single iteration of a pattern that is repeated several times in phrase 18, extending the melodic trajectory of phrase 17. Although there is a jump of a 9th between the first and second nuclear notes, this primary interval, *i.e. F* to *G*, should considered a major second rather than an octave jump.

- Phrases 33 through 39 differ from the others. They have three nuclear notes whose primary *kakuontei* is a minor third. We hear melodic patterns in which the players alternate between an ascending phrase played by one and a corresponding descending phrase mirrored in response by the other.

Grouping

Phrase grouping occurs in three ways.

- The first grouping occurs when a group of phrases played by one player are repeated unchanged by the other. For example, phrases 17-21 are repeated as phrases 22-26. The *shakuhachi* players have to play these phrases as a group rather than simply as individual phrases. When a player repeats a group of phrases, he is doing so in response to the other player. The quality of the performance depends on the musicians' grouping of the phrases. As the title *Distant cry of the Deer* suggests, this duet represents two deer, unseen to one another, that call and respond to each other in the forest.
- The second grouping occurs in section D' from phrases 27-32. This is the only section where the players do not play the same thing while responding each other.
- The third grouping occurs from phrases 33-38. This grouping includes both players, rather than only one followed by the other.

Comparison of Daiwa gaku *and* Shika no Tōne

Finally, I compare both pieces to point out stylistic differences between the more traditional Jin Nyōdo style and the more modern *dokyoku* style.

Each *shakuhachi* school makes use of stylistic devices that are generally not written down in the scores of their respective pieces.

Some of these devices are common among all schools. Some may be found in some schools and not in others, while others might be unique to a particular school.

For example, the motive on phrases 6, 15 and 18 in *Daiwa gaku* can be played in four different ways (the *F-G* motive, the *F* being the intermediary note): 1) as is, with no extraneous device; 2) the intermediary note can be played in the lower octave with a *muraiki* sound and the main note in the upper octave; 3) the intermediary note can be played with a quick snap of the finger on the fourth hole for emphasis; or 4) it can be played by bringing the finger down on the fourth hole more slowly, resulting in the addition of an extra grace note, as shown in red in phrases 2 and 3 of *Shika no Tōne*.

In the last case, the first of these notes is played in the upper register, the second note (which is the intermediary note, *i.e. F*) in the lower register, then the *kakuon* is played back in the upper register. In order to emphasize the intermediary note in case 1, 2 or 3, the second, third, or the fourth hole may be hit, depending on the school or the player.

However, in north-east Japan, north of Tōkyō, the second note (*i.e.* the *G*), not the intermediary note, is hit for emphasis, thus giving a fifth way to play this particular motive. As these are stylistic devices, it is considered good taste not to overdo it.

Interestingly, the *dokyoku* style of Katsuya Yokoyama uses the fourth device above only in *Shika no Tōne*, not in other pieces. The reason for its use in this particular piece is to allow students of the *dokyoku* school to play it with players of other schools.

As for the melodic two-note cell starting phrase 15 of *Daiwa gaku*, it is a common motive that can be found in all styles of *shakuhachi*, including in the *shakuhachi* part of the ensemble pieces of *sankyoku* (三曲, meaning music for three instruments) for *koto*, *shamisen* and *shakuhachi*.

The intermediary note, which is a *C*, is always done with a particular fingering giving it a unique tone-color, though the fingering can differ from school to school. However, phrase 16 of *Daiwa gaku* is not found in *dokyoku* pieces since it uses a fingering that the *dokyoku* school does not employ.

The jagged lines found in *Shika no Tōne* are mainly used in the *dokyoku* notation.

A Music of Tone-Colors

To the notion of "tetrachord" and *kakuon* put forward by Koizumi and expanded by Tokumaru, I have added the notions of *kakuontei*[49] and phrase grouping. Although both Koizumi and Tokumaru consider the intervals important, they put a greater importance on the *kakuon* than the intervals. I suggest that the primary aspects that structure melodic lines in any *shakuhachi* piece are not the *kakuon* as such, but how they relate to each other to form intervals. These *kakuontei* give form to the flow of each phrase and, consequently, to the motives of these melodies, they provide a flow that finds its full meaning in performance, as Gutzwiller emphasizes.

The half-tone interval that is emblematic of the Japanese *in* mode and heard across a wide spectrum of Japanese musical genres is not a theoretical construct *per se*, but is more an auditory effect, a tone-color, an aesthetic as well as a performing imprint, obtaining its musical meaning in the act of being played and listened to.[50]

When the monks of the Fuke sect were composing their solo pieces for the *shakuhachi*,[51] the basis of their rationale was in all probability the aesthetic and tone-color impressions they were hearing in the music surrounding them during the Edo period, including the pleasure quarters that some of them were visiting. They were imprinting their music with the musical conventions that existed at the time.

Even though they did not give performances of any kind, and were not composing songs, their music was influenced by that in their surrounding environment. The intervals in *honkyoku*, being half-tones, minor thirds, or fourths, among others, should not be viewed as components of some theoretical constructs, but as auditory tone-color impressions that the *shakuhachi* player brings to life when playing. In this line of thought, Koizumi's *kakuon* should not be viewed as pitches or tones, but as tone-colors that end up being sensed as musical tones. That is, what the ear senses first is the quality of sound, which then becomes, for the listener, a musical tone[52].

Again, the *kakuontei* should not be viewed as intervals in the theoretical sense of the term, but more as shifts or alterations in tone-color in the *shakuhachi*'s sounds. In this sense, the pieces of *honkyoku* repertoires are melodies formed not by pitches, but by shifting tone-colors. The quality of a sound precedes its pitch perceptually, and not vice-versa.

In all traditional Japanese arts, the way in which something is done is more important than what is being done. To give but one example, ethnomusicologist Jay Keister mentions in his book *Shaped by Japanese Music* that his *shamisen* teacher told him that he should not worry about the quality of the sounds he was producing, but just focus on form; with proper form, the proper sound comes over time.[53] This type of comment is quite typical of all traditional Japanese arts. How to play or perform a piece of music has precedence over the music itself, including its theoretical underpinnings.

This applies as well to *honkyoku*: the forms of these pieces, of their phrases, of their motives, including how their sounds are produced and their relationships to one another, rather than their theoretical constructs, give meaning to the melody.

The silence between phrases underlies an important aesthetic concept in traditional Japanese arts called *ma* (間). This term can be translated either as a distance in reference to the space between two objects, or as an interval of time between two events.

It is particularly applied in architecture, garden design, theater, dance, and even martial arts, in reference to the space between oneself and what one perceives in the world, or between actors, dancers, or martial arts practitioners.

[49] Although it is most uncommon for a non-Japanese native to create a Japanese term.

[50] According to musicologist Yoshihiko Tokumaru, the attraction of Japanese musicians to Western instruments at the end of the 19th century was about their tone-colors which was unknown to them – *cf.* [Tokumaru, 1991, p. 91–92]. Similarly, Henry Burnett suggests that the importance of tone color in traditional Japanese music is such that a musicological analysis of any piece does not have meaning for Japanese musicians – *cf.* [Burnett, 1989, p. 80].

[51] I of course refer to the monks in the Fuke sect who use the *shakuhachi* in hope of reaching enlightenment, not the *rōnin* who, under the cover of the sect, served as spies for the *shōgun*.

[52] And sometimes not. For example, the *muraiki* (windy sound) can have a pitch of some sort, but usually does not, though it can be added to a pitch.

[53] For *shamisen*, see [Keister, 2004a, p. 42]. The same can be said of traditional dance of *nihon buyō*. For *nihon buyō*, see [Hahn, 2007].

ma is not about a calculated space or interval of time, but about how that space or time interval is felt when perceived or sensed; it is a quality that is experienced. In theater and dance, it will refer to how an actor or dancer feels other peoples' presence while acting or dancing. In *nō* theater, the pauses, empty moments, and silences are also called *ma*.

These are just as important, and sometimes even more important than what the actor does while performing. In other words, the unspoken and unexpressed tells as much as what is explicitly performed. If silence is not merely the absence of sound but in actuality the source of all sounds as mentioned before, a phrase should not start and end abruptly, but should arise out of one's breathing and silence, then return to it again, both aesthetically and musically. Each silence prepares for the phrases to come. And here too, as in *nō*, the silence is just as important as the tones produced.

There is one interesting particularity of *honkyoku* melodies that distinguish them from many other genres of music in that they can be played on flutes of different lengths, hence changing their tone-color.[54] When playing a piece on flutes of different lengths, the pitches of the melodies will differ, while the form of each phrase and the piece as a whole remain the same.

The aim in using flutes of different lengths is not to transpose a melody, but to create a change in tone-color while using the same melodic form. Today, most *shakuhachi* players choose a *shakuhachi* for any piece they perform that has the tone-color they feel will best express what they envision musically and aesthetically for the piece. They might choose a flute with a softer or brighter tone, seeking the flute with the most appropriate tone-color.

Moreover, there are no strict rules requiring a player to play a piece on a flute of a certain length, though there are a few pieces that are usually played on a particular length of *shakuhachi*.[55]

In this sense, pitches in *honkyoku* melodies are not "stated" but "inferred" as an outcome of their tone-color, as well as from their shifts from one tone-color to another – shifts that our ears perceive as intervals and distinct pitches. For this reason, among others, accuracy in tuning is secondary.[56]

Conclusion

Uehara and Koizumi's "tetrachord" theory is not entirely adequate for the *honkyoku* repertoire, because they refer to tones in the Western sense of the term, while these melodies were not written from that point of view.

The modern preference for perfect tuning when making and playing *shakuhachi* is a result of influence from Western music.

The view among most Japanese *shakuhachi* masters I have met is that a tone is never static, but is in constant tone-color fluctuation; the pitch is an outcome of this fluctuation.

Most well-known Japanese *shakuhachi* masters I have met say that playing *shakuhachi* has to do first and foremost with tone-color, not pitches. The melodic quality of each phrase and each piece is more in the melodic forms and contours created by the *kakuontei* and the *kakuon* than it is in the pitches.

[54] The *shakuhachi* is still made by hand today. No two flutes from the same maker will have exactly the same tone-color, with even greater variation for flutes from different makers. One reason for this is that no two pieces of bamboo have exactly the same shape and bore size. As well, the same flute played by different musicians will also sound different. More and more makers are finding ways to make modern *shakuhachi* so that they are in tune with Western instruments. Lately, this has also come to include the *jinashi shakuhachi*, which is considered the traditional *shakuhachi* of the monks of the Fuke sect. Traditionally, these flutes were made by the monks themselves; they did not bother with tuning. The professional *shakuhachi* maker did not appear until the end of the 19th century.

[55] For example, the piece *Hi-fu-mi hachigaeshi* is normally played on a 1.8 *shakuhachi*.

[56] The authors I mention, at least in the literature reviewed in this article, do not say anything about tone-color.

Glossary

- *biwa* (琵琶): Japanese lute.
- *bunraku* (文楽): Japanese puppet theater.
- *gakki* (楽器): Musical instrument. The monks of the Fuke sect did not consider the *shakuhachi* to be a musical instrument.
- *hōki* (法器): Refers to the *shakuhachi* as a spiritual tool to reach enlightenment.
- *honkyoku* (本曲, original piece): the name given to the repertoire of pieces composed by the monks of the Fuke sect. It includes the traditional pieces as well as the modern ones.
- *in* (陰): When used to describe a scale, refers to one with half-tones. Also called *miyakobushi* (都節).
- *kabuki* (歌舞伎): Japanese classical drama.
- *kagura* (神楽): Shintō singing and ceremonial dancing. Shintō is a native religion of Japan.
- *kakuon* (核音): Nuclear notes.
- *kakuontei* (核音程): Nuclear intervals.
- *koten honkyoku* (古典本曲): Classical *honkyoku*. *koten* is used to distinguish these repertoires from more modern ones.
- *koto* (琴): Japanese table zither.
- *min'yō* (民謡): Japanese folk music.
- *miyako bushi* (都節): Urban music.
- *muraiki* (群息): A type of windy sound unique to the *shakuhachi*.
- *nagauta* (長唄): Long songs of the Kabuki Theater.
- *nihon buyō* (日本舞踊): Japanese traditional dance.
- *nō* (能): A traditional Japanese theatrical art.
- *onkai* (音階): Scale.
- *shakuhachi* (尺八): An upright bamboo flute that was played by the monks of the Zen Buddhist Fuke sect during the Edo period (1603-1868).
- *senpō* (旋法): Mode.
- *shamisen* (三味線): Japanese three-string lute.
- *shōmyō* (声明): Japanese Buddhist chant.
- *yō* (陽): When used to describe a scale, refers to one without half-tones. Also called *ritsu* (律).

References

1. Alison McQueen Tokita : "Mode and Scale, Modulation and Tuning in Japanese Shamisen Music: The Case of Kiyomoto Narrative", *Ethnomusicology 40 1* |1996-1-1| [doi: 10.2307/852434. url: http://www.jstor.org/stable/852434] p. 1–33.
2. Berger, Donald P. and David W. Hughes : "Shakuhachi", *The New Grove Dictionary of Music and Musicians 12* |2001| p. 831–836.
3. Beyhom, Amine : "Un lexique de la modalité", *Near Eastern Musicology Online 2 2* |2013-11| [url: http://nemo-online.org/articles] p. 5–24.
4. Beyhom, Amine : "*Dossier*: Hellenism as an Analytical tool for Occicentrism (in musicology) (V2)", *Near Eastern Musicology Online 3 5* |2016-11| [url: http://nemo-online.org/articles] p. 53–275.
5. Burnett, Henry : "Minezaki Kōtō's Zangetsu: An Analysis of a Traditional Japanese Chamber Music Composition", *Perspectives of New Music 27 2* |1989-Summer| [url: http://www.jstor.org/stable/833405] p. 78–117.
6. Deschênes, Bruno : "La transmusicalité: ces musiciens occidentaux qui optent pour la musique de l'"autre", *MUSICultures 34–35* |2007-8| p. 47–70.
7. Deschênes, Bruno : "Le musicien transmusical", *Territoires musicaux mis en scène*, ed. Monique Desroches, Marie-Hélène Pichette, Claude Dauphin, and Gordon E. Smith, Presses de l'Université de Montréal |Montréal, 2011| p. 385–398.
8. Deschênes, Bruno : *Le shakuhachi japonais: Une tradition réinventée*, Éditions L'Harmattan |Paris, 2017-1-15|.
9. Ferranti, Hugh De : *The last biwa singer: a blind musician in history, imagination and performance*, East Asia Program, Cornell University |Ithaca, New York, 2009-5-30|.
10. Gutzwiller, Andreas B. : Shakuhachi*: Aspects of History, Practice, and Teaching*, Ph.D., Wesleyan University (Ann Arbour, Michigan) |Middletown, 1974| [url: http://www.shakuhachi.com/PG-Gutzwiller.html].
11. Hahn, Tomie : *Sensational Knowledge: Embodying Culture through Japanese Dance*, ed. Includes DVD. edition, Wesleyan |Middletown, Conn, 2007-5-7|.
12. Johnson, Henry Mabley : *The* Shakuhachi*: Roots and Routes*, Brill |Leiden and Boston, 2014|.
13. Keister, Jay : *Shaped by Japanese Music: Kikuoka Hiroaki and Nagauta Shamisen in Tokyo*, Routledge |2004a|.
14. Keister, Jay : "The *Shakuhachi* as Spiritual Tool: A Japanese Buddhist Instrument in the West", *Asian Music 35 2* |2004b-4-1| [url: http://www.jstor.org/stable/4098447] p. 99–131.
15. Lee, Riley Kelly : *Yearning for the bell: a study of transmission in the* shakuhachi honkyoku *tradition : a dissertation submitted in fulfilment ... for the degree of Doctor of Philosophy ...*, Ph.D., University of Sydney/University Microfilm International, No. 982066 |Ann Arbor, 1993|.
16. Malm, William P. : *Traditional Japanese Music and Musical Instruments*, ed. New, Revised edition of the 1959 first published book, Kodansha International |Tokyo, 2000-1959|.
17. Marra, Michael F., trans. : *A History of Modern Japanese Aesthetics*, University of Hawai'i Press |Honolulu, 2001|.
18. Matsu Také Ensemble : *Yamabiko*, ARC, EUCD 2731 |Montreal, 2017|.
19. Sanford, James H. : "*Shakuhachi* Zen. The *Fukeshu* and *Komuso*", *Monumenta Nipponica* |1977| [url: http://www.jstor.org/stable/2384045] p. 411–440.
20. Simon, Amy D. : "*Shakuhachi Honkyoku*: Motivic Analysis of *Sokaku Reibo*", *AAWM - Analytical Approaches To World Music Journal 5 2* |2017| [url: http://www.aawmjournal.com/articles/2017a/Simon_AAWM_Vol_5_2.html] p. 1–48.
21. Tamba, Akira : *La Théorie Et l'Esthétique Musicale Japonaises du 8e au 19e Siècle*, Publications Orientalistes de France |1988|.
22. Tamba, Akira : *Japon/Japan. Gagaku. Ensemble Ono*, Audio CD, Gallo-Vde MEG-AIMP CXI / VDE-1466 |2015-11-26|.
23. Tokumaru, Yoshihiko : "Le timbre dans la musique japonaise", *Le Timbre: métaphore pour la composition*, ed. Jean-Baptiste Barrière, Ircam-Centre Pompidou/C. Bourgois |Paris, 1991|.
24. Tokumaru, Yoshihiko : *L'aspect mélodique de la musique de syamisen*, *Ethnomusicologie* 6, Peeters |Paris, 2000|.
25. Tukitani, Tuneko, Tôru Seyama, Satosi Simura and Riley Kelly Lee : "The *Shakuhachi* : The instrument and its music, change and diversification", *Contemporary Music Review 8 2* |1993-1| [doi: 10.1080/07494469400640091] p. 103–129.
26. Weisgarber, Eliott : "The *Honkyoku* of the *Kinko-Ryū*: Some Principles of Its Organization", *Ethnomusicology 12 3* |1968| [doi: 10.2307/850029. url: http://www.jstor.org/stable/850029] p. 313–344.

Dossier: *MAT for the VIAMAP*

Maqām *Analysis Tools for the Video-Animated Music Analysis Project*

Amine Beyhom[*]

"The Pythagorean's opinion that the planets and the stars, while following their course, produce sounds which combine harmonically is erroneous. In Physics, it is proven that their hypothesis is impossible, that the movement of heavenly bodies can generate no sound at all. Nearly everything that concerns music theory is a product of the Art, and foreign to Nature"

[*Shaykh* Abū-n-Naṣr Muḥammad ibn Muḥammad ibn Tarkhān al-Fārābī, *The Great Book of Music*][1]

"There is a tradition – which could even be taken as central to Occidental culture – according to which rational music would only be the reflection of a more intellectual reality, expressible by means of numbers. This is what one would construe as Pythagorean tradition"

[Jean Molino, "Expérience et savoir"][2]

Introduction[3]

"Neo-Pythagoreans aside, music is man-made. Music is a product of culture, not of nature"
[George List, "The Musical Significance of Transcription"][4]

Musical notation has been reputed as disqualified for the analysis of "Foreign" musics since – at least – the experiments of Charles Seeger with the Melograph. It is nevertheless still used as the main analytic – and teaching – tool for these musics in most researches in musicology, and today in the teaching of these musics in autochthonous conservatories.[5]

Seeger's experiments brought at his time cutting-edge solutions – and alternatives – to score notation but, surprisingly enough, these solutions seem to have not worked out very well in the long run.

Not surprisingly, however, the explanation of such a persisting situation could be found in the Orientalist foundation of ethnomusicology, while musicology as such was borne to Western music – and score notation.[6]

This dossier relies on the pioneering works of Seeger and other ethnomusicologists and on the improvements of his method that we have witnessed in the last decades. It is accompanied by a short power point show (PPS) and 41 video-animated analyses[7]. It describes, *in fine*, the author's work and propositions for the implementation of video-animated analyses in the teaching of ethnomusicology – as one major basis for this teaching.

[*] Amine Beyhom is Chief Editor of NEMO-Online and director of the CERMAA (Centre de Recherche sur les Musiques Arabes et Apparentées), a research center affiliated to the FOREDOFICO foundation in Lebanon. The author wishes to express his heartfelt thanks to François Picard and Wim van der Meer who reviewed this dossier and made critical remarks and suggestions. Additionally, Meer's insightful propositions helped enlarging the scope of the dossier and complementing it.

[1] (Al-) Fārābī in [Erlanger, 1930, p. 28]. Fārābī's influence on "Middle-Age" European scholars is not to be underestimated (see for instance [Carpenter, 1954, p. 128–129] on Johannes de Grocheo's *Theoria*), although Pythagorean thought predominated in the study of music in Europe.

[2] [Molino, 1995, p. 112].

[3] This dossier expounds some of the latest achievements in graphical Computer-aided Pitch analysis of melodic contours. It would have not been possible to establish these tools were it not for the pioneering work of Wim Van der Meer whose web publications (see notably [Meer ; Meer, 2015 ; Meer, 2018a], based originally on Seeger's work with the Melograph – see Part I of this dossier) inspired the author for his work on pitch analysis of *maqām* music. Likewise, Meer would not have achieved all the developments proposed in the abovementioned references were it not for the existence of the program Praat, a computer program developed by Paul Boersma and David Weenink for speech analysis (see http://www.fon.hum.uva.nl/praat/) – which was first used by Meer, to the knowledge of the author, for music (melodic) analysis.

[4] [List, 1963, p. 196].

[5] This was also the observation of Bruno Nettl back in 1983 – see [Nettl, 1983, p. 80–81].

[6] This is mainly tangible in the discussions on the use of score notation for the analysis of extra-western musics referenced – and partly cited – in Part I of this dossier, and in the aforementioned book (previous footnote) of Bruno Nettl.

[7] Of which 9 previously published (in February 2018), and the rest for this dossier.

The first part consists of a retrospective on the "virtues" of score notation applied to "foreign" musics and the problems raised and discussed by this notation – mainly in the 20th century.

The second part is mostly based on previously published material[8] and is a relatively short retrospective on the different notations used in autochthonous musicology of the *maqām*, from the known[9] beginnings (al-Kindī) till today.

The third part outlines some of the improvements brought to the "Seeger Solution"[10] – from rudimentary analyses that can be found in the "literature"[11] to the *Music in Motion*[12] website resulting from research by Wim van der Meer and Suvarnalata Rao, and expounds the further developments[13] undertaken in the CERMAA[14] in Lebanon.

The most important part of this dossier, however, lies not in the written text – or in the accompanying figures, but in the videos themselves – which are (intended, eventually, as) self-explanatory.[15]

* * *

Part I. About the transcription of "foreign" musics and the virtues of notation

"The new art of music is derived from the old signs – and these now stand for the musical art itself"

[Ferruccio Busoni, "Sketch Of A New Esthetic Of Music"][16]

"Notation […] serves the theorist as a medium by which to demonstrate musical […] laws"

[Bent et al. in the entry "Notation" of the *New Grove*][17]

"[S]cience […] is supposed to be cumulative, explicit, predictive*, and* empirically testable*"*

[Daniel Hirst, "The analysis by synthesis of speech melody: from data to models"][18]

"The important thing is to recognize the falsification for what it is, and not to confuse the imaginary objects of music with the temporal experiences for which they stand […]. [T]he score conceals as much as it reveals"

[Nicholas Cook, *Music: a very short introduction*][19]

"The map is not the territory"

[Alfred Korzybski, "A Non-Aristotelian System and its Necessity for Rigour in Mathematics and Physics"][20]

[8] But which was never put together, and even less in one single language.

[9] And extant.

[10] As it was named by Mantle Hood – cited in Part I of this dossier.

[11] Are audio-visual products and the internet still to be called as such?

[12] https://autrimncpa.wordpress.com/.

[13] Which take the lion's share in this third – written – part.

[14] Reminder: the CERMAA (Centre de Recherche sur les Musiques Arabes et Apparentées) is the research center on music under the Lebanese FOREDOFICO foundation for the arts.

[15] The reader can watch the videos in parallel to the text, or watch them then come back to the text, or even read the text then watch them – whatever order he chooses, this is not a classical musicological discourse, so the author's plea is: "please watch the videos".

[16] [Busoni, 1911, p. 16].

[17] [Bent et al., 2001].

[18] [Hirst, 2012, p. 57]. Or: "It is crucial, in order to avoid misunderstandings, that the word 'scientific' […] be understood […] as 'investigations aimed at acquiring accurate knowledge of factual matters relating to any aspect of the world by using rational empirical methods analogous to those employed in the natural sciences'. Alternatively, one could use the phrase evidence-based worldview" – [Sokal, 2008, p. 14].

[19] [Cook, 2000, p. 71, 81].

[20] [Korzybski, 1931].

About notations of music[21]

The author firmly believes that music is an art, which may be structured by rules – of composition, of performance, of social behavior – but never by "laws".[22] Musicology, on the other side, is supposed to be a science, which means that it should use scientific tools for the research of music. The major "scientific tool" of classical musicology – and of ethnomusicology – for the analysis of music is – still – score notation.

Molino[23] clearly places written languages, and the process of writing music as such, at the center of Max Weber's reflection on (the superiority of Western) music. Let us however remember that musical notation[24] is not a western exclusivity: many non-European, non-Western notations have been invented throughout history and are still being used throughout the world, be it for pitch (or beat, or interval) and duration or instrumental – such as tablatures and other instrument-specific oriented notations.[25]

Musical notation can further be absolute or relative, normative or indicative. Its usefulness seems, at first sight, obvious: it allows for a visual (sometimes graphical) consignation of a music piece – or of one possible, specific or standardized version of it – and for sharing it with other musicians or musicologists who can decipher it.[26]

[21] This section does not aim to supplement major articles and books about the notation of music readily available to musicologists, but to serve as a reminder to the reader about the goals and the different forms of notation.

[22] Colleague and friend Richard Dumbrill rightly here raised the question of the overlapping meanings of "law" and "rule" in English (but also in most other languages). "Rule" is multiply defined in the Merriam-Webster dictionary (see https://www.merriam-webster.com/dictionary/rule), notably as:

"1 a: a prescribed guide for conduct or action

b: the laws or regulations prescribed by the founder of a religious order for observance by its members

c: an accepted procedure, custom, or habit

d (1): a usually written order or direction made by a court regulating court practice or the action of parties

(2): a legal precept or doctrine

e: a regulation or bylaw governing procedure or controlling conduct".

I use here the term "rule" as in 1a and 1c in the definition above, and partly as 1e. I would like to remind also that, while acoustic laws may play the role of a *guide* for musicians and composers (see notably the Synthesis of [Beyhom, 2017]), this role is limited and is frequently superseded by the role of heterophony and by the inharmonism which is intrinsic to most instruments of the world (see here notably the role of timbre in the perception of pitch and how harmonics influence it in [Plomp, 2002]). The western evolution towards the use of "harmonic" instruments, together with the use of electronic instruments with near-perfect sound spectrum, precipitates today a similar evolution for instruments of music in the world – with notable exceptions that I shall not cite here. Let's remember also that while rules can be broken, laws cannot (or should not) be breached; laws can however always be circumvented, especially in the Arts, especially in music. I would even add that circumventing the laws of acoustics is a sport which suits well modal – and particularly *maqām* – music, as I explain in the aforementioned "Synthesis".

[23] [Molino, 2008].

[24] A general theory on Symbol Systems is expounded in Nelson Goodman's *Languages of Art*, and more specifically for notational systems in [Goodman, 1968, p. 127–173] – as for Goodman's theories and thought, see [Giovannelli, 2017]. Notation is defined in the *New Grove* – [Bent et al., 2001] – as "a visual analogue of musical sound, either as a record of sound heard or imagined, or as a set of visual instructions for performers".

[25] One reference book on (Western) Early notations is [Apel, 1961], while [Atkinson, 2008] explains the interaction(s) between Early notation(s) and the modal system of European music in practice. Short – and useful – general retrospectives on musical notation(s) are available in [Cook, 2000, p. 51–63], in https://www.mfiles.co.uk/music-notation-history.htm, and in [Wikipedia Contributors, 2018b] in which, however, Byzantine notation as such is disregarded to the benefit of the Russian *znamenny* notation (FHT 1: 207 – "FHT" stands for "Figure Hors Texte" or "Plate") which derives from it (see https://churchmotherofgod.org/orthodox-terminology/glossary-z/918-znamenny-notation.html – accessed 07/01/2018, notably: "[w]hile in its initial form it was borrowed from Byzantium, *Znamenny Notation* underwent an evolutionary process in Ancient Rus', and towards the 15th-16th centuries lost its connection with Byzantine notations") – see also for the *znamenny* notation and its history https://web.archive.org/web/20130613084202/http://www.churchofthenativity.net/old-rite/znamenny and subdivisions and links shown on this archived page. In Walter Kaufmann's *Musical notations of the Orient* [Kaufmann, 1967] different Chinese (for these notations see [Picard, 1999] – in French), Indian and Korean notations and tablatures are also described; a special *tanbur* tablature (see [Matyakubov and Powers, 1990]) was devised in the 19th century Khorezm (also "Khwarezm", an oasis region today belonging partly to Uzbekistan, partly to Kazakhstan and partly to Turkmenistan – see [Wikipedia Contributors, 2018a]) and is expounded in Part II of this dossier; there even exists "turntablatures" for DJs as explained in [Miyakawa, 2007]; see also [Lee, 1988] for the changes induced in the *honkyoku* (*shakuhachi*) repertoire in Japan by the use of Western notation and principles, [Lependorf, 1989] for the inclusion of the techniques of the *shakuhachi* in Western notation and [Deschênes, 2017] for a contradictory view; a short description of Japanese notations is also available in [Berger, 1969, p. 33–34].

[26] Here is the complete definition in the *New Grove* of the use(fullness) of notation – with which I do not agree completely: "Broadly speaking, there are two motivations behind the use of notation: the need for a memory aid and the need to communicate. As a memory aid, it enables the performer to encompass a far greater repertory than he or she could otherwise retain and realize. It may assist the performer's memory in music that is already basically known but not necessarily remembered perfectly; it may provide a framework for improvisation; or it may enable the reading of music at sight (this last concept is a predominantly Western one). A written notation provides the means to sketch and draft musical ideas during the composing process. As a

It also allows musicians (and performers) to work together on the basis of a written document shared by all, or for a specific musician/composer to consign in written form subtleties of interpretations, or (notably for a composer) whole music pieces which he would reluctantly entrust to his memory alone, etc.[27]

Western musical notation, in its mainstream use today – I mean by that as employed in Common-practice Western (or today World) music – is specifically based on (absolute) pitch and duration. Its usefulness – even when modified and adapted – for other types of music is debatable (and debated) as can be inferred from the quotes reproduced in the next section.[28] Moreover, this notation has been used, along with the forged Hellenistic legacy and the theories of the scale in western music(ology), as a privileged tool for Occicentrism.[29]

In the next section, different approaches to the transcription of non-western music are expounded, with a focus on the 1960s and 1970s in which this question was hotly debated – notably in the United States.

Prescriptive or Descriptive?

Two main milestones for notating "exotic" musics from the beginnings of the 20th century[30] consist in the works of Abraham and Hornbostel, then Béla Bartók.

These authors thought – as many after them – that the use of additional accidentals and indications in the score (Fig. 1) could suffice for a correct reproduction of the music they heard.[31]

means of communication, it preserves music over a long period; it facilitates performance by those not in contact with the composer; it equips the conductor with a set of spatial symbols by which to obtain certain responses during performance; it presents music as a 'text' for study and analysis, and offers the student the means of bringing it to life in his or her mind when no performance is possible; and it serves the theorist as **a medium by which to demonstrate musical** or acoustical **laws**" – [Bent et al., 2001]. (Bold font is mine: note that music has "laws" – and not "rules" – in this widely consulted reference.)

[27] "[S]igns of [music] are everywhere – in scores, books, instruments – and yet they aren't the music. You can't point to the music, or grasp hold of it, because as soon as it has come into being it has already disappeared, swallowed up into silence, leaving no trace. […] And what are [scores] for, what work do they do within our musical culture? You might say that they serve three distinct functions. One, the most obvious, is conservation: like photographs, they stop time in its tracks and give a stable, visible form to the evanescent. The second is almost equally obvious: they are a means for the communication of music from one person to another, for example (but it is only an example) from composer to performer. The third is less obvious but at least as important as the other two: in many traditions, notation is integral to the conception of music, to the ways in which composers, performers, and others who work with music, imagine or think about it" – [Cook, 2000, p. 51].

[28] "[M]usical notations are highly specific about what they will or will not record; they are more like filters or prisms than DAT recorders or samplers. And ethnomusicologists, who use essentially Western techniques to study non-Western music, are more aware of this than anyone. Some ethnomusicologists are prepared to use staff notation to transcribe the music they study, as a means both of understanding it and of communicating that understanding to their readers. But they are painfully conscious that in doing this they are shoehorning Indian or Chinese music, or whatever it might be, into a system that was never designed for it. For instance, staff notation treats all music as if it were made up of separate notes each a set distance apart; in effect it assumes that all instruments work on the same principle as the piano, which has a separate sound-producing mechanism for each of the eighty-eight notes it can play. But many instruments are not like this; on the violin you can play any number of pitches between a B and a C, say, or you can slide continuously from the one note to the other so that there is no way in which you can say exactly where the B ended and the C started. The same applies to the human voice, or the electric guitar if you bend the note. And the point is that in Indian and Chinese music it is often the notes between the notes, so to speak, that are responsible for the effect of the music. Similarly in florid singing (and again Indian music is a good example) trying to say where one note starts and another stops, as 'note' would be defined in terms of staff notation, becomes a completely arbitrary exercise; the music just doesn't work that way. There is a collision between music and notation".

As a conclusion: "Predictably, this situation has resulted in endless controversies between those ethnomusicologists who see staff notation as a blunt but necessary instrument for conveying something of the music to readers unfamiliar with the notational system (if any) of the musical culture in question, and those who regard its use as a kind of neo-colonial exercise in which Western notation is set up as a universal standard" – [Cook, 2000, p. 58–59].

[29] See [Beyhom, 2016a]: Occicentrism is – in short – Western ethnocentrism; see [Sachs, 1976] for "Europocentrism" (which is much the same thing, but goes back in time somewhat farther).

[30] The author will evidently not examine here simple transnotation of "Foreign" – and in particular – *maqām* music in Western notation (see for example fn. 252 in [Beyhom, 2016a] with the quote from [Pasler, 2012]), which fully neglects the intonations of the transcribed musics to conform them to Western – unaltered – staff notation. I shall also pass on early attempts such as Villotteau's and Kiesewetter's in [Villoteau, 1826 ; Kiesewetter, 1842], etc., and concentrate on the more general problematic of the notation of non-western (or non-conventional – *i.e.* "popular", "traditional", if not the even more unflattering "Folk") musics.

[31] See the various recommendations in [Abraham and Hornbostel, 1909, p. 6], translated as [Abraham and Hornbostel, 1994]. As for Béla Bartók, he started by using quarter-tone accidentals such as #/2 and b/2, with ↑ and ↓ to raise or lower less than a quarter-tone, then came back to the ↑ and ↓ applied, this time, to quarter-tone accidentals while using literal indications for other divisions of the tone – as can be inferred from [Somfai, 1996, p. 269].

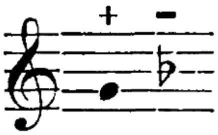


Fig. 1 Recommended use of the plus and minus signs in the key signature of a score for raising or lowering all corresponding notes in "exotic" melodies – [Abraham and Hornbostel, 1909, p. 6].

Hornbostel further embraced Ellis' division of the (tempered) semi-tone in cents,[32] and warned against the "natural" western bias towards the interpretation of foreign melodic musics through the western looking glass but,[33] as meticulous and comprehensive as he and Abraham may have been in their "*Vorschläge fur die Transkription exotischer Melodien*"[34] the two authors, by promoting western notation[35] – even by modifying and supplementing it – for the comprehension and analysis of music(s) from "other cultures", strengthened the analytical biases of Orientalist musicology.

Abraham and Hornbostel were intellectual and academic representatives of their century and their culture:[36]

> "The increasing interest of ethnologists and musicologists in the music of non-European cultures has stimulated more and more field workers, missionaries, and colonial officials to make acoustical recordings of the songs and instrumental music of natives and to turn over the results of these activities to scientific institutions for study".[37]

Even more interesting in this article is the translators'[38] comment, in the review *Ethnomusicology*, stating:

> "[this] article contains a number of penetrating observations whose value time has not diminished",[39]

while, however:

> "[t]he authors also included materials concerning the development of scales and the classification of musical genres which many would not now consider part of the transcription process as such".[40]

In the case of Hornbostel, openness to other cultures can at least not be denied as he states in a later (if not next[41]) article:

[32] [Hornbostel, 1927].

[33] "By overwhelming habit we have become unable to assess a melody purely melodically without reinterpreting it according to our tonal system and an assumed harmonic accompaniment" – [Hornbostel, 2017, p. 11].

[34] [Abraham and Hornbostel, 1909]: these authors had previously explored methods for transcribing "exotic" music in voluminous articles such as [Abraham and Hornbostel, 1903 ; Abraham and Hornbostel, 1904]. In the latter article, examples of Indian music in plain western notation are found on almost every page, while the authors undertake [p. 380-388] a long discussion the purpose of which is to deny the existence of the "21-steps scale" (theoretically, if not practically, 22-steps = *śrutis* – see for example the second part of [Beyhom, 2012]) in Indian music, the main scale of which would have been identical to the western "diatonic" scale [p. 383] and based on a twelve-semitones division of the octave. In a later article [Abraham and Hornbostel, 1905] both authors acknowledge a possible western influence on Indian music, while Hornbostel wrote one year later an article on Tunisian music entitled "*Phonographierte tunesische Melodien*" [Hornbostel, 1906] in which he also used western notation but acknowledged that the intonations in the analyzed melodies did not correspond to the Western tempered (or even "harmonic") scale. This is also the conclusion of a recent Ph.D. thesis [Zouari, 2014] about Tunisian music conforming gradually – at least since the beginning of the 20th century – with the equal-tempered western scale.

[35] In their "Suggested Methods for the Transcription of Exotic Music", namely: "[T]he peculiarities of musical expression of differing cultures can be reproduced more or less faithfully only by European notation which is appropriately modified and supplemented. It is indispensable to notate the melodies whether the purpose is to study them or to convey them to others" –[Abraham and Hornbostel, 1994, p. 427].

[36] And they were near-contemporaries to writings such as Baker's Ph.D. thesis [Baker, 1882] on the "Music of the North-American Savages" which they cite in [Abraham and Hornbostel, 1903, p. 342], and the introduction of which begins [p. 1]: "Through music, as well among savages as among cultivated folk, the expression of feelings gain in intensity, which they can not share with words and gestures alone. The Savage, however, instead of the variety of feelings, which is vivid in the civilized world, feels relatively few spiritual and sensual drives, in which his language, as well as his music – the language of feelings – remains simple and limited". This appreciation remains far more "open" to the "music of the savages" than the quote of Hofmann by Hornbostel reproduced farther. It shows however a persistent need to distinguish between "Art" music and other musics. It could also be compared, by its occicentrism, with the conclusion of another "Anthropologist" at the same period: "when savage man makes music spontaneously he obeys the universal law of all activity and follows the line of least resistance, and that in every instance this line is found to be a chord line, a harmonic line. Folk-melody, so far as now appears, is always and everywhere harmonic melody, however dim the perception of harmonic relations, and however untrained and inexperienced as regards music the untaught savage may be" – [Fillmore, 1899, p. 318]. Note that this belief in the universality of Western canons in music persists today with some authors, as in Schenkerian analysis applied in [Stock, 1993] to "Foreign" musics.

[37] [Abraham and Hornbostel, 1994, p. 426].

[38] George and Eve List.

[39] [Abraham and Hornbostel, 1994, p. 425].

[40] [Abraham and Hornbostel, 1994, p. 426].

[41] The original article "'Über vergleichende akustische und musikpsychologische Untersuchungen.' *Beiträge zur Akustik und Musikwissenschaft* 5, 1910, 143–167" was published one year after the "*Vorschläge …*". It is here quoted from the translated version [Hornbostel, 2017].

> "the scholarly potential offered by non-European tonal art has been badly underestimated. To some extent, misled by melodies notated merely by ear and therefore often unwittingly translated into European ones, one believed the musical language of all peoples to be a natural universal language. Further, the analysis of dialectal differences, which were discernible after all to be a narrowly confined special field of musicology, was considered completely extraneous to psychology. These conclusions occurred precisely because the psychic fundamentals of all music were regarded as universally human. To some extent one believed what the 'savages' produce to be nothing but noise and nasty sounds, at the most comparable to the utterances of animals, but not to our tonal art",[42]

adding here a footnote:

> "Thus, as recently as 1908 an author writes: 'Many peoples have hardly reached the first step of musical development so that their musical achievements are considerably surpassed by those of certain birds. Many still do not have a pronounced tonal system, many perform a completely non-rhythmic music which either sounds appallingly monotonous or constitutes a raving chaos of tones.' (B. Hofmann, Kunst und Vogelgesang [Art and Bird Song]. Leipzig 1908, p. 164.)".[43]

Today, the use of adapted accidentals for non-conventional – and not only "Foreign" – musics[44] has probably reached its climax[45] but it should be not forgotten that staff notation

> "is a systemically conditioned mnemonic aid and not a scientifically valid, intrinsically logical, fully objective or universally applicable communications code",[46]

and that the memory of a regular musician is mostly unable to embrace dozens of accidentals, which, furthermore, are – generally – not created in the aim of describing the music, but of prescribing it.

Beyond the pioneering writings of the historical ethnomusicologists (till the 1930s?), the use of western notation to describe non-western music has been seriously questioned, as soon as after WWII, for example by Curt Sachs and Charles Seeger.[47]

In Curt Sachs' *The Wellsprings of Music* we find:

> "Only he who knows the pitfalls of western habits and has learned to escape them is up to such intricate, delicate work and can hope to do justice to eastern and primitive music. And even such a man is far from being infallible. When we compare an original phonogram with a transcription made by another person, we will more often than not disagree. This is not necessarily a question of keener ears, but rather of the analytical apparatus in the brain – just as two painters of equal ability (and even photographers) might be at variance in seizing the likeness of a model. Indeed, our own transcriptions will often be unsatisfactory when we resume and revise the work of yesterday. One cannot too earnestly warn the student against accepting printed transcriptions as gospel truth",[48]

while in his "Prescriptive and descriptive music writing" Charles Seeger (Fig. 2) explains:

> "[A]s we find it today, our conventional notation is still a mixed symbolic-linear music-writing in which the symbolic element is the more highly organized and therefore dominates. […]. It does not tell us as much about how music sounds as how to make it sound. Yet no one can make it sound as the writer of the notation intended unless in addition to a knowledge of the tradition of writing he has also a knowledge of the oral (or, better, aural) tradition associated with it – i.e., a tradition learned by the ear of the student, partly from his elders in general but especially from the precepts of his teachers. For to this aural tradition is customarily left most of the knowledge of 'what happens between the notes' – i.e., between the links in the chain and the comparatively stable levels in the stream. In employing this mainly prescriptive notation as a descriptive sound-writing of any music other than the Occidental fine and popular arts of music we do two things, both thoroughly unscientific. First, we single out what appear to us to be structures in the other music that resemble structures familiar to us in the notation of the Occidental art and write these down, ignoring everything else for which we have no symbols. Second, we expect the resulting notation to be read by people who do not carry the tradition of the other music. The result, as read, can only be a conglomeration of structures part European, part non-European, connected by a movement 100% European. To

[42] [Hornbostel, 2017, p. 1–2].

[43] [Hornbostel, 2017, p. 2].

[44] But in conventional Western notation.

[45] See for example the document entitled "The Extended Helmholtz-Ellis JI Pitch Notation – microtonal accidentals designed by Marc Sabat and Wolfgang von Schweinitz, 2004" [Sabat and Schweinitz, 2004] (see also http://www.marcsabat.com/ – accessed 29/12/2017) with dozens (more than 75) accidentals and combined accidentals to describe Pythagorean intervals.

[46] [Cazden, 1961, p. 117].

[47] Sachs' *Wellsprings of Music* was edited by Jaap Kunst and published posthumously (both Sachs and Kunst had passed away at the time of publication, Sachs on the 5th of February 1959 – see [Kunst, 1959] – and Kunst on the 7th of December 1960 – see [Wikipedia Contributors, 2017d]) in 1962. It may have been completed (well) before the publication of Seeger's seminal article in 1958.

[48] [Sachs, 1962, p. 22–23]: part of this quote and the following quote (by Seeger) are the initial (epigraph) quotes for the article of Udo Will "La baguette magique de l'ethnomusicologue. Repenser la notation et l'analyse de la musique" [Will, 1999b], translated into English in [Will, 1999a].

such a riot of subjectivity it is presumptuous indeed to ascribe the designation 'scientific'".[49]

Fig. 2 Photograph of Charles Seeger, philosopher, musicologist, ethnomusicologist, political activist.[50]

The use of western notation to describe non-western musics was further criticized by ethnomusicologists such as Mantle Hood and James Reid, thus in the first's "Musical significance":

> "The constant and justifiable complaint about the inadequacies of musical notation indicate a great reservoir of energy which could be more profitably applied to the task of finding some constructive solution. Personally, I would rather attempt interplanetary flight in a Wright Brothers' plane than to continue doctoring the five-line staff with the mystical signs of diacritical annotation",[51]

and in Reid's "Transcription in a New Mode":

> "The case for Western notation rests essentially on three points:
>
> 1) 'Universality,' that is, the assertion that Western notation is the best medium for transcription of non-Western music because 'all' trained musicians can already read it. They are thus spared the time-consuming trauma of learning some other system, and their time can be fully devoted to the unimpeded examination of their material.
>
> 2) 'Adaptability,' the assertion that Western notation can be altered (in Hood's word 'doctored') with various symbols to represent the many elements of non-Western music that resist normal transcription.
>
> 3) 'Accuracy,' the notion that Western notation is 'accurate and reliable enough' for ethnomusicological purposes, and in any case allows for a consensus of scholars to decide what is meant by a given transcription […].
>
> None of these arguments will stand close examination".[52]

The continued use of this same Western notation for the analysis of *maqām* music[53] – among other non-Western musics – is but one additional symptom of the persistence of Orientalist musicology: the more when this notation is used by autochthonous *maqām* musicologists and musicians as the basis for their teaching.

Whenever Abraham and Hornbostel stated in 1909 that it was

> "indispensable to notate the [exotic] melodies whether the purpose is to study them or to convey them to others",

the question that remains asked is, "why did these intelligent and highly educated academics which believed in progress not realize that the best way of 'conveying' melodies was to simply provide recorded examples (or copies) of those?".

As for the western notation system as the only (reliable?) method of analysis ["study"] for such melodies…

Problems raised by transcription (and notation) as further analyzed by Western ethnomusicologists

Seeger's "Prescriptive and Descriptive Music-Writing" – quoted above – triggered numerous responses.

In Mantle Hood's 1971 *The Ethnomusicologist*,[54] a complete chapter is dedicated to "Transcription and Notation" with a presentation of the problems and, under the subtitle "The Chronic Problem of 1893", of three "solutions" respectively entitled "The Hipkins Solution", "The Seeger Solution" and "The Laban Solution".

"The Problem of 1893" was stated about Japanese music by Francis Taylor Piggott[55]:

[49] [Seeger, 1958, p. 187]. Note that, apart from being one of the founders of the Society for Ethnomusicology in 1953 (as noted in https://www.ethnomusicology.org/page/History_Founding? accessed 15/07/2018), Seeger was also one of the founders of the American Musicological Society in 1934 as explained in [Crawford, 1984, p. 1] (and before that – also in 1934 as concluded from [Crawford, 1984, p. 9] – of the American Association for Comparative Musicology). {See also [Fraser, 1979] and, about the legacy of Charles Seeger [Anon. "How Can I Keep From Singing? A Seeger Family Tribute (The American Folklife Center, Library of Congress)"; Anon. "Seeger Family Concert"].}

[50] Downloaded 23/01/2018 from https://upload.wikimedia.org/wikipedia/commons/0/0f/Charles_Seeger.jpg.

[51] [Hood, 1963, p. 190–191].

[52] [Reid, 1977, p. 416].

[53] Notably in most dissertations and research in the French academic system – not to single it out, but as an example with which I am most familiar.

[54] I am using here a further edition [Hood, 1982].

[55] Here quoted by Hood.

> "To the many beauties, and to the great merits, of the structure which has been raised upon [the rudiments of this music][56], only my own ears can bear witness. The difficulties which stand in the way of reducing the music into Western written forms are so great, that, unless Japanese musicians will come and play to us here in England [for the English], accurate knowledge of their art, due appreciation of their craft, can only come into being in the West very gradually… Much of the charm of the music, all its individuality, nearly, depend upon its graceful and delicate phrasing: and although I think that Western notation is capable of expressing these phrases to one who has already heard them, I feel a little uncertain whether their more complicated forms could be set down in it with sufficient accuracy to enable a stranger to interpret them satisfactorily".[57]

Hood comments:

> "As an essayist, I am not sure whether it is reassuring or discouraging to point out that almost a century later we are still concerned with the same chronic problem".[58]

While pinpointing the persistence of Occicentrism ("ethnocentric prejudice") in matters of scales and tunings,[59] Hood begins unfolding his "Solutions" with a quote from Alfred Hipkins'[60] Introduction to Charles Russel Day's *The music and musical instruments of southern India and the Deccan*:

> "[Day] shows us the existence of a really intimate expressive melodic music, capable of the greatest refinement of treatment, and altogether outside the experience of the Western musician. What we learn from such inquiries is that the debated opinions of musical theorists, the cherished beliefs of those who devote themselves to the practice of the art, the deductions we evolve from historic studies—all have to be submitted to larger conceptions, based upon a recognition of humanity as evolved from the teachings of ethnology. We must forget what is merely European, national, or conventional, and submit the whole of the phenomena to a philosophical as well as a sympathetic consideration, such as, in this century, is conceded to language, but has not yet found its way to music".[61]

Hood deems performance (learning the music) a first approach to music(s) along with – as a second approach – the search for written descriptions of the tunings and scale systems and – as a third approach – the implementation of the "Hipkins Solution" by ethnomusicologists.

While noting that

> "The usage of some form of modified Western notation for transcription purposes, in spite of the fact that its limitations are generally understood, tends to be self-perpetuating",[62]

he reminds of the "Seeger Solution" which tries to take into account the subjectivity of the hearing of the ethnomusicologist who is conditioned by his culture and must try to "hear beyond" it, notably with the use of electronic devices, namely the Melograph Model C.[63]

[56] Inclusions between brackets are by Mantle Hood.

[57] Original quote in [Piggott and Southgate, 1893, p. 5]; Hood's reproduction in [Hood, 1982, p. 85]. Note that Seeger's formulation quoted above conveys the same questioning as Piggott's.

[58] [Hood, 1982, p. 85].

[59] [Hood, 1982, p. 87].

[60] Hipkins collaborated notably with Ellis as in [Ellis and Hipkins, 1884] in which they noted, [p. 372] among others, the correspondence between the "Highland Bagpipe scale" and the "Damascus form of Zalzal's scale". (Manṣūr a-ḍ-Ḍārib Zalzal – or Zulzul? – was a famous *ʿūd* player in the Golden Age of Arabian civilization who has supposedly introduced the "neutral" intervals in performance.) As he himself states in [Hipkins, 1903, p. 372–373], he also "had some share" in Ellis' lecture "On the Musical Scales …" [Ellis, 1885].

[61] In [Day, 1891, p. xii], [Hood, 1982, p. 90].

[62] [Hood, 1982, p. 92].

[63] Note also the works of Edith Gerson-Kiwi in this field, notably [Gerson-Kiwi, 1953]. Note that [Hood, 1979, p. 78] describes the pros and cons of Melograph Model C: "A vital core of twenty-five years of friendship was the eleven years of our association in the famous Wednesday seminars at UCLA. Charles dubbed me the 'orchestrator' of those weekly meetings of twenty-five to thirty graduate students, Seeger himself, Klaus Wachsmann, Leon Knopoff, Jozef Pacholczyk, Bill Hutchinson and colleagues on sabbatical from round the world who, at first, were usually shocked by unabashed equality in discussion held among students and professors. In a lecture given much later at UCLA, Klaus Wachsmann referred to those years as the Golden Age of ethnomusicology. Out of this period came the Seeger Melograph Model C. He and I made an exhaustive search for funds at such likely places as the National Science Foundation in Washington, D.C., where we were told that if we needed a fleet of automobiles, air conditioning, an added wing on an existing building, there would be no problem. But a laboratory instrument? In the name of music research? Impossible! We heard the word 'no' from many sources, until one day an impassioned plea to Chancellor Franklin Murphy prevailed. He immediately understood (being an M.D.) the importance of this development when we compared the existing tools of music research to the magnifying glass and Model C to an electron microscope. Subsequently, in the discovery of research, development and testing of Model C, we even began plans for [Melograph] Model D. Of course, they were never realized. **On the contrary, a few years ago, even Seeger Melograph Model C was dismantled**. Sent to the Physics Department for an estimate needed for repair, it was cannibalized instead. Seeger talked to one of the physicists who praised its unique camera developed for Model C which, today, is part of some unrelated research tool in physics. Professorial ignorance of our field and administrative indifference have forced us back to the crudities of the magnifying glass in music research. Notwithstanding Metfessel's indisputable demonstration and Seeger's internationally hailed developments of an automatic music writer, we have turned back the clock more than fifty years. For shame! After the brief period of revelations realized on Model C, we know there can be no 'scientific' research in music without its equivalent or better". (Bold font is mine in all quotes of this dossier except otherwise stated.)

As for the "Laban Solution", to the future of which the "Hipkins Solution" and the "Seeger Solution" – because of the international orientation of the first and of the descriptive accuracy of the second – are important, it is expected to be based on the Labanotation system[64] used for dance, in which various characteristics (such as pitch, dynamics, density, etc.) would be notated graphically. No concrete example of this "future" notation is, however, provided by Mantle Hood in the closing pages of this chapter on transcription and notation.[65]

Fifteen years after Seeger's "Prescriptive and Descriptive Music-Writing" Simha Arom explained[66] his use of field-recording technology with the sole aim of establishing [p. 166] a "score", which in his view is a "synthesis" of the music he studied.[67] This seems a reversal of his previous views on notation as, few years before this article – and two years before the publication of Mantle Hood's *The Ethnomusicologist* – Arom proposed in his "*Méthodes d'analyse en musicologie*"[68] an elaborated "new" transcription method for melodies (only), based partly on Jean-Jacques Rousseau's numeral notation expounded in the latter's "*Dissertation sur la musique moderne*"[69] and partly on Nicolas Ruwet's propositions for a "paradigmatic analysis"[70] of melodies.[71] The essence of this method is the use of successive numbers which are substituted to the notes of the score on the basis of a tonic note (numbered 1) with equivalences of the notes to the (upper or lower) octaves, differentiated by upper or lower (simple or double – for double octaves) lines.[72] The basis scale (1 2 3 4 5 6 7) is, obviously for Arom, the major scale with accidentals – when they exist – expressed with oblique bars crossing the numbers.

Arom explains this choice through the comparison of the use of the notation system for the purposes of composition in western music, on one side – which is to convey the idea of the composer to the performer(s) in such a way as they would be able to reproduce the music he composed, whenever for an ethnomusicologist the aim is the opposite: transcribing live music in order to be able to understand the underlying "code" which rules it.[73]

Arom further explains that he rejected from the outset the possibility of an intervallic transcription[74] because:

[64] See for example [Wikipedia Contributors, 2017a] or the writings of Ann Hutchinson-Guest, Albrecht Knust or of the main developer of the notation, Rudolf Laban.

[65] Hood's three "solutions" are also summarized in [Reid, 1977, p. 418–419]: "The first of these solutions […]: we should provide the original, indigenous notation where such a notation exists and teach our colleagues how to read it. [… T]he use of mechanical transcription to unravel the detail of the musical performance. […] The need still remains for Hood's projected third solution, a universal system of manual music notation. Hood suggests that the solution may be found in an adaptation for music of the admirable Labanotation now in use for dance". Reid himself proposes a mixed solution using graphical (tonograms of pitches) and numbered notation.

[66] In [Arom, 1973].

[67] In the emendated English translation of this article [Arom, 1976, p. 483] Arom's position is even more clearly stated: "[T]he sum of the parts [of the polyphonic or the polyrhythmic music] in their respective combinations displays all the relevant features that distinguish a given piece from all others. Transcription of this sum produces **a score which alone allows a musical analysis**".

[68] "Methods of Analysis in musicology" – [Arom, 1969].

[69] "Dissertation on Modern music": explanations about this method are to be found mainly in [Rousseau, 1782, v. XVI, p. 69–92]: the method was used by Constantin Brăiloiu for his (secondary according to Arom – as a complement to western classical notation) transcriptions, notably in [Brăiloiu, 1953].

[70] The term "paradigmatic" has been challenged for this type of analysis, with "sequencing" proposed as a replacement. (See the document for the doctoral course of François Picard at the university of Sorbonne – 2010-2011 – http://seem.paris-sorbonne.fr/IMG/pdf/analyse_paradigmatique_et_se_quenc_age.pdf.)

[71] [Ruwet, 1966], translated two decades later (and preceded by a critical introduction) in [Ruwet and Everist, 1987].

[72] Octave equivalences are explicitly stated by Arom who reproduces in [Arom, 1969, p. 179] Rousseau's argumentation based on the "keyboard".

[73] [Arom, 1969, p. 174].

[74] Already in use – according to Arom – in western music(ology), notably by Nanie Bridgman, and assigning 12 numbers to the intervals of the chromatic scale. For the latter, Arom cites "'L'établissement d'un catalogue par incipit musicaux', in Musica disciplina, vol. IV, 1950, pp. 65-68", and "'Le classement par incipit musicaux, Histoire d'un catalogue', in Bulletin des Bibliothèques de France, 4e année, no 6, 1959, pp. 303-308"; another system would have been used by the SACEM, the French Society of Authors, Composers and Publishers of Music (see https://www.sacem.fr/en). Reid cites Willi Apel [p. 149] in the 1969 "*The Harvard Dictionary of Music*. Cambridge: Harvard University Press" explaining that numerical notation was first developed in the West by Chevé for music education in France – see also [Wikipedia Contributors, 2017c ; 2017e] (the first being in French and explaining that the first numerical notation could be by Juan Bermudo in the 16th century – see mainly aforementioned [Picard, 1999], notably p. 46). See also [Bent et al., 2001, §I: General], notably: "Number notations are far later developments [than alphabetical, ideographic, tablature and neumatic notations]: apart from the use of numbers in Chinese *qin* tablature of the 10th century and Japanese *koto* tablature by the 12th, they arose in Korea in the 15th century, in Western tablatures in the 16th and thereafter with increasing popularity in the 19th and 20th centuries".

> "it is easier to draw on degrees [of the scale] than intervals;[75] moreover, for the consignment of rhythmic values, it is clearly evident that the duration of the sound – or of the degree which symbolizes it – takes precedence over the duration of the interval which separates it from another [degree]".[76]

While it is difficult to understand this subtlety in the reasoning of Arom,[77] let us note that later on, in an article entitled "*Nouvelles perspectives dans la description des musiques de tradition orale*"[78] Arom includes, as the opening section of his explanations on "Analysis Methodology", a sub-section on "*Transcription*"[79] in which he draws on Seeger's *prescriptive* and *descriptive* "writing(s)" of music.

He further explains that the representation of the (to be analyzed) music must necessarily be graphical (written?) and that two choices are offered to the researcher for a descriptive notation which are: (1) notating with the utmost precision the details of the audio material and (2) a preliminary determination of the relevant – for the members of the given community whose music is researched – aspects of the musical language.

The author discards the first option on the basis that precision in sonic details is limitless and impractical, thus his preference for the second choice based on a "preliminary analysis of the elementary constituents of the sonic material". While the latter choice corresponds, however, to a "reduction" imposed through a model – which implies simplification,[80] Arom does not explain how to undertake this preliminary analysis and which analytical tools (Western? Preliminary scores?) must be used for the determination of these "elementary constituents".[81]

Answers to this question were given, before Arom's analytical approach, by various ethnomusicologists including Merriam's (very) anthropological explanations[82], here reported by William Poland:

[75] This depends, however, on the musician's (singer's) background: it is typically much easier for a trained cantor of Byzantine chant to read intervallic notation than to read pitch notation.

[76] [Arom, 1969, p. 176, footnote 2 continued on p. 177].

[77] Why should the duration of an interval (between two notes or degrees of the scale) be different from the duration of the note with which the interval begins? Unless this pitch is changing (*portamento* for example), in which case no effective pitch duration seems possible unless graphical – such as with computer analyses with Praat shown farther in this article, or as a *portamento* sign in the score in which case the duration of the pitch in the score is irrelevant for the pitch as such, but shows the duration of the *portamento* process. Or unless Arom's restriction concerns chronology: a pitch which is maintained is heard "before" the interval it defines with the following pitch (but not with a simultaneous one). Note that in the case of (more or less) stable pitches and with graphical analyses such as with Praat expounded farther, intervals between pitches are well defined and constitute a better marker for scale(s) used in a particular music piece.

[78] "New perspectives for the description of traditional musics based on oral transmission": [Arom, 1982], an emendated translation of the " 'Symposium'80 – On Methodology', *The World of Music*, XXIII/2 (1981), p. 40-62".

[79] [Arom, 1982, p. 202–203].

[80] The first years of my working life were dedicated, concurrently with a thesis for Doctor in Sciences I was preparing at the *École Nationale des Ponts et Chaussées* in Paris, to the conception and programming of models of material stress under load in the conditions of fire. This implied the use of complex non-linear algorithms coupled with the method of finite elements, a procedure which allowed to break up a plane structure (a concrete slab for example) into a small number of elements with finite dimensions and on the nodes (the end points of the three or four sided finite elements used in the model) of which were calculated the stress and other characteristics of the material. One of the critical parameters at that time, because of the load on the computers we used, was the size of these finite elements: the smaller they were, the more precise the results were, but computing time augmented exponentially with the reduction of these sizes. At some point too, further reduction of the sizes of the finite elements gave no substantial additional information about the behavior of the (general) studied structure. The same would apply for a model on music as described by Arom, if there was one unique component of the music which was under scrutiny. When ignoring which of the characteristics of the studied music is (more) important (than others), the remaining "skeleton" may however give irrelevant information on the operation and progress of the studied process (this corresponds to what Mantle Hood entitled "The Horns of the Dilemma" in [Hood, 1982, p. 54]). In the case of the concrete slab the laws of physics and the characteristics of the material are previously known (data), whenever in a "foreign" music the "code" – as Arom calls it and which corresponds to the laws of physics in the concrete slab example – must still be determined, which means that the model interacts with vacuum, or at least with a series of unknowns ("variables") which interact together, when you change one parameter, in a non-linear way. This makes it very unlikely that such a model would "simplify" the analysis of music whenever it is somewhat complex, and likely that (at least) some of the important aspects of the studied phenomenon (here music) would be overlooked by the analyst. In the case of *maqām* music and as explained in the next footnote, the heart of the music lies in the small details and in heterophony, both phenomena being irreducible to usual "model" analyses used in Western (ethno-) musicology.

[81] This is a vicious circle indeed. Note also that the "reductive" procedure, as for example Schenkerian analysis applied in [Stock, 1993], is suitable to musics in which local instant variations (and modulations) do not play a major – and structural – role. In *maqām* music these aspects are most important as well as the heterophonic – constant – procedure at work, which makes most reduction procedures irrelevant.

[82] Alan Merriam was a strong supporter of the "Anthropological" trend of ethnomusicology. Mantle Hood (quoted next in the text) highlights this attitude at the beginning of his "Musical significance" [Hood, 1963, p. 187]: "In 1961 at Princeton I met with Alan Merriam, David McAllester and Nicholas England, to discuss some of the problems of ethnomusicology. In one of these discussions, Merriam questioned the importance of precise measurements of tuning systems. He went on to ask whether tuning and scale were really significant".

"The Basongye people who live in the Republic of the Congo 'conceptualize music as a uniquely human phenomenon'. They make distinctions between noise and music with statements like these: 'When you are content, you sing; when you are angry, you make noise. When one shouts, he is not thinking; when he sings, he is thinking'. Merriam concluded: The Basongye 'theory' of music […] seems to involve three essential features […] first, the fact that music always involves human beings, and that those sounds emanating from non-human sources are not music. Second, the musical sounds that humans produce are organized […] And third, there must be continuity in time",[83]

or in a (much) broader manner by Ki Mantel Hood who writes (in "Musical significance"):

"I want to repeat the overriding question [at a Symposium of the Royal Anthropological Institute of Great Britain and Ireland held in London in March 1962] 'What is <u>musically</u> significent [sic?]?' Not 'What is <u>symbolically</u> significant?' The latter question is more the concern of the anthropologists. I am reminded of an example of symbolic meaning given by a student of anthropology who was impatient with some of his colleagues because of their expectations of ethnomusicology. 'The anthropologist,' he said, 'wants to know that when F-sharp is played on the flute used in initiation rites, that all male members of the tribe will urinate blue.' Before the anthropologist can understand what some aspects of music symbolize, we ethnomusicologists will have to discover what is musically significant. This question must be applied to three equally important and interdependent considerations. Given a musical tradition, 1) What is its significance in relation to the world of music? 2) What is its significance within the context of its own society? 3) What, in terms of the tradition itself, has significance?",[84]

while explaining further:

"I have chosen to present six broad headings for discussion in the knowledge that there could be more and aware of the fact that each merits greater detail than we can afford here. The first is concerned with <u>sources and informants</u>, the second with <u>recording</u>, the third with <u>notation and transcription</u>, the fourth with <u>physical measurements</u>, such as tuning, scale and tone quality, the fifth what I have chosen to call purely <u>musical factors</u> such as mode, melody, form, etc., the sixth <u>text and speech</u> associations",[85]

and concluding:

"I wish to stress two points which should temper the latent fires of discussion on our subject. We must constantly bear in mind 1) that there are different degrees of musical significance and 2) that the musical significance of a given factor may vary in degree, depending on the context of its application".[86]

George List's response to Mantle Hood's "Musical significance", in his "The Musical significance of transcription", is very instructive:

"[Transcription] is a prerequisite when it is desired to make detailed comparisons of certain aspects of musical events. Among these aspects are those listed under the fifth topic suggested by Mantle Hood, musical factors: mode, melody, form, etc."[87]

adding:

"Notation by ear of vocal music usually omits much detail. The notes indicated on the staff admittedly often represent points in continuums rather than stable pitches. The same omissions are made in transcriptions by ear of singing in the Western European art tradition. In the latter case, however, we know that the concept of a scale of stable pitches is operative in the culture. We know that the composer was also governed by this concept. We are therefore in a position to make reasonably valid judgments concerning which details are musically significant in the culture and which are not",[88]

and concluding:

"First: Neo-Pythagoreans aside, music is man-made. Music is a product of culture, not of nature.[89] Our perceptions are limited. We cannot overstep the thresholds of audibility or feeling nor can we react to frequencies outside a certain gamut. Past this what is music is determined by the culture, not by the harmonic series. Since music is man made, what is musically significant must be phenomena which man can hear, not phenomena which he cannot hear. There is therefore no value in considering in analysis aspects of a musical event which man cannot distinguish, whether these details are secured by decreasing the speed of a tape player or turntable or by means of electronic apparatus.
Second: The human ear is fallible. The two means mentioned are therefore extremely useful in checking on the accuracy of the ear. Our ears have been trained primarily to discriminate stable pitches, not pitches that are unstable. Until the time this lack of training is rectified we must depend upon electronic apparatus to assist us in plotting the melody of speech and of forms intermediate to speech and song, in graphically describing the vibrato and the effect of breath accent in vocal production. In producing

[83] [Poland, 1963, p. 153] quoting "Alan P. Merriam, *A Prologue to the Study of the African Arts* (Antioch Press, Yellow Springs, Ohio, 1961) 27-28".

[84] [Hood, 1963, p. 188].

[85] [Hood, 1963, p. 189]: we can notice that, in this latter definition by Hood, the anthropological aspect is reduced to the first and sixth headings.

[86] [Hood, 1963, p. 192].

[87] [List, 1963, p. 193]. Note that "George List, [is] the Julliard-trained flutist and composer who represented the older, formal, approach to the study of folk and non-Western musics—the kind of scholarship that grew out of musicology" – in [Ivey, 2009, p. 20]; George List was still alive (and ninety-six years old) in 2007 (see [Walker, 2007], accessed 21/01/2018).

[88] [List, 1963, p. 195].

[89] This – with which I totally agree – was already said, one millenary ago, by Fārābī (see the epigraph to this dossier).

melographs it will probably facilitate analysis if they are 'smoothed' until they represent as closely as possible what a properly oriented and trained ear can distinguish.

Third: When a hierarchy of musical values for a culture cannot be developed through work with informants from the culture, the researcher must determine the musical significance of the various style elements by reference to their frequency of occurrence and their stability versus their variability. Those which occur the most frequently and are the most stable are declared the most musically significant. Frequency or stability cannot be assessed until many transcriptions have been made and compared. It is thus necessary to indicate all detail possible that the ear can distinguish since there is as yet no means of determining which details are musically significant and which are not".[90]

This would have been an interesting step towards the recognition of different musical cultures, different ways of hearing and listening to music. However, a year later, in "Transcription III", one of four transcriptions published in 1964 in *Ethnomusicology* after a session held at the meeting of SEM at Middletown on November 1 - 1963,[91] List explains that in his analysis:

"The tonal aspects […] are based upon theories advanced by Paul Hindemith.[92] The differential tones utilized in determining the roots of harmonic and melodic intervals are a type of combination tones. However, the differential tones are physiological rather than acoustical phenomena",[93]

concluding:

"Since the inner ear of all men is similar in construction, differential tones are audible to some extent to all men. Theories based upon their effect may therefore be justifiably employed in the analysis of the music of either the Bushman or of the German Romantic movement".[94]

The roots of this (very) occicentric remark are to be found in Hindemith's theories. In his "Theories of Music and Musical Behavior", William Poland explains:

"The standard work in English on theories of music is by Shirlaw[95]. It is a curious and unsatisfactory work but it does represent the point of view which may be called the main stream of theories of music in western civilization. This stream is commonly considered to have its source in the mathematical mystic, Pythagoras. Those who hold this point of view believe that the object of the music theorist is to discover eternal, unchanging, laws of nature 'derived' in the words of Hindemith, 'from the natural characteristics of tones, and consequently valid for all periods'[96]. Hindemith is the most important contemporary theorist who has tried to generate a universally applicable theory of music based on "natural laws". Hindemith characterized this main stream of thought in his description of the views of those he called 'the ancients': 'Intervals spoke to them of the first days of creation of the world; mysterious as Number, of the same stuff as the basic concepts of time and space, the very dimensions of the audible world, building stones of the universe, which, in their minds, was constructed in the same proportions as the overtone series, so that measure, music, and the cosmos inseparably merged'[97]. In his own theory Hindemith finds 'the intervals imbedded in the tonal raw material which Nature has made ready for musical use, consisting of an infinite number of tones […]. Into this inchoate tonal mass we can introduce a certain order by the use of the immutable measures of the octave and the fifth'[98]. Hindemith is at one with Zarlino, Mersenne, Rameau, and Helmholtz in his use of the first six harmonic partials of a tone as the basis for his theory. He asserts that partials one through six outline an extended major triad, and that 'Music, as long as it exists, will always take its departure from the major triad and return to it'[99]",[100]

adding that

"Natural-law theorists still hold the position that explanations may be found in immutable measures – whatever they may be – related to supposed physical characteristics of that limited set of sounds which have harmonic partials. They are also most vehement in their assertion that music is a universal language which expresses our innermost feelings, and in the denial of the study of musical behavior as a source of information which might effectively contribute to more adequate theories of music".[101]

All is said here as Hindemith's theoretical thought is the basis for the "evolutionary" theories of music, based on the Resonance theory and the cycle of fifths.[102]

A decade later, the same George List explains in "The reliability of Transcription":

"[T]here are two principal methods by which […] visual representations [of performances] can be secured. They can be made by ear and hand or produced by an electronic device. In

[90] [List, 1963, p. 196].

[91] This was a symposium on the transcription and analysis of one song as explained in [Anon. "From the Editor (Vol. 8, issue 3)", 1964].

[92] List makes here a reference to [Hindemith, 1945, p. 57 sq.] in which the author expounds "Combination tones" and, most probably, to the next sections in Hindemith's entitled "Inversion" and "Interval roots".

[93] [List, 1964, p. 255].

[94] [List, 1964, p. 259].

[95] Poland refers here to *The Theory of Harmony* [Shirlaw, 1955].

[96] Poland makes here a reference to the 1941 edition of "P. Hindemith, *The Craft of Musical Composition*, Bk. 1. A. Mendel, trans. (Associated Music Pub., New York, 1942) 9", corresponding to [Hindemith, 1945, p. 9].

[97] [Hindemith, 1945, p. 12–13].

[98] [Hindemith, 1945, p. 15].

[99] [Hindemith, 1945, p. 22].

[100] [Poland, 1963, p. 152–153].

[101] [Poland, 1963, p. 155].

[102] See Chapter II in [Beyhom, 2016a].

the first case the result is usually a transcription in musical notation; in the second it may take the form of a graph of the fundamental pitches. To the latter may be added a graph of intensity or amplitude. Other possible methods of visual representation are the making of hand graphs or the measurement of individual tones by the monochord[103] or an electronic device.[104] Our purpose here is to assess the reliability of transcription in the form of musical notation made by ear and hand. Only transcriptions made of a single melodic line will be considered and only two aspects of melody, pitch and duration".[105]

A comparison between hand (ear) transcription (notation) and electronic graphs is undertaken further by List in this article, for a Rumanian carol and for two (Yiddish and Thai) lullabies (an example for the Thai lullaby is reproduced in Fig. 3):

"[T]he two methods of producing transcriptions are not comparable. The hand notation is a product of the human mind which attempts to synthetize the data heard and to offer an intelligible description of the whole in symbolic guise. The electronic device, on the other hand, makes no judgments. […] Finally, to make the desired comparisons we must first interpret the electronically produced graphs".[106]

In his endeavor to exclude events not fitting in the score we find, in the comments for the "Thai lullaby", the following gem:

"The instruments utilized in Thai art music are tuned in a different temperament than that utilized in our Western music. It is conceivable that Thai folksongs [such as this lullaby] may be influenced by Thai instrumental art music".[107]

Arguing further about the inaccuracy of the measurements of the "Melograph"[108], List discards the discrepancies shown between the Western notation and the "electronic device" results shown in Fig. 3 and concludes (as a supplementary gem) for this lullaby:

"It therefore would seem reasonable to assume that the pitches notated reflect what is found in the graph",[109]

and in general for his article (as a final gem):

"Finally, and this is the principal point to be derived from this aspect of the discussion, when transcriptions in the form of notation made by ear and hand are compared with electronically produced graphic transcriptions of the same recorded performance the former display proportionally more accuracy than inaccuracy, and the modifications made on the basis of the information offered by the graph are slight. […] the inescapable conclusion is that the capability of the unaided human ear should not be underestimated. The evidence indicates that transcriptions made by ear in notated form are sufficiently accurate, sufficiently reliable to provide a valid basis for analysis and comparative studies of the two aspects of musical style discussed, pitch and duration".[110]

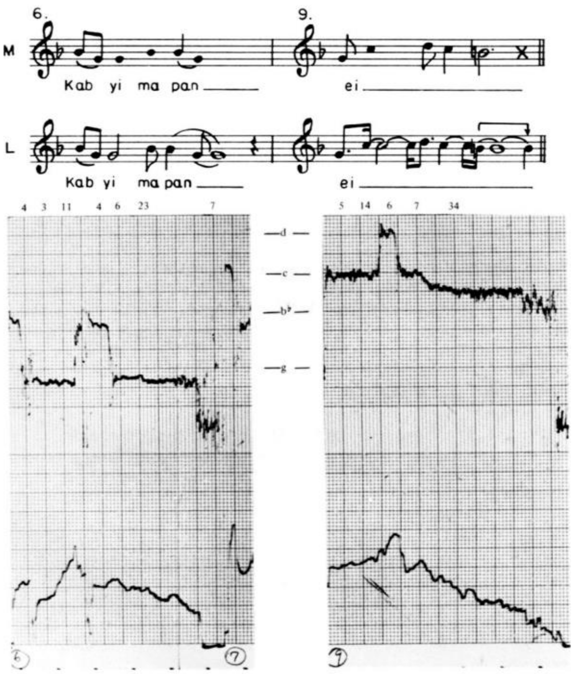


Fig. 3 Figure 9 in [List, 1974, p. 371] with a notated melody and Melograph transcription.[111]

To such an assertion could be opposed[112] another experiment, undertaken by myself when I was teaching

[103] As explained in Chapter IV of [Beyhom, 2016a] for the "measurements" of the Music Committee (for the Second 19th-century Reform of Byzantine chant), the reliability of pitch measurements with the monochord is very relative, if not impossible to establish in real life situations.

[104] A review of Pitch measurement methods and their reliability (and a test of the program Praat) is available (for French-speaking readers) in [Beyhom, 2007].

[105] [List, 1974, p. 353].

[106] [List, 1974, p. 365].

[107] [List, 1974, p. 373].

[108] See http://seem.paris-sorbonne.fr/IMG/swf/an_mhaighdean_mhara.swf in which Picard shows the nearly exact correspondences between the graphics of the "Melograph" of Seeger and graphics produced by advanced pitch-measuring programs such as Praat.

[109] [*ibid.*].

[110] [List, 1974, p. 375–376].

[111] The original legend stands: "Thai Lullaby, Phrases 6 and 9. Comparison with Melograph of Majority Opinion of Students [who participated in the transcription process and formulated their observations about pitch and time duration] and Transcription by George List". Above: pitch graph; below: intensity graph; "M" and "L" are staff identifiers. Quarter-tone discrepancies between Western notation and tonogram (graph above) are clearly distinguishable.

[112] Besides point "3)" in Reid's quote as epigraph to this article, in which he mentions specifically (withdrawn from the epigraph) List's analyses.

ethnomusicology in a Lebanese university. The students listened to Breton songs and tried to determine the scale used in one of the songs. Most of the students – who were all trained in the *maqām* tradition as well as in western music – could not determine a definite scale, while one student (who later graduated brilliantly) determined, obviously by ear, that the song was in the scale of *maqām Rāst*, which obviously it was not.[113]

Other aspects of *maqām* music[114] or subtleties of ornamentation or of pitch positioning shown elsewhere by the author[115], or predominant in Indian music,[116] – in fact all we know about non-tempered music – contradict these (very) occicentric statements of George List.

The "inescapable conclusion" is that List made in this analysis all the errors that he himself and others warned about, and imposed a reading grid – here western notation – "to be read by people who do not carry the tradition of the other music" (to quote Seeger once again).

Anyways, Arom's (changing) position on the use of western notation, which is challenged when applied to monodic music but becomes essential when applied to polyphony – including non-western polyphonic or polyrhythmic music(s) – is typical of the biases of Western (and here – maybe – typically French and European) ethnomusicology – which still relies mainly on the (equally) western musicology for its analysis of "foreign" music(s).

Moreover, and whenever Arom's method for the notation of "monodies" seems to have been too radical a change from western notation despite all critics about the latter when applied to musics not complying with western common practice, one real change would have been the shift from pitch to intervallic notation – as used for example in Byzantine chant notation – but this was probably asking too much from a discipline so closely dependent on (Pitch) music scores for centuries.[117]

Finally: there is no better conclusion(s) to this part as the introductory paragraph of Bruno Nettl's sixth chapter of his *Study of Ethnomusicology*, entitled "I Can't Say a Thing Until I've Seen the Score"[118]:

> "Western urban society has a special view of music. We may say that a folk singer deviates from the way a song is 'written' when we really mean from the particular form in which he has learned it. We use the term 'writing music' broadly, substituting it for 'composing,' whether notation is involved or not. We think of a piece of music as existing in its truest form on a piece of paper. The academics among us can hardly conceive of discussing music without knowledge of a single, authoritative, visible version. 'I can't say a thing until I've seen the score,' the critic may say upon hearing a new piece; it is surprising that he does not normally say about a new score, 'I can't say a thing until I've heard it.'[119] Dealing with the written music is the classical musician's ideal. 'Can you read music?' is the question used to separate musical sheep from goats, to establish minimum musical competence",[120]

and Cooks reflections on the role of "ear-training" in Music education:

> "An even more basic example of how educational institutions construct and naturalize musical culture is provided by what is sometimes revealingly termed 'ear training', a kind of conditioning that takes place at an early stage of conservatory or university education: students are taught to recognize such things as the notes of the scale, the chordal types of 'common-practice' harmony, and the basic formal schemes of the classical tradition (binary, ternary, sonata, and so on). When I say 'things', I mean the word literally: students are being inducted into the world of Western musicianship, in which music is made up of 'things' to hear, constructed out of notes in the same sense that houses are constructed out of bricks. And this has two results. The first is that music is transformed from being primarily something you **do** (but do not necessarily know how you do) to something you **know** (but may not necessarily do); in other

113 Traditional Breton scales, according to my analyses with Praat, are generally not tempered, but different from the scales of *maqām* music. Erik Marchand, a well-known Breton singer, used to call the nearly "major" scale of Breton music "the Breton *Rāst*". See also in Part III of this dossier the analyses of *Ar bern plouz* by Manu Kerjean, published as video-analyses at http://foredofico.org/CERMAA/analyses/breton-music, and underlining the differences between the singer's performance and the "minor" scale.

114 As for example for the song *Ḥawwil yā Ghannām* sung by Najāḥ Salām – as expounded in [Beyhom, 2016a, p. 151–152, fn. 782 and FHT 11: 185].

115 See the Interlude in [Beyhom, 2016a, p. 151–152].

116 See for example [Krishnaswamy, 2003 ; 2004 ; 2004], but also the comprehensive blog of Wim Van der Meer at http://thoughts4ideas.eu/ including notably the video https://vimeo.com/120632175 – accessed 10/01/2018, not forgetting Meer's invaluable Praat manual at http://thoughts4ideas.eu/praat-manual-for-musicologists/.

117 The suitability of intervallic relative notation for *maqām* music is discussed farther in this article.

118 [Nettl, 1983, p. 65–81]: this whole chapter is a retrospective of the problems of notation and transcription, with Nettl implicitly disapproving "automatic notation" while at the same time criticizing Western attitude towards score notation. This attitude is common enough among western ethnomusicologists to raise the question why can such highly educated scientists not overcome their fear of losing their last – however important – castle.

119 The author of this dossier totally agrees with the second formulation of this anonymous critic.

120 [Nettl, 1983, p. 65].

> words, it is embraced within the structures of the knowledge industry, and of a society which tends to value theory above practice. The second is that it becomes increasingly difficult to conceive that music might work in other ways, or to hear it properly if it does; the harder you listen, the more you hear it in terms of the notes and chords and formal types of the Western tradition, and the less you can understand music that works primarily in terms of timbre and texture, say",[121]

concluding

> "At all levels, then, what you know about music can open your ears to it or close them, make certain types of music seem 'natural' and others not just inconceivable but, in effect, inaudible. No wonder, then, that music education has become a political battleground on both sides of the Atlantic".[122]

***

Part II. A historical review of the notations of *maqām* music

"The notation of pitch […] has never been of more than three kinds–alphabetical, imitative, and by the ladder"

[John Stainer, "On the Principles of Musical Notation"][123]

"We have no record to prove that the Phoenicians or Hebrews had any method of noting music, nor, indeed, do we imagine that any music worth noting existed amongst them"

[Henry Lunn, "The History of Musical Notation"][124]

Is it possible to notate a music the notes of which do not lend themselves to standardization, or – simply stated – to notation as it has evolved within Western music? This depends on the purpose of this notation, descriptive or prescriptive as stated by Seeger – or also, from the author's point of view, on whether it is anterior or posterior to the music itself.

Ethnomusicologists deal mostly – if not exclusively[125] – with pre-existing music that they try to understand and, for some of them, to analyze. Analytic ethnomusicology needs then a descriptive as well as an analytical tool to research non-Western musics.[126]

Musicians[127] and composers, on the other side, whenever they may use the tools of Analytic ethnomusicology to (try to) understand some of the peculiarities of a given music, need to notate music for the purpose of being able to reproduce it when needed, to share it with others as a practical means of producing (performing) it, or with the aim of preserving a repertoire from oblivion. They need to write – or consult – a *score* which implies a reduction of the characteristics that are scored.

Notations of *maqām* music have always evolved between the prescriptive and the descriptive aspects of music. From the – known – alphabetical beginnings to the latest computer-aided adapted western notations,

[121] [Cook, 2000, p. 104] – Bold font by the author.

[122] [Cook, 2000, p. 105].

[123] [Stainer, 1874, p. 89–90].

[124] [Lunn, 1866, p. 261].

[125] Except in the cases of "Revivalism" of nearly-extinct traditional musics.

[126] It may be useful here to remind the reader of the purpose of conventional musicology when dealing with these musics – and the use of conventional musicological tools to analyze *maqām* music: there are thoroughly expounded in [Beyhom, 2016a].

[127] Note that traditional musicians did not need a score to perform music.

the discussion about the aims of notation was never decided in one way or the other.

Moreover, in a society based on oral tradition – such are still (somehow) the *maqām* societies[128] – the usefulness of notation could also be debated. This is no more the case today when almost all *maqām* music is taught using adapted western scores.[129]

Early notation of maqām *music*

The first – known – notation of *maqām* music is by Yūsuf Abū Yūsuf Yaʿqūb ibn Isḥāq ibn a-ṣ-Ṣabbāḥ ibn Ismāʿīl ibn al-Ashʿath ibn Qays al-Kindī (9th century). It is in fact a sort of literal tablature for the *ʿūd.*[130] It is also the first known example of – limited and hypothetical – polyphony in Arabian writings on music. (FHT 21: 218)

Other Early notations of pitch – reduced however to the scale – were based on the Arabian alphabet (*Abjad* – Fig. 4 and Fig. 5) while combining these with a tablature for the *ʿūd* such as with Abū-n-Naṣr Muḥammad ibn Muḥammad ibn Ṭarkhān ibn Uzlagh al-Fārābī in the 9th-10th centuries (FHT 2: 208, and FHT 3: 208 as a modern equivalent).

Later writings by *maqām* theoreticians are all influenced by the first book of Ṣafiyy-a-d-Dīn ʿAbd-al-Muʾmin ibn Yūsuf ibn (ab-ī-l-Ma)Fākhir (al-) Urmawī (d. 1294)[131], the *Kitāb al-Adwār* [*Book of Cycles*] in which, in parallel to a Pythagorean construction of the scale based on string-lengths divisions (Fig. 6), Urmawī uses an *Abjad* notation (Fig. 7, FHT 4: 209, FHT 5: 209) concurrently with an intervallic – literal – notation (FHT 6: 210).[132]

أ	ʾAlif	ʾ	1	س	Sin	s	60
ب	Ba	(a)	2	ع	ʿAyin	ʿ	70
ج	Jim	b	3	ف	Fa	f	80
د	Dal	j	4	ص	Ṣad	ṣ	90
ه	Ha	d	5	ق	Qaf	q	100
و	Wa	h	6	ر	Ra	r	200
ز	Zay	w	7	ش	Shin	sh	300
ح	Ḥa	z	8	ت	Ta	t	400
ط	Ṭ	ḥ	9	ث	Tha*	th	500
ي	Ya	ṭ	10	خ	Kha*	kh	600
ك	Kaf	y	20	ذ	Dhal*	dh	700
ل	Lam	k	30	ض	Ḍad*	ḍ	800
م	Mim	l	40	ظ	Ẓa*	ẓ	900
ن	Nun	m	50	غ	Ghayin*	gh	1000
		n					

* These letters were added to the initial 22 Phoenician letters.

Fig. 4 The *Abjad* alphabet and numerical equivalences.[133]

The later book of Urmawī, the *A-sh-Sharafiyya Epistle*, features notated examples of melodic phrases using the extended *Abjad* notation devised in the *Book of Cycles.*[134]

Later (intermediate) writings use a literal description of the notes to describe – notably – the scales of Arabian music, with accidentals in "half of the interval" or *nuṣf* (pl. *anṣāf* – Fig. 8).[135]

[128] Which are becoming, as all other Human societies, audio-visual cultures?

[129] A notable exception is *tajwīd* (Koranic recitation) – but for how much longer? Ironically (and most probably), this chant still survives because it is not considered, by the clerical hierarchy, as "music" (*mūsīqī*). As for Byzantine chant: in Volos, during his presentation at a conference on Psaltiki (Byzantine religious chant – see Part III of this dossier), speaker (and cantor in Sophia - Bulgaria) Jordan Banev warned against the classification of Byzantine chant as "Music", precisely to avoid further distortions in this chant.

[130] In the *Risāla fi-l-Luḥūn wa-n-Nagham (Mukhtaṣar al-Mūsīqā fī Taʾlīf a-n-Nagham wa Ṣinʿat al-ʿūd)* [from Manisa (Turquie), MS. 1705, f^os 110v°-123r°. In Arabic رسالة الكندي في اللحون و النغم [Kindī (al-) and الكندي, 1965].

[131] صفي الدين الارموي was the founder of the so-called – by Western Orientalists – "Systematist School", the theory of which is based on a Pythagorean division of the octave in 17 intervals.

[132] Note that the theoretical scale of Urmawī, based on a division of the octave in 17 *leimmata* and *commata*, comprises intervals of one whole tone *T* composed of two *leimmata* + one *comma*, and two *mujannab*(s) ("neutral" second or "medium tones") which can be either composed of two successive *leimmata* (M_1), or of one *leimma* + one *comma* (M_2). His intervallic divisions of the polychords in the manuscripts (one of which is shown in FHT 6: 210) suggest that he based himself on a proportional progression, the whole tone being (evidently) greater than the two *mujannab*(s) and the two *mujannab*(s) being conceptually equivalent one to the other.

[133] According to [Ifrah, 1994, p. 585].

[134] See [Urmawī (d. 1294) and [Jurjānī (al-)], 1938, v. 3, p. 169–173].

[135] These are treatises and epistles such as [Anonyme, 1983 ; {Ṣafadī (a-ṣ-)}, 1991]. As long as the exact general scale is not described by these authors, resulting scales of *maqāmāt* (= pl. of *maqām*) can only be approximated – notably on the basis of the contemporary scale of *maqām Rāst.*

Mnemonic words	Breakdown	
أبجد *Abajad*	أ ب ج د *d j b ʾ(a)* ←	أ ب ج د 4. 3. 2. 1 ←
هوز *Hawazin*	ه و ز *z w h* ←	ه و ز 7. 6. 5. ←
حطي *Ḥuṭiya*	ح ط ي *y ṭ ḥ* ←	ح ط ي 10. 9. 8 ←
كلمن *Kalamuna*	ك ل م ن *n m l k* ←	ك ل م ن 50. 40. 30. 20 ←
سعفص *Saʿfaṣ*	س ع ف ص *ṣ f ʿ s* ←	س ع ف ص 90. 80. 70. 60 ←
قرشت *Qurshat*	ق ر ش ت *t sh r q* ←	ق ر ش ت 400. 300. 200. 100. ←
ثخذ *Thakhudh*	ث خ ذ *dh kh th* ←	ث خ ذ 700. 600. 500. ←
ضظغ *Ḍaẓugh*	ض ظ غ *gh ẓ ḍ* ←	ض ظ غ 1000. 900. 800 ←

Fig. 5 Mnemonic words (*ab*[*a*]*jad haw*[*w*]*az* …) for the *Abjad* alphabet and breakdown.[136]

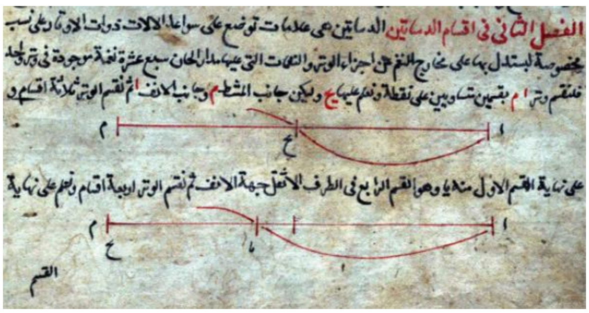


Fig. 6 Using the division of the string for constructing the scale in [Urmawī (d. 1294), 2001, p. 2].

The most probable position of the *nuṣf* of a *burda* (degree of the basic scale) is the upper one.[137] The resulting scale would be composed of 14 adjacent intervals, the exact size of which is still unknown.[138]

Fig. 7 Use of the *Abjad* alphabet in [Urmawī (d. 1294), 2001, p. 4].

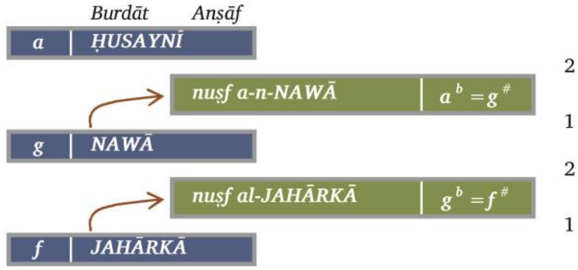


Fig. 8 Most probable division of the intervals in the *A-sh-Shajara* treatise. (Contemporary note names for the Arabian scale and western equivalents are provided in FHT 8: 211.)[139]

Other representations of the scale, mainly in the so-called (a-ṣ-) Ṣafadī epistle,[140] feature two *anṣāf* ("upper" and "lower") with two possible explanations for their positioning (Fig. 9 and Fig. 1).[141] In this case, the theoretical scale would have been composed of seven intervals divided in three "thirds", a hypothesis which is further expounded in FHT 7: 211.

Most importantly, the denominations featured in these treatises are still in use today – with slight modifications – in *maqām* teaching,[142] including the first writings of the "Modern" era, notably with Mīkhāʾīl Mashāqa and Kāmil a-Khulaʿī[143] which used however multiple ways for the delineation of the intervals of the "Arabian" scale.[144]

[136] According to [Ifrah, 1994, p. 587].

[137] This seems to be the case for all the "halves" cited in the *A-sh-Shajara* treatise [Anonyme, 1983], independently from the direction of the intervals, *i.e.* ascending or descending.

[138] See also [Beyhom, 2005] and [Beyhom, 2012].

[139] Previously published in the endnotes of [Beyhom, 2012]. *Burda* (pl. *burdāt*) = "degree" or "interval"; *nuṣf* (pl. *anṣāf*) = "half".

[140] [{Ṣafadī (a-ṣ-)}, 1991].

[141] A third possibility – yet to be explored – is that the scale of the two cited treatises corresponds theoretically to the scale of Urmawī – based on a division of the octave in 17 *leimmata* and *commata* – with some intervals (the whole tones) having two "*anṣāf*" and the others – the "neutral" seconds – having only one "*nuṣf*".

[142] See FHT 54: 242 to FHT 56: 244.

[143] Which are reviewed in the following sections.

[144] Including string-lengths divisions and frequency ratios, together with geometric constructions – most of these are theoretical although some may have been based on interval perception.

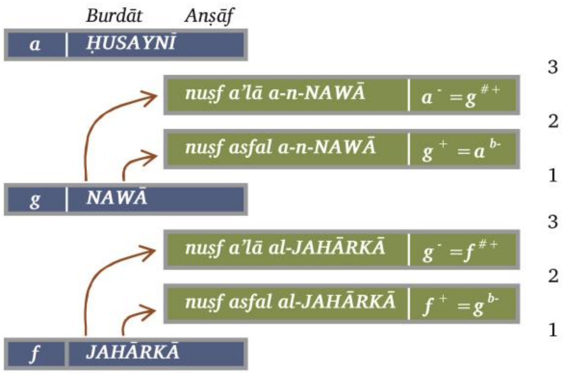


Fig. 9 Two upper *anṣāf* possible divisions (1) of the intervals in [{Ṣafadī (a-ṣ-)}, 1991].[145]

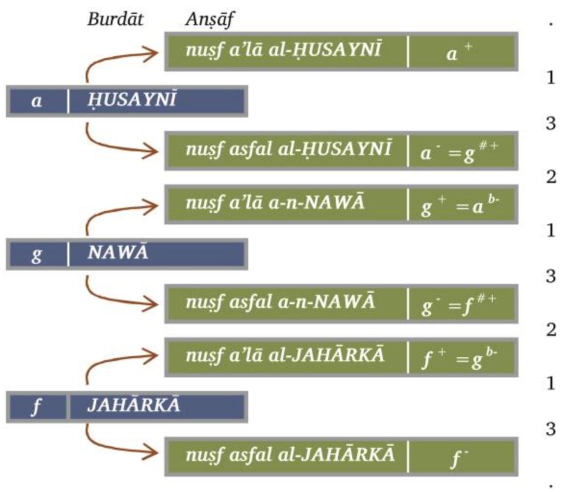


Fig. 10 Two upper *anṣāf* possible divisions (2) of the intervals in [{Ṣafadī (a-ṣ-)}, 1991].

One notable addition to the authors of the "Intermediate" period[146] is the case of Shams-a-d-Dīn a-ṣ-Ṣaydāwī a-d-Dimashqī, who uses a graphical color code for his explanations about the scales of *maqām* music (Fig. 11).

Fig. 11 (Detail from) Folio 14 *v°* from the BNF Ms. or-2480[147] *Kitāb al-Inʿām fī Maʿrifat al-Anghām wa Sharḥihā* by Shams-a-d-Dīn a-ṣ-Ṣaydāwī a-d-Dimashqī[148].

This unique[149] code, despite its – relative – dissemination[150], and although it uses similar terminology as other writings of the same period, is still however not completely deciphered notwithstanding the numerous research published about it.[151]

[145] *Burda* (pl. *burdāt*) = "degree" or "interval"; *nuṣf* (pl. *anṣāf*) = "half"; *aʿlā* = "high, higher, [*aʿlā min*] higher than"; *asfal* = "low, lower, [*asfal min*] lower than".

[146] I use the following division of the history of Arabian music (theory) in [Beyhom, 2010c]: 1. *The Forerunners*: mostly Kindī (9th century) and Munajjim (9th and beginning of the 10th centuries); 2. *The Golden Age*: from (al-) Fārābī (Latinized "Alfarabius" – 10th century) to ibn Zaylā (d. 1048), not forgetting the mentor of the latter, ibn Sīnā – or Avicenna – (980-1037); 3. *The Systematists*: beginning with (al-) Urmawī (13th century), with followers such as (al-) Lādhiqī or (al-) Marāghī; 4. *The Intermediate Period*: with writings such as the anonymous *A-sh-Shajara dhāt al-Akmām* [Anonyme, 1983], or [Ṣaydāwī (a-ṣ-), XVe siècle] (translated to French in [Ṣaydāwī (a-ṣ-) and Antar, 2001]), or the pseudo Ṣafadī published as [{Ṣafadī (a-ṣ-)}, 1991]; 5. *The Moderns*: beginning with (ʿAṭṭār and) Mashāqa (19th century) and ending with the 1960s (not forgetting [Khulaʿī (al-), 1904]); 6. *The Contemporary Period*: roughly since the 1970s and the predominance of the Conservatoires in the teaching of Arabian music. (Note that periods 3 and 4 may overlap.) As for Arabian music *per se*, [Jargy and Chottin, 2001, p. 527] identify (for example – other theoreticians propose other time divisions still) five time periods (which correspond in part only to the aforementioned six, and disregard the post-*Congrès du Caire* period), namely: "1) *Bedouin period*, from the *Jāhiliyya* ['the time of ignorance'] till Early Islam (death of ʿAlī, 661); 2) *Assimilation period*, from the Umayyad dynasty till the First Abbasid cycle (*circa* 830) ; 3) *Period of Fulfillment and Dispersion*, with the second Abbasid cycle and the establishment of the Umayyad in Spain; 4) *Period of Decline*, from the taking of Granada (1492) till the end of the 18th century; 5) *Renaissance*: from the *Nahḍa* in the 19th century, beginning with the expedition of Bonaparte in Egypt, until the [*C*]*ongrès du Caire* (1932)".

[147] [Ṣaydāwī (a-ṣ-), XVe siècle].

[148] See [Neubauer, 1997] for more details on this author and his *urjūza*, notably: "The 'little Arabic book on music' [of Ṣaydāwī] aroused considerable excitement when it reached Paris in 1634. It figures in Diderot's Encyclopédie (Planches, vii, 3-4) and in d'Herbelot's Bibliothèque orientale (ii, 758), and it was partly translated, around 1780, by Pigeon de Saint-Paterne on behalf of de La Borde".

[149] [Neubauer, 1997]: "al-Ṣaydāwī's musical notation is unique in Arabic (and also Persian and Turkish) music literature".

[150] See [Odeimi, 1994, p. 29].

[151] See fn. 148 above and, for example, [Shiloah and Berthier, 1985], [Ṣaydāwī (a-ṣ-) and Antar, 1979 ; 1999], [Odeimi, 1994] and [Ṣaydāwī (a-ṣ-) and Ghrab, 2002].

Few other notations preceding westernized scores[152]

The 19th century brought with it massive interventionism of Western musicology[153] – which was not yet thus called – in *maqām* music and many different ways of coping with this influence *and* try to keep the characteristics of this music intact.[154]

The main subdivisions of *maqām* music which devised alternative notating systems were both at the heart of the Ottoman Empire, namely Ottoman music and Byzantine chant. Both were triggered by Western influence.

Byzantine notations from the 19th century[155]

Byzantine melodic notation is, from the outset, an intervallic notation.[156] While undergoing many reforms in its centuries long history, Byzantine chant was subject to two major reforms in the 19th century alone, both initiated by the Patriarchate of Constantinople. These were attempts at acknowledging Western influence while, in the same time, trying to maintain Byzantine chant tradition – and its "Oriental" characteristics – alive.[157]

One of the most important "novelties" brought by the First Reform (1814-1818) was the introduction of a specific solmization based on the Greek alphabet (Fig. 12) together with basing the intervallic notation of the scales on a division of the octave in 68 unequal "minutes"[158] (Fig. 15 and Fig. 16). In Fig. 15, in which two systems for constructing the scales are shown, the central octave (beginning with *νη*) is identical for the two systems and corresponds theoretically to the scale of *maqām Rāst* in Arabian music.[159] (Fig. 13)

Byzantine degree	*Πα*	*Βου*	*Γα*	*Δι*	*Κε*	*Ζω*	*Νη*	*(Πα)*
	πα	*βου*	*γα*	*δι*	*κε*	*ζω*	*νη*	*(πα)*
Western	*d*	*e-*	*f*	*g*	*a*	*b-*	*c*	*(d)*
Rōmanou	pa	bou	ga	di	ke	zo	ne	(Pa)

Fig. 12 Solmization of Byzantine chant – from the First Reform (1814-1818) of the 19th century – and equivalences.[160]

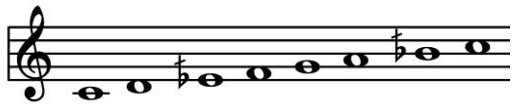


Fig. 13 Scale of *maqām Rāst* in "Modern" Arabian notation – taken from [Beyhom, 2015, p. 170 (Figure 141)]. The "flat" accidentals with an oblique crossing dash are "half-flat" (quarter-tone) accidentals.

Specific accidentals *for intervals* (Fig. 14) allowed for a more precise notation of the subtleties of Byzantine chant based on the division of the whole tone in quarter-tones and thirds-of-the-tone.

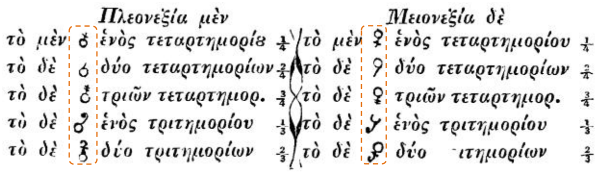


Fig. 14 Accidentals [for intervals] as explained by Chrysanthos Madytos, the theoretician of the First Reform of Byzantine Chant in the 19th century.[161]

[152] Note that excerpts from the musics and analyses addressed in the following sections are available as byproducts of previously published material by the author – mainly Power Point shows.

[153] While it may be argued that Western notation – and musicology – brought some clarity into the (mess of the) analysis of *maqām* music, we will see that the influence of this musicology eventually implemented new contradictions and ambiguities in this music while (see [Beyhom, 2016a]) modifying its characteristics.

[154] See [Beyhom, 2016a] for a detailed review of Orientalism in musicology.

[155] For Byzantine notations before the Reforms of the 19th century see the interesting – however misled as to the roots of Byzantine chant – Wikipedia article [Wikipedia Contributors, 2018f] – accessed 19/07/2018. For Byzantine music after the 2nd Reform of the 19th century see the very complete article [Skoulios, 2012], with tables for the intervallic signs [p. 21] and alterations [p. 32].

[156] See previous footnote and [Levy and Troelsgård, 2001, "1. Manuscript sources and their notation"].

[157] See Chapter IV in [Beyhom, 2016a] and, mainly, [Beyhom, 2015] for detailed explanations about this process.

[158] The numbers of "minutes" (or *moria*) are mainly used for proportionality: the *moria* are not equal in each of the intervals, and most probably also not equal within the same interval composing the scale (see Fig. 15). They are probably the result of a double division, first of the strings of a "*tanbur*", then of the resulting intervals in particular – and proportional – numbers of *moria*. (See previous footnote.) Note also the *diphonic system* (to the left in Fig. 16) in which 64 *moria* (and not 68) compose the octave.

[159] See Fig. 13.

[160] Reform of the "Three Masters", among which Chrysanthos Madytos was the theoretician – see Chapter IV in [Beyhom, 2016a] for more details. The bottom row shows the Latin equivalents used by Rōmanou in her translation(s) [Chrysanthos (de Madytos), 2010; Chrysanthos (de Madytos) and Rōmanou, 1973] of Chrysanthos *Great Book on Music* [Chrysanthos (de Madytos) and Pelopidēs, 1832].

[161] [Chrysanthos (de Madytos) and Pelopidēs, 1832, p. 101]: raising accidentals to the left, lowering accidentals to the right. Subdivisions (accidentals) in fractions of the tone are, from top to bottom: 1/4, 1/2 (2/4), 3/4, 1/3 and 2/3.

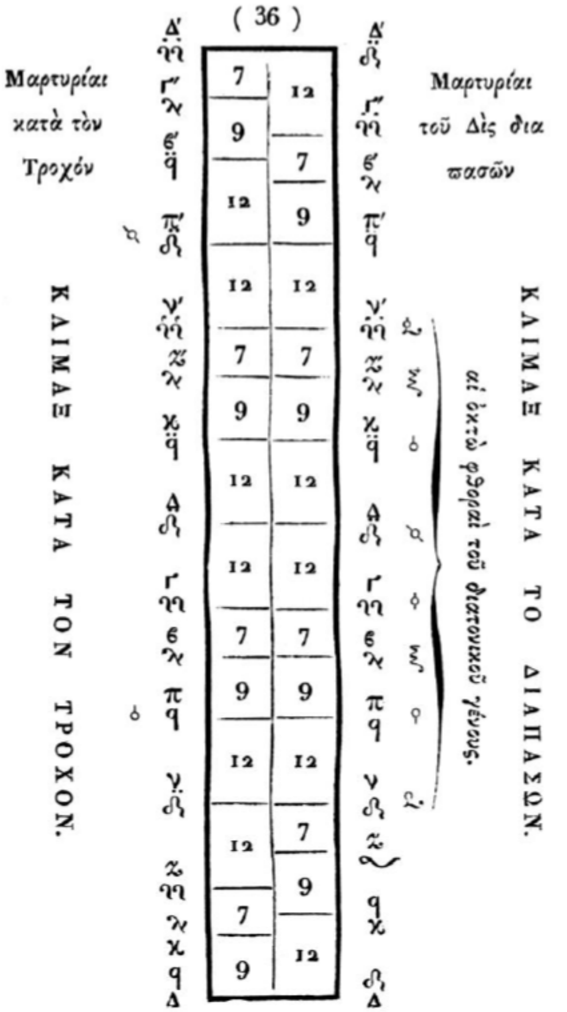


Fig. 15 *Diatonic system* of the *wheel* (pentachordal – Left) compared to the *diapason diatonic system* (Right – effectively based on a tetrachordal construction) in Chrysanthos Madytos' *Eisagogē*.[162]

While keeping the same solmization and notations signs, the Second Reform (1881) waived – among other things – the unequal division of the octave of Chrysanthos Madytos and replaced it with an equal-division (in 72 *moria*) based on equal-temperament (Fig. 18 to Fig. 20).[163]

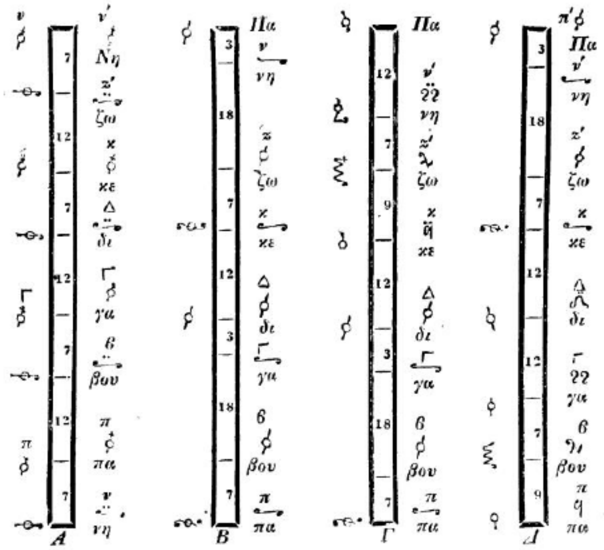


Fig. 16 *Chromatic systems* according to Chrysanthos Madytos, with the *diphonic system* to the left.[164]

It also replaced Chrysanthos' accidentals by accidentals effectively based on the division of the whole tone in six equal intervals (and of the octave in 36) allowing thus for the use of exact (and tempered) semi-tones. (Fig. 17)

As for the intervallic – and simplified – resulting notation, two examples are provided in FHT 43: 233, FHT 44: 234 and FHT 51: 239 with westernized transnotations in FHT 45: 235, FHT 46: 236 and FHT 52: 240.[165]

Sharp signs					"New" Byzantine
					Westernized
Divisions	2	4	6	8	
equ. in cents	33.33 c.	66.66 c.	100 c.	133.33 c.	
Flat signs					Westernized
					"New" Byzantine

Fig. 17 Byzantine accidentals – Second Reform of the 19th century – with westernized equivalents and values in cents.

[162] [Chrysanthos (de Madytos), 1821, p. 36].

[163] The theoretical justification of the scale being, nonetheless, a harmonic division based on superparticular intervals. (For this and other particularities of the two reforms see, as proposed in fn. 157, Chapter IV in [Beyhom, 2016a] and [Beyhom, 2015].)

[164] [Chrysanthos (de Madytos) and Pelopidēs, 1832, p. 106-107, §245], corresponding to [Chrysanthos (de Madytos) and Rōmanou, 1973, p. 99]. The *diphonic system* is composed of 64 (instead of 68 in other systems) *moria* in the octave, which proves the inequality of the *moria* among themselves; the 12 *moria* interval is a whole tone, while the 7 *moria* interval is a (nearly exact) three-quarter-tones interval.

[165] See also [Skoulios, 2012, p. 21] for a table of the signs used in the reformed notation.

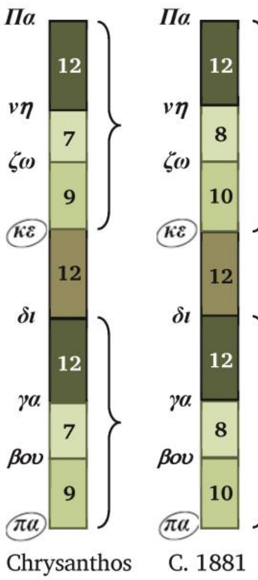


Fig. 18 Structure of the *diatonic system* (main scale) of Byzantine chant.[166]

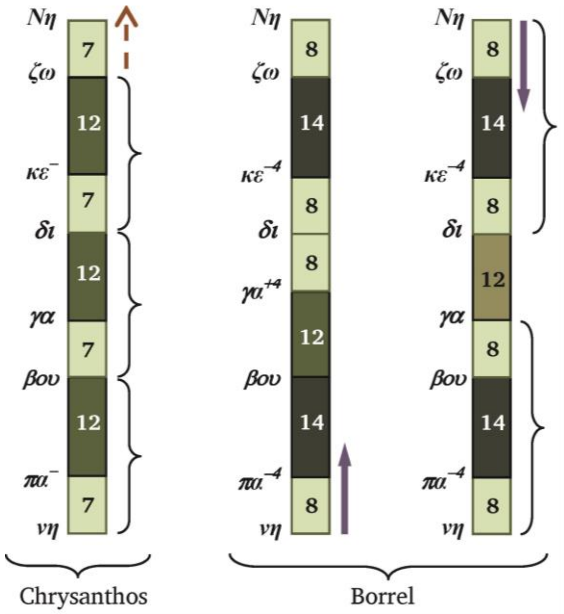


Fig. 19 The *diphonic system* of Byzantine chant.[167]

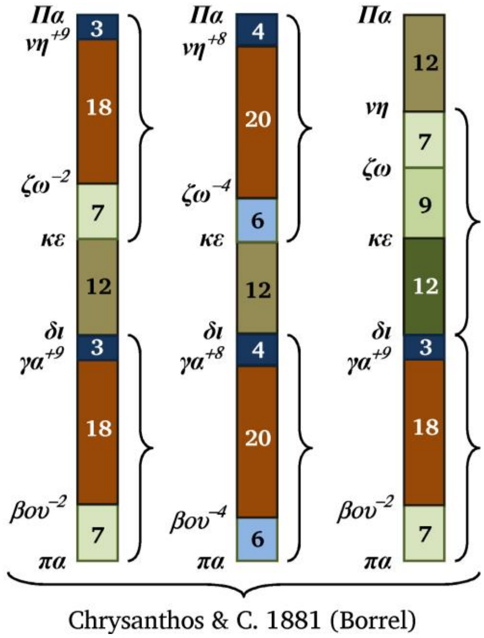


Fig. 20 Some Byzantine *chromatic systems*.[168]

In the meanwhile, and preceding or accompanying Byzantine reforms, a few attempts at notating Ottoman music took place in the 18th to 20th centuries.

Late Ottoman notations[169]

It took a while for musical notation to be accepted in the Ottoman Empire, first by Europeans – and in Western scores – then in forms presumably more adapted to Ottoman music:

> "The very slow acceptance of any form of musical notation during the 19th century, documented by Behar […], seems to have been largely due to the perception of the necessity for lengthy rote-learning in order to assimilate both musical detail and style. However, by the middle of the 20th century the acceptance of both musical notation and a consistent form of theory for pedagogical purposes led to the existence of two forms

[166] In disjunct tetrachords and as deduced from the theories of Chrysanthos Madytos (left) and of the Music Committee of 1881 (right). The background colors of the intervals follow a code used in the book of the author [Beyhom, 2015]: Green in different shades for the "diatonic" intervals (7 to 13 *moria* in Chrysanthos' scales), reddish for the intervals greater than the whole tone, and blue(ish) for the other intervals. The green 12-division (whole-tone) interval gets a maroon(ish) shade when it is a disjunctive tone – previously published in [Beyhom, 2014].

[167] According to Chrysanthos Madytos (left) and the evolution of its presentation in the theory of the Music Committee of 1881 as the *soft chromatic system* (right – rising and descending scales are subject to the phenomenon of "attraction") as explained by Borrel. (+ and – alterations are in numbers of *moria* for the 2nd Reform. Note that the degrees *πα* and *κε* with Chrysanthos are slightly offset.) See [Beyhom, 2015] for more details – Previously published in [Beyhom, 2014].

[168] On this figure are represented the second main *chromatic system* of Chrysanthos (left) and its evolution in the representation by the Music Committee (1881) of the Second Byzantine Reform of the 19th century ("C. 1881" – center). To the right: a *diatonic-chromatic* variant (third main *chromatic system*) by Chrysanthos. These *systems* (mostly the first to the left) are typical of the Sixth Mode of Byzantine chant. (Previously published in [Beyhom, 2014].)

[169] Most of the information in this section relies on two secondary sources which are [Feldman, 1996] and [Jäger, 2015].

of legitimation, one through conservatory instruction and the other through master-pupil training".[170]

The first known Intermediate[171] notations, together with later notations as well as the first westernized scores, were created by groups somewhat atypical of the Ottoman mainstream:

> "The musical theory which was created between 1700 and 1900, and which dominated Arab musical theory until the mid-20th century […] had its beginnings primarily in the treatise of Prince Cantemir, and not in the 15th-Century treatises by Ottoman writers or in older Persian or Arabic theory. The indigenous, emic response to these Western influences seems to have been created primarily by two groups who were somewhat atypical of the Ottoman mainstream: Mevlevi dervishes like Osman Dede, Mustafa Kevseri, Abdulbaki Nasir Dede and Rauf Yekta, and non-Muslims like [the Armenians] Tanburi Harutin and Baba Hamparsum".[172]

These notations are well-established since the 18th century[173] which marks the beginning of autochthonous melodic notations.[174]

Besides the Bobowski accident,[175] the first pre-Western notations in Ottoman music (Fig. 21)[176] date back to the 18th-Century Moldavian Prince Cantemir and Osman Dede. This first attempt at a notation specific to Ottoman (court) music was based on the parallel use of numerals and letters[177]. (Fig. 21)

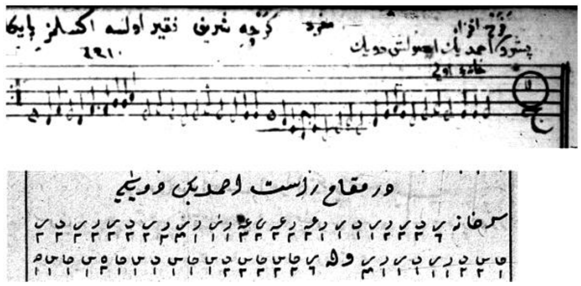


Fig. 21 Comparison of an extract of the same *peşrev* of Ahmed Bey as notated by Ali Ufkî (Bobowski – Top) and Cantemir (bottom).[178]

It remained however isolated until the creation of the so-called *Hamparsum* notation (Fig. 22) which uses graphical signs instead[179]:

[170] [Feldman, 1996, p. 18].

[171] Between the very rudimentary notations by Urmawī expounded above and the adapted Western notation used today.

[172] [Feldman, 1996, p. 25].

[173] "Many of the structural and stylistic changes which had occurred between 1600 and 1750 are documented in the notations and treatises which form the material for the present study. Although there is a dearth of notated documents dating from the second half of the 18th century, and although certain crucial documents of the first half of the 18th century are presently unavailable to scholarship, the final results of these developments of the 18th century can be judged by assessing the Turkish repertoire and performance practice of the Modern Era. This is well known thanks to a continuous series of notations starting in the early 19th century (i.e., the Hamparsum notebooks 1813-1815) which record repertoire of several key instrumental musicians of the end of the previous century, a major treatise written in 1795, the first notation of a Mevlevî *âyîn* from the same date, and a continuous lineage of performers spanning the period from the reign of Selim Ill (1789-1808) until the present day" – [Feldman, 1996, p. 24].

[174] "The stages of transmission [of Ottoman notation systems are] 1650 (Ali Ufkî), 1700 (Cantemir), 1750 (Tanbûrî Petros) [Petros Peloponnēsios] and 1815 (Hamparsum)" – [Jäger, 2015, p. 48].

[175] "Toward the end of the century a new cultural climate both at the court and among the Mevlevi dervishes encouraged a variety of initiatives in musical writing, focusing on notation, theory and lyric collections ('*mecmû'a*') of the courtly *fasil* repertoire. However, in the first half of the century, an historical accident resulted in the entry of a multi-talented and musically educated European into the Ottoman Palace Service first as a slave-musician (from 1633 to 1651-57) […], then as an interpreter, who recorded a significant sample of the courtly and other repertoires in Western staff notation. The '*Mecmû'a-i Saz ü Söz*' ('Collection of Instrumental and Vocal Works') by the converted Pole, Wojciech Bobowski (1610-1675), who took the Turkish name Ali Ufkî Bey was created before the cultural developments of the later 17th century, and evidently was removed from Turkey so that it could not play any part in musical thinking there. While Bobowski wrote several other works, including musical settings for the Biblical Psalms […] and a brief description of the Palace and its musical life, his major significance rests on this '*Mecmû'a*'. The '*Mecmû'a*' is a collection, without a treatise. It contains over three hundred pages of Western staff notation written right to left and the texts of the vocal pieces. There are 195 instrumental pieces, of which 145 are *peşrevs* and 40 are *semâ'îs*. Bobowski evidently wrote this work for himself alone" – [Feldman, 1996, p. 29].

[176] "The most important musicological materials created in the 18th century, […] are contained in the collection of notations and musical treatise of the Moldavian voyvod Prince Demetrius Cantemir (1673-1723), known in Turkish as Kantemiroğlu" – [Feldman, 1996, p. 30]. (See also fn. 184 for Osman Dede.)

[177] "The notation [of Cantemir] uses letters and numerals to write down the quality and quantity of the tone on two interconnected levels. The method parallels the one used already in the 17th century to write down the *usûls*. Cantemir's notation is appropriate to notate the course of a melodic line in parameters of pitch and rhythm" – [Jäger, 2015, p. 46].

[178] Courtesy of Ralf Martin Jäger – originally published in [Jäger, 2015, p. 44].

[179] "The notation method of Hamparsum Limonciyan, a century later, is based largely on the same conception that Cantemir used: quality and quantity of the single tone are notated on two interconnected levels. *Hamparsum-notası* proves to be a method that emerged in the context of older Ottoman notations. However, it differs from Cantemir's notation in important details: instead of letters and numerals, it uses abstracted graphical signs (derived from Armenian *khaz* notation) which are combined into groups of equal duration. It develops additional signs for the graphical depiction of the groups. More important is the differentiation in major line and additional tones, which complement the melodic line in the form of grace notes. Moreover, Hamparsum's notation allows the notation of rests for the first time. It is

"The question of Cantemir's influence upon later Turkish theorists has been debated. In the following generation only the Mevlevi dervish Mustafa Kevserî (d. 1770?) seems to have learned his notational system, and neither his notes nor his theory were referred to by the later 18th-century theorists. The Frenchman Charles Fonton was unable to locate a copy of Cantemir's treatise in 1750. Cantemir's fame as a musicologist seems to have been better established among European visitors such as Fonton or Toderini, and among the local Greeks than among the Turks".[180]

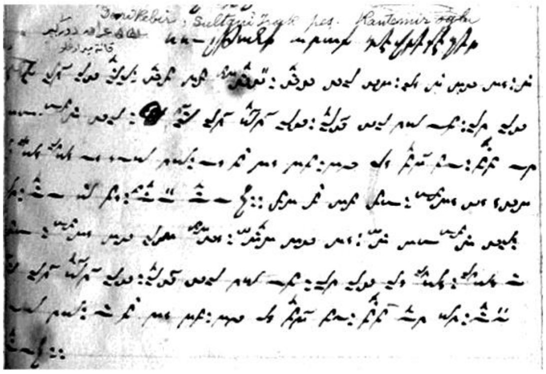


Fig. 22 Detail view of Y.203-1 (Y.86-01), fol. 1 – *Sultani arak devr-i kebîr* in *Hamparsum*('s) notation [originally notated by Cantemir].[181]

Note however that

(1) "Osman Dede wrote a notated collection using his own system of alphabetic notation, whose alphabetical symbols are distinct from those of Cantemir […]. It is not known whether Osman Dede's collection is earlier or later than Cantemir's. This collection is still extant in Turkey, but is in private hands and has never been the object of serious study",[182]

and that

(2) "After Cantemir's treatise, [… there] is a treatise in Armeno-Turkish (Turkish in the Armenian script) by the Armenian Tanbûrî Harutin, who was a court *tanbûr* player for Sultan Mahmud I (1730-1754). […] Harutin also was the inventor of a notational system based on the Armenian alphabet which he included in his book without any notated examples",[183]

whenever

(3) "Between 1794 and 1795 the Mevlevi Sheikh Abdülbâkî Nâsir Dede (1765-1821) [Osman Dede's grandson – p. 95 of the same reference] created a musical treatise […] and notated a score for a Mevlevi *âyîn* written by his patron Selim Ill using a new notational system [based on his grandfather's]".[184]

One further notation by the well-known composer of Byzantine chant Petros *Hirsis* ("Thief" in Turkish)[185] is to be mentioned, based on the Byzantine neumes of the pre 19th-Century-Reforms period. (Fig. 23)

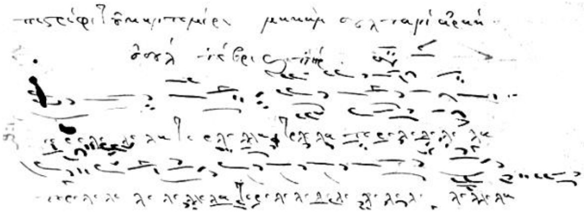


Fig. 23 Detail from the transcription by Petros Peloponnēsios of *pistrífi tô kantemira makám sultaní ârák ûsúl dévri k[e]bîr* – from Gritsanis Ms. 3, fo 14 ro.[186]

All these notation methods, as Jäger underlines, focus on different characteristics of sound and none is completely descriptive: they serve before all as a mnemonic aid and score each different details which may have seemed important to the composer or the musician:

"Both the notation and the notes [used by Petros] focus entirely on details other than the two Ottoman methods. Tanbûrî Petros did not write down the single tones of the melodic line, but rather their melodic flow in intervals: neume notation emerged to set a music which serves to deliver texts. Thus, only a part of the signs notates the melodic progression and its rhythmical structure, while another – for instance the 7 *Achrona* – captures the style of performance and indicate rest, tremolo, sforzato, mordent, legato, the intonation of a caesura or the 'humming' of a tone".[187]

Aural tradition remained, however and through, the main vector of the transmission of music as it was practiced at the Ottoman court.

Moreover,

"[t]he comparison of the sources provides evidence that each notated variant of an [Ottoman] *opus* has an individual character. It is this parallel transmission of variants within the '*opus*-cluster', which accounts for the peculiarity of the Ottoman sources. It is not the search for the 'original text', i.e. the binding

also suitable to write down performance details to a limited extent, along with the melodic line" – [Jäger, 2015, p. 46–47].

180 [Feldman, 1996, p. 32].

181 With transcriptions of the title by Refik Fersan [Ottoman writing] and Suphi Ezgi [Latin writing]. Courtesy of Ralf Martin Jäger – originally published in [Jäger, 2015, p. 47].

182 [Feldman, 1996, p. 33].

183 [Feldman, 1996, p. 33, 34].

184 [Feldman, 1996, p. 35].

185 This is Petros Peloponnēsios, well-known for his ability for notating a melody after having heard it once – see also [Conomos, 2007].

186 Courtesy of Ralf Martin Jäger – originally published in [Jäger, 2015, p. 48].

187 [Jäger, 2015, p. 47]. See also the quotes from the same reference above.

form of the *opus*, but the determination of the synchronous individual variants which could be a central point of investigation in the study of these sources. The associated methodological concept differs fundamentally from the approaches and aims which had been developed for research and documentation purposes, and ultimately for the creation of critical complete editions of European music of modern times".[188]

KHOREZMIAN *TANBUR* TABLATURE

In 1990 an interesting article about a *tanbur* tablature was published in the ICTM revue, in which Otanazar Matyakubov explained:

"In Khiva, in the last quarter of the 19th century, a special tablature for the *tanbur* was created by means of which an abbreviated text of the Khorezmian *mäqams* was fixed. Among musicians these manuscripts are called *tanbur chizigi* (tanbur transcriptions), while in present-day literature they are known as 'Khorezmian *tanbur* notation'".[189]

This tablature (see the *chizigi* – graphics – in FHT 18: 217 to FHT 20: 218) was very detailed:

"The notation can be converted into sound by anyone who has the indispensable aural experience and commands the tradition of the Khorezmian *mäqams*. Principles of Notation[:] The *tanbur* notation fixes five parameters of the *mäqams*: the pitch (parameter), the metric-rhythmic, the syntactic (microstructure), the compositional (macrostructure), and the poetic. The pitch of the tones constitutes the basic core of the transcription. The *tanbur* notation justifies its name: the height of the tones is fixed corresponding to the 18 frets on the fingerboard of the *tanbur*, the horizontal lines of the notation. They are designated by order numbers in vertical order. The dots indicate the number of plucks of the *nakhun*, a special plectrum that is worn on the index finger of the right hand for performing on the *tanbur*. A dot above the line is a pluck from above, below the line, from below. A single pluck, the stroke *yäkkä-z[ä]rb*, is written separately, a double pluck, *khush-zärb*, in pairs above and below the line. The *usul*—a metric formula that is written down with the syllables *gul* and *täk*—gives an indication of the grouping of the pulse."[190]

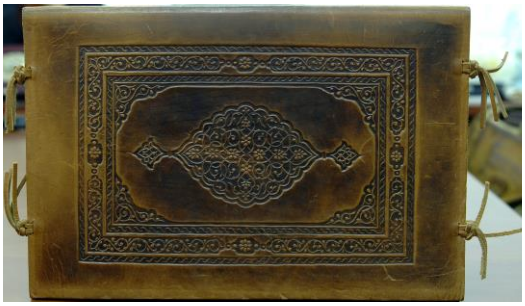


Fig. 24 Bookbinding of a copy of the *Khorezmian tanbur notation.*[191]

At practically the same period and still in Khiva,

"[t]o fix the repertoire, Feruz Khan [Muhämmäd Rähim Bähädur Khan] commanded as early as 1878 to notate it in a specially invented system. At the dawn of the 20th century twentieth century, the Master Qalandar Donmas recorded the integral repertory on barrel organ punch cards [Fig. 25]. No sponsor has yet been found in order to perform them".[192]

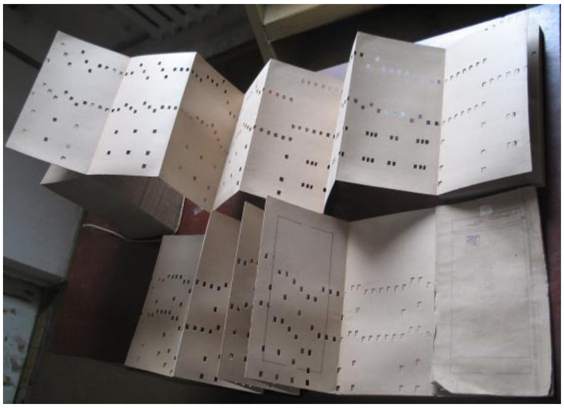


Fig. 25 Barrel organ punch cards recorded by Qalandar Donmas.[193]

This is the main reason why a relation between the two notations has not yet been established.[194]

As for the Arabian countries, and as explained above, the major change was to be the implementation of the quarter-tone scale – and eventually notation – in the theoretical discourse on *maqām* music.

188 [Jäger, 2015, p. 45].

189 [Matyakubov and Powers, 1990, p. 29].

190 [Matyakubov and Powers, 1990, p. 32].

191 Property of Jean During. Photo courtesy of the owner.

192 Translated from a private communication from Jean During in French.

193 Photo courtesy of Rustam Boltaev via Jean During.

194 One possibility is that the "piano rolls" could correspond, according to During (who refers to https://uz.wikipedia.org/wiki/Tanbur_chizig'i – in Uzbek, and to his own [Anon. "DOTĀR"]), to the classic repertoire of 30 songs transcribed for the *dutor* in 1883 – the *Dutor Maqomlari.*

Mīkhāʾīl Mashāqa and Kāmil al-Khulaʿī – Or the implementation of the Western theory of the scale in *maqām* music

Fig. 26 Photograph of Kāmil al-Khulaʿī appearing in the reprint of his book on Arabian music.[195]

The Arabian countries, still under Ottoman rule,[196] were the most receptive in the 19th century to the Siren song of Western musicology. Theoreticians and *maqām*-connoisseurs began (at least) as early as the beginning of the 19th century discussing the concept of the "quarter-tone" division supposedly at the basis of "Arabian" music.[197] Thus Mīkhāʾīl Mashāqa[198] in the 1820s relating a discussion in Damascus between his mentor sheikh Muḥammad al-ʿAṭṭār and a protagonist named ʿAbd-al-Lāh Effendī Mühürdār, in which the former defended a division of the octave half-string in 24 equal parts to obtain the "quarter-tones" of Arabian music.[199]

Notwithstanding the fact that *maqām* music never used a division of the octave in (equal) quarter-tones,[200] Mühürdār objected that equal quarter-tones could not be obtained with this method.

In the *Epistle to the Emir Shihāb*[201] Mashāqa tries to prove Mühürdār right by giving a geometric method for dividing the string in order to obtain (nearly) exact quarter-tones (Fig. 27).[202]

Mostly, however, he deems the quarter-tone division "inferior" (for *maqām* music obviously) to the division of the scale of the "Modern Greeks"[203] and compares them together – underlining the (theoretical) discrepancy between the two.[204] (see a table of the in FHT 10: 212 and a detailed reproduction of the two scales in FHT 12: 213)[205]

Nevertheless, and whenever Mashāqa expressed his disbelief in the virtues of this division, he has been considered as the "inventor" of the quarter-tone division by Orientalist musicology.[206] On the other hand, he certainly used the concept of quarter-tones to describe literally the scales and formulae of Arabian *maqām* music.[207]

About one century later the quarter-tone division had become a must through the pen of – mainly – Egyptian authors such as Kāmil al-Khulaʿī[208] who – also[209] – divided the "Arabian" (*Rāst*) octave in intervals of one-whole-tone and three-quarter-tones (Fig. 28) – based on quarter-tone multiples.

However, at least one other division was proposed in the meanwhile by Shihāb-a-d-Dīn (Muḥammad ibn Ismāʿīl ibn ʿUmar al-Makkī) al-Ḥijāzī, based on 28 "quarter-tones" in the octave (Fig. 29).

[195] [Khulaʿī (al-), 1993].

[196] And influenced by Ottoman theories of the scale – see fn. 172: 166.

[197] The Arabs, in their endeavor to differentiate themselves from the Ottomans, found it – at least for most of them – easier to fully embrace the Western semi-tonal division of the scale by simply dividing the semi-tone in two – theoretical if not practical – parts.

[198] The first chapter of [Beyhom, 2015] expounds the contribution of this author to the Modern theory of *maqām*.

[199] [Beyhom, 2015, p. 12].

[200] Early theoreticians of *maqām* based themselves from the outset on Greek theories of the scale. They used thus the concept of the quarter-tone theoretically, namely for the enharmonic *genos*. (See [Beyhom, 2010c].) Later theoreticians complied either with Urmawī's theoretical division or with the literal description of the scale by naming the notes.

[201] [Mashāqa, 1887] or an English translated version in [Mashāqa and Smith, 1849].

[202] See also the caudal plates in [Mashāqa and Smith, 1849].

[203] The Byzantine chant theory of the 1st Reform of the 19th century.

[204] Note that Mashāqa assumes in his "epistle" that the *moria of* Chrysanthos were equal, which they were not.

[205] An obvious comparison, however, would have been between the scale of the Second Byzantine Reform of the 19th century (in sixths of the tone) which shows a greater compatibility with the quarter-tone division (FHT 11: 212) – but the latter reform took place first in the 1880s. (See also both Byzantine scales compared with the "Arabian" quarter-tone scale in FHT 13: 214 – remember however that Chrysanthos' scale is not based on equal-temperament.)

[206] See for instance [Parisot, 1898].

[207] See [Azar Beyhom, 2012].

[208] As one example – another important Egyptian author contem-porary to Khulaʿī is Muḥammad Dhākir (Bey) who published booklets on Arabian music theory (see [Dhākir (Bey), 1890a; 1890b; 1903]).

[209] Khulaʿī copied off Mashāqa and Ḥijāzī (see farther for the latter).

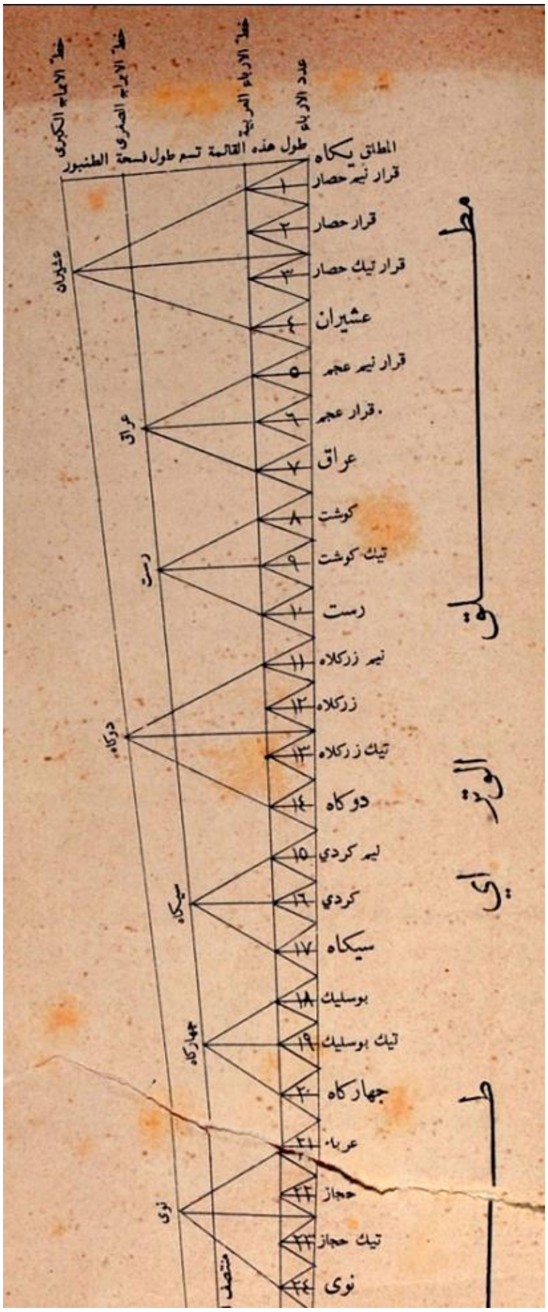


Fig. 27 Detail from Mashāqa's division of the string of the *ṭunbūr* explaining how to establish an equal-division of the octave in 24 quarter-tones.[210]

Shihāb-a-d-Dīn also explains[211] how the names of the main degrees of the scale evolved and became the ones shown in the figure.[212]

The quarter-tone based octave division was soon to be adopted – in the 24 quarter-tones per octave version – together with the use of a Western notation with adapted accidentals for Arabian music in the famous – or infamous? – *Congrès du Caire* of 1932[213] (Fig. 30).

It was also used in the equally well-known series of books on Arabian music by the team of Rodolphe (d') Erlanger (Fig. 33: 172 and FHT 22: 219).[214]

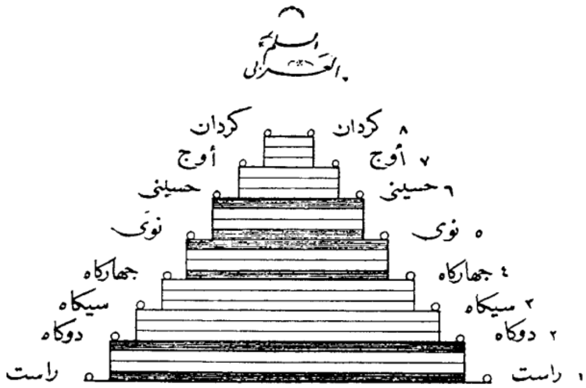


Fig. 28 The scale of "Arabian" [*maqām Rāst*] music according to Kāmil al-Khulaʿī with whole-tone and three-quarter-tones intervals.[215]

Finally, scale notation in the quarter-tone theory uses concurrently a numeric – intervallic – notation in multiples of the quarter-tone (FHT 14: 214), still in use today for theoretical purposes (Fig. 31 and Fig. 32, FHT 9: 212, FHT 15: 215, FHT 17: 216 and FHT 16: 215)[216].

[210] [Mashāqa, 1899, plate inserted between p. 1076 & p. 1077] – previously published as [Beyhom, 2012, p. 72, Fig. 13].

[211] [1864, p. 14–15].

[212] I use in the following figures the standard contemporary names of the *burdāt* and *ʿarabāt*. Note that the division of al-Ḥijāzī is fully expounded in the first part of [Beyhom, 2012].

[213] [Collectif, 1933 ; 1934 ; Hassan, 1990 ; Moussali, 2015] – see also the very complete [Vigreux and Hassan, 1992].

[214] [Erlanger, 1930]: let us here note that, while most – if not all – autochthonous theoreticians of the beginning of the 20th century (and beyond) were aware that their "quarter-tones" were not equal, this belief is today firmly rooted in the layman's thought, if not with conservatoire students and composers of Arabian popular songs.

[215] As shown in [Khulaʿī (al-), 1904, p. 29]. Degrees from bottom upwards: *RĀST DŪKĀ SĪKĀ JAHĀRKĀ NAWĀ ḤUSAYNĪ AWJ KARDĀN*; three-quarter-tones intervals in white (three stripes), whole-tone intervals with two white central stripes and two black bordering ones.

[216] See also [Beyhom, 2017].

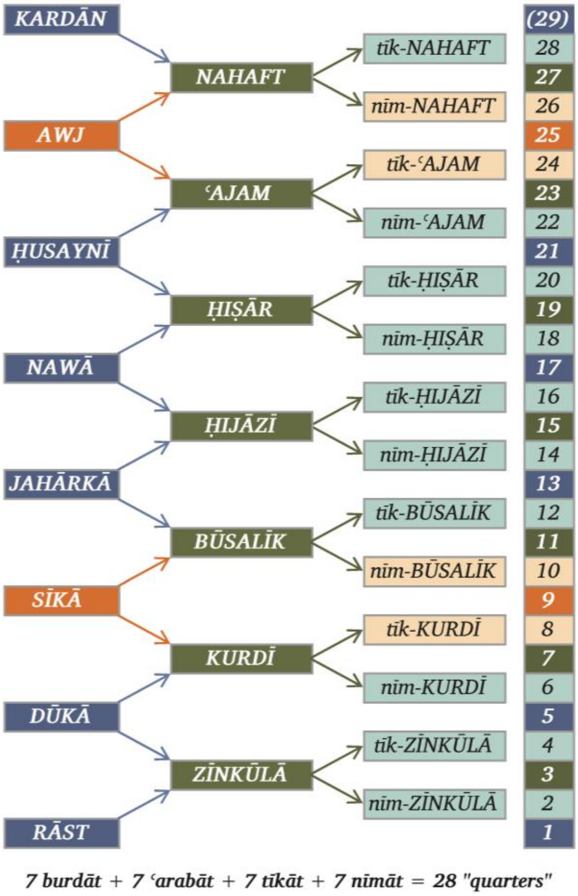


Fig. 29 The 28 "quarter-tones" ("*maqāmāt*" = pl. of *maqām*) of Shihāb-a-d-Dīn divided into *burdāt*, *ʿarabāt*, *tīkāt* and *nīmāt*.[217]

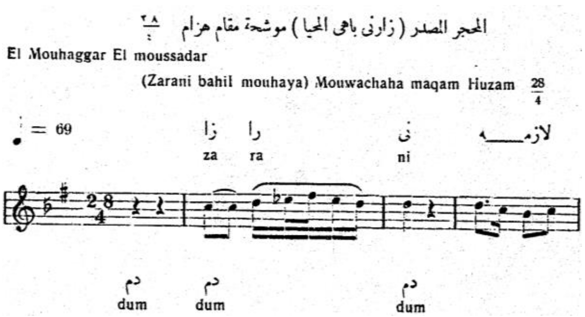


Fig. 30 Beginning of a *muwashshaḥ* in mode *Huzām* as notated in the Conference proceedings of the *Congrès du Caire* of 1932.[218]

HIGAZ / RAST								
2	6	2	4	4	3	3		
6	2	4	4	3	3	2		
2	4	4	3	3	2	6		
4	4	3	3	2	6	2		
4	3	3	2	6	2	4		
3	3	2	6	2	4	4	Re	SABA
3	2	6	2	4	4	3		
RAST / RAST								
4	3	3	4	4	3	3	Do	RAST
3	3	4	4	3	3	4	Re	HUSSEINI
3	4	4	3	3	4	3	Mb'	SIKA
4	4	3	3	4	3	3	Fa	GIHARKA
4	3	3	4	3	3	4	So	YEKAH
3	3	4	3	3	4	4	La	H OSHAIRAN
3	4	3	3	4	4	3	Tb'	IRAQ

Fig. 31 Detail from FHT 15: 215 showing the *ḥijāz/rāst* and the *rāst/rāst* matrices in Fatḥī Ṣāliḥ's intervallic investigation of the combination of "Arabian" tetrachords.[219]

"Enharmonique" si^db	1er degré	1er int.	2e degré	2e int.	3e degré	3e int.	4e degré
Erlanger (quarts)	si^db	→ 1	si	→ 8	ré^#	→ 1	mi^db
Quarts (conceptuels)	si^db						mi^db
Conceptuel 17es	si^-	→ 1	si	→ 5	ré^+	→ 1	mi^-
Notation simplifiée 17es	si^b	→ 1	si	→ 5	ré^#	→ 1	mi^b

Fig. 32 Detail from FHT 17: 216 turned 90° counter-clockwise and showing intervallic equivalences and literal notations for the enharmonic *genos* on B^{hf}.[220]

[217] The *burdāt* (s. *burda*) are the main degrees of the scale (left); the *ʿarabāt* (s. *ʿaraba* – main intermediate degrees between the *burdāt*) figure on a dark green background (middle), the *tīkāt* (s. *tīk*) and the *nīmāt* (s. *nīm* – intermediate degrees between the *burdāt* and the *ʿarabāt* – the *tīk* raises the degree, the *nīm* lowers it) on light green-blue and green-orange backgrounds. The result is a scale divided in 28 conceptually equal "quarters" (column to the right), while in the contemporary theories of *maqām* the degrees with orange background (*SĪKĀ* and *AWJ*) delineate two (upper and lower) three-quarter-tones intervals. (Figure previously published as [Beyhom, 2012, p. 68, Fig. 4].)

[218] [Collectif, 1934, p. 417]. Note the key signature using both half-flat (with an oblique crossing dash) for the *b* and a sharp sign for the *f*.

[219] Numerals represent multiples of the quarter-tone.

[220] In Erlanger's formulation (1st row), in the author's proposition in quarter-tones (2nd row – no formulation for this *genos*) and in 17ths of

Westernized scores[221]

There are two main subdivisions in the western notations of *maqām* music, which are the use of unmodified notation (with the usual # and b accidentals) or of the modified notation (with adapted accidentals). I shall not explore the first subdivision[222] as it is a pure Orientalist tool of musicology and cannot apply to *maqām* music.

Adapted western notations may be divided in two subdivisions further: the "simplified notation" of Arabian (Fig. 33 – FHT 25: 221 to FHT 30: 226) and Persian (Fig. 34 and Fig. 35) musics, and the "complex" notation of post-Ottoman Turkey.

Fig. 33 An example of *taqsīm* (improvisation – traditionally performed as a prelude to the song or music) in *maqām ʿArḍibār* by the team of Erlanger.[223] (Here a "transnotation" in [Erlanger, and Kriaa, 2018, v. 5, p. 269].)

In the first notations only two supplementary accidentals are used for raising or lowering the pitch by one quarter-tone interval (Fig. 30 and Fig. 33 for Arabian music, Fig. 34 and Fig. 35 for Iranian music). These are based on the adaptation of the autochthonous scales to the Western scale by using a "half" of the semi-tone, resulting in a 24 quarter-tones octave.[224]

Fig. 34 Westernized notation of the scales of Iranian music using the *koron* (inverted flat sign for a quarter-tone lowering of the pitch) with corresponding key signatures.[225]

Fig. 35 *Darâmad* of *Dashti* according to the *radif* of Borumand in westernized notation using the *koron*.[226]

The Turkish adaptation of western notation uses more complex accidentals. Although based on Pythagorean justifications (Fig. 38) and on a division in Holderian commas[227], it is in fact based on a division in twice

the octave (3rd and 4th rows). From the author's habilitation thesis [Beyhom, 2010b, p. 127, Plate no. 10].

[221] Some paragraphs in this section are translated and adapted from [Beyhom, 2003a] and [Beyhom, 2014].

[222] Mostly because such notations were adaptations for the piano – see [Pasler, 2012]. Note that standard western notation has been used by both Orientalist and autochthonous theoreticians to describe *maqām* music. In the case of the latter (mostly), implicit alterations of the *e* (= e^{-}) and the *b* (= b^{-}) – in the Arabian scale – are assumed. (Compare with the standardized notation of Scottish bagpipes, the scale of which is also incompatible with such notation – see for example [Allan, 1940].)

[223] [Erlanger, 1949, v. 5, p. 257].

[224] Eventually, and with the near-disappearance of aural tradition (notably after the disappearance of the founders of these "new" theories and the gap in aural transmission that followed – see [Beyhom, 2016a]), most aficionados – if not conservatoire musicians – of *maqām* music came to believe that the "quarter-tones" were exact (equal), and that *maqām* music effectively used "quarter-tones".

[225] [During, 1984, p. 105] – Courtesy of the author.

[226] [During, 1984, p. 112] – Courtesy of the author.

[227] 9 (Holderian – also called Mercatorian) commas – not italicized to differentiate them from Pythagorean and other Ancient Greek

the intervals of the Western 12-ET octave (24 intervals – see FHT 38: 229) as will be expounded farther, but these intervals are conceived as unequal.

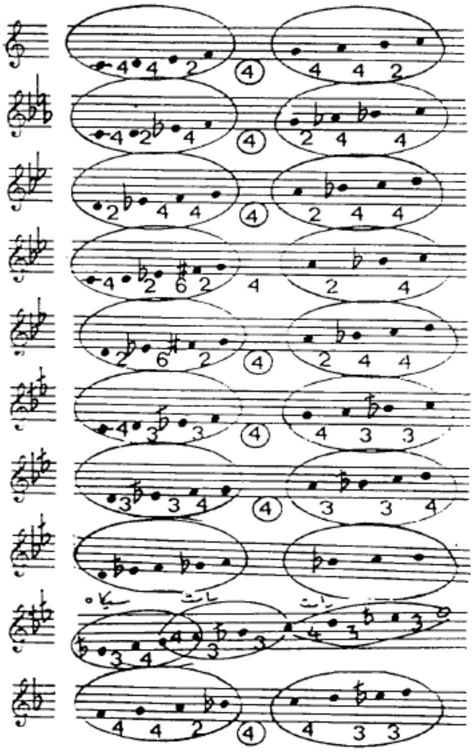


Fig. 36 Notation and key signatures of the main scales of Arabian *maqām*(s) according to Jabaqjī, concurrently with their intervallic formulation in multiples of the quarter-tone.[228]

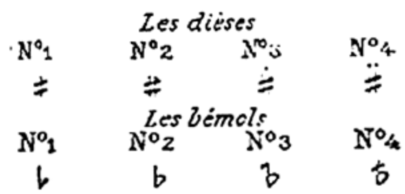


Fig. 37 Turkish accidentals as in [Yekta, 1922, p. 2986].[229]

The desire, common to most – if not all – autochthonous theoreticians, to reconcile western notation and *maqām* tradition(s) led to deep misunderstandings in the autochthonous formulations and raised problems which are still not solved today.

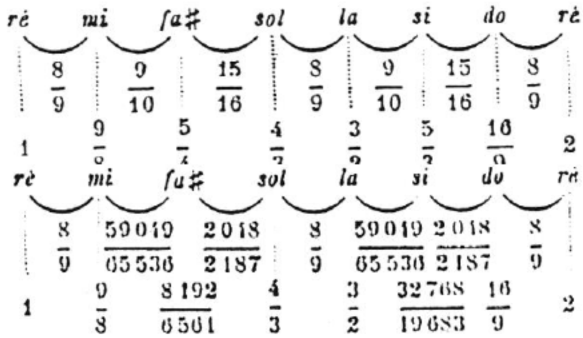


Fig. 38 Simplified Turkish scale according to [Yekta, 1922, p. 2986]: Above → "approximate" ratios ; Below → "exact" (Pythagorean) ratios.

THE *TĪK-NĪM* MISUNDERSTANDING

The Arabs inherited a music theory which was established in the Ottoman Court, and was applied to a highly refined repertoire.

The concept of accidentals in the Ottoman – then Turkish – theories of the scale included a raising (sharp) term for the intermediate notes[230] between the main pitches (the *ʿarabāt* in Fig. 29) – the "*tīk*" – and a lowering term for the same degrees – the *nīm*.[231]

One of the main problems in teaching score notation adapted to *maqām* music arises from this *tīk-nīm* terminology. Fig. 39 shows the two-octavial notation of the scale by Lebanese author, theoretician and *ʿūd* player Salīm (al-) Ḥilū.

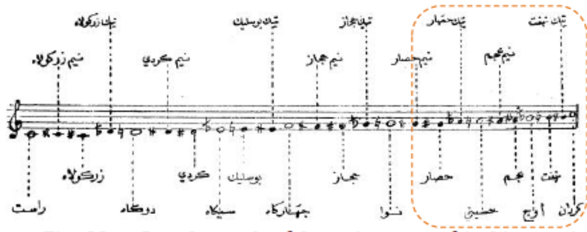


Fig. 39 Complete scale of the main octave of Arabian music according to [Ḥilū (al-), 1972, p. 68].

The detail proposed in Fig. 40 features a *tīk-ḤIṢĀR* ($a^{half\text{-}flat}$) – which is a *ḤIṢĀR* ($g^{\#}$) raised by a quarter-tone: its accidental is a "half-flat" sign.

comma(s) – make up one whole tone, 4 one semi-tone (*leimma*), 53 in all in the octave – see [Holder and Keller, 1731].

[228] [Jabaqjī, sd., p. 28].

[229] The n°1 sharp sign ("*dièse*") raises the pitch by 524288/531441 (one Pythagorean *comma* ≈ 24 cents), n°2 by 243/256 (*leimma* ≈ 90 c), n°3 (dotted) by 2048/2187 (*apotome* ≈114 c), n°4 (two dots) by 59049/65536 ("minor tone" or *di-leimma* ≈ 180 c). The n°1 flat sign (flattened) lowers by one Pythagorean *comma* ≈ 24 c, n°2 (plain flat sign) has an approximate ratio 24/25 (equivalent to a 17th of the octave ≈ 71 c), n°3 → *leimma*, ≈ 90 c, n°4 (with a stricken off stem) → *apotome* ≈114 c.

[230] It is the interval which is, in fact, made greater – or lesser in the case of the *nīm*. However, whenever one interval in the scale is made lesser, the adjacent interval is automatically made greater: this is but one of the semantic pitfalls in the complex Arabian-Ottoman-Turkish-Persian-Iranian music theories and scales, not speaking of the Byzantine ones.

[231] See Fig. 37, FHT 32: 227 and FHT 37: 229.

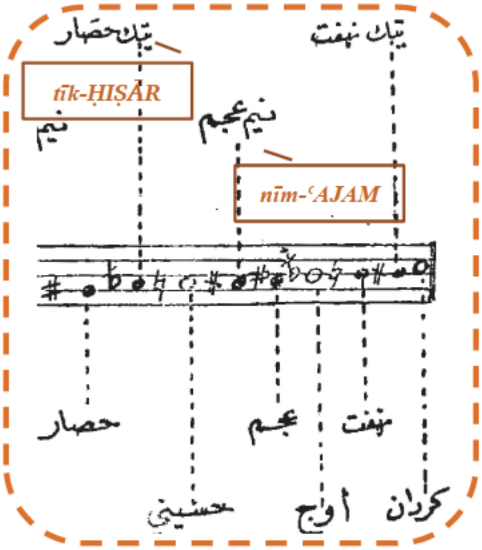


Fig. 40 Detail from the scale of the main octave of Arabian music according to Ḥilū (see previous figure) showing the contradiction with the *tīk-nīm* usage in "modern" theories of the scale. Here, *tik-ḤIṢĀR* ($a^{half\text{-}flat}$) is a *ḤIṢĀR* ($g^{\#}$) *raised* by a quarter-tone: its accidental is a "half-flat" sign. The mirrored *nīm-ʿAJAM* ($a^{half\text{-}sharp}$) is a *ʿAJAM* (b^{b}) *lowered* by one quarter-tone: its accidental is a "half-sharp" sign.

The same applies to the degree *nīm-ʿAJAM* ($a^{half\text{-}sharp}$) which is a *ʿAJAM* (b^{b}) lowered by one quarter-tone: its accidental is a "half-sharp" sign.

Needless to say, students in the conservatoires have always had problems understanding these contradictory concepts, which is one of the cons of Western notation applied to *maqām* music.[232] The moreover when "innovative" Arabian theoreticians improvise arbitrary tetrachordal constructions of the scales with "disjunctive" tones of which nearly none is equal to a whole tone (FHT 30: 226).

The problem of the key signature(s)

In their desire to mimic the West *and*, strangely enough, to retain their traditional music, Arabian theoreticians could not avoid a(nother) formidable pitfall: the key signatures of their numerous scales and modes. The use of "adapted" key signatures leads to sometimes considerable inconsistencies as between the key signatures of *maqām Huzām* by the theoreticians of the *Congrès du Caire* (Fig. 30 – and Fig. 44: 175 with no key signature at all) and by further subsequent theoreticians such as the Syrian Shirzād ʿAmr[233] (Fig. 41, central row – bottom) or the Lebanese Salīm al-Ḥilū (Fig. 42 and Fig. 43 – and a notated example in FHT 24: 220) whose two versions are not even consistent one with another.

With the key signatures of Western music based on the cycle of fifths and Pythagorean theory, their introduction in the westernized notation of *maqām* music imposed this theory as the inevitable reference for all and every Arab theorist, who had to adapt their scales for such use. One simple modification was – as seen above – the use of "half-flat" signs instead of "flat" signs[234] (Fig. 41 to Fig. 43).

Fig. 41 Key signatures and "dissenting" notes of the Arabian modes.[235]

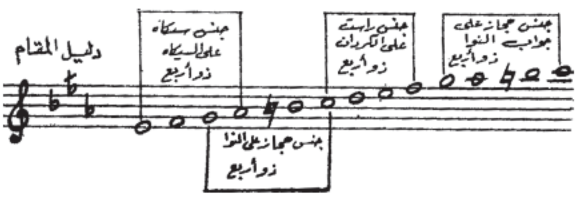


Fig. 42 Scale of *maqām Huzām* by al-Ḥilū (1).[236]

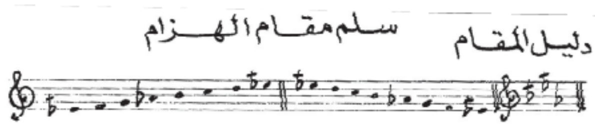


Fig. 43 Scale of *maqām Huzām* by al-Ḥilū (2).[237]

The complete inadequacy of the theory of the cycle of fifths applied to *maqām* scales appears in all its glory

[232] Evidently, all traditional terminology could be avoided for conservatoire students – who will very probably then even more believe that the quarter-tone alterations do apply exactly to the degrees of the scale: all *maqām* musicologists are aware that this is not the case, but…

[233] Having, however, a Persian forename – see [Anon. "First name Shirzad - NamepediA"].

[234] And of "half-sharp" signs instead of "sharp" signs – mostly however in Turkish – or Turkish-influenced – notations.

[235] [ʿAmr, 2000, p. 89]. Left row (top to bottom): modes *Nakrīz*, *Ḥijāz* and *Sulṭānī-Yākā*. Central row: modes *Sūznāk*, *Shūrī* and *Huzām*. To the right: modes *Nawā-Athar* and *Shatt-ʿArabān*.

[236] [Ḥilū (al-), 1972, p. 132].

[237] [Ḥilū (al-), 1980, p. 175].

in one further example of key signature for the "polychord *mukhālif*" by Iraqi Thāmir ʿAbd-al-Ḥasan al-ʿĀmirī (Fig. 45) in which he uses 3 "natural" signs to neutralize implicit flattening of notes (would the scale have followed the cycle of fifths construction scheme).[238]

Fig. 44 Detail from the notation of *maqām Huzām* in the proceedings of the *Congrès du Caire* of 1932.[239]

Fig. 45 Notation of the "ʿ*uqd*" (pentachordal polychord) *mukhālif* according to ʿĀmirī.[240]

FEW OTHER PROBLEMS RAISED BY THE USE OF WESTERN NOTATION FOR *MAQĀM* MUSIC

Most problems of notation derive, however, from the (un-) precision of Western notation and from the desire of autochthonous theoreticians, on one side, to have more precise signs for accidentals and, on the other side, to avoid the exclusive use of "exact" quarter-tones (Fig. 46, Fig. 47 and Fig. 49) – which would undermine traditional *maqām* music.

These attempts remained however inconclusive whatever refinement the accidentals could achieve – as with Chabrier (Fig. 50 and FHT 23: 220) – which brings us (back) to the Ottoman (Turkish) notations in the 20th century and to the headlong rush for more precision in notation.

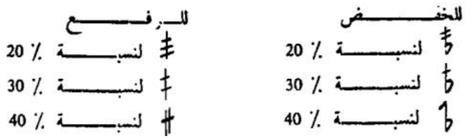


Fig. 46 Accidentals used by Mahdī.[241]

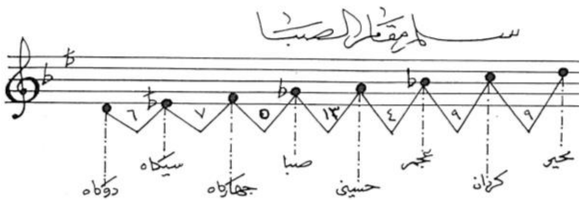


Fig. 47 Scale of *maqām Ṣabā*, using Western modified notation in quarter-tones concurrently with interval values in HC[242].

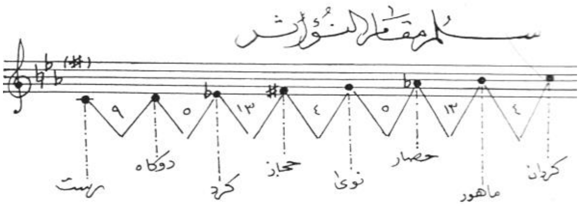


Fig. 48 The same author as in Fig. 47 uses Western modified notation in quarter-tones concurrently with interval values in HC, with a key signature comprising one "natural" sign and a # sign between brackets for *maqām Nawā-Athar*.[243]

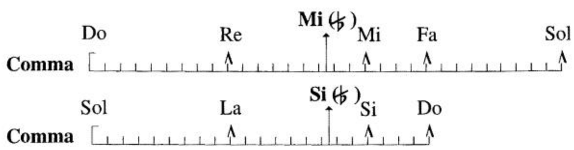


Fig. 49 Positioning of the "quarter-tones" for *maqām Rāst* according to (al-) Bāshā – Based on HC.[244]

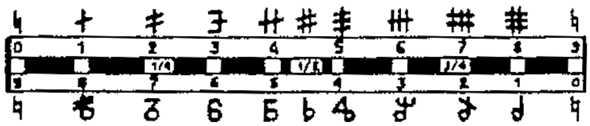


Fig. 50 Accidentals used by Chabrier, based on a combined Holderian comma and equal-temperament division of the whole tone.[245]

***

[238] See also the key signature in Fig. 48 in which ʿAbbās uses one "natural" sign in the key signature *and* a # sign between brackets for *maqām Nawā-Athar*.

[239] [Collectif, 1934, p. 528].

[240] [ʿĀmirī (al-), 1987, p. 169].

[241] [Mahdī (al-), 1982, p. 18].

[242] "HC" stands for "Holderian comma" – [العباس and ʿAbbās (al-), 1986, p. 101]. From left to right intervals of 6 7 5 13 4 9 9 commas.

[243] [العباس and ʿAbbās (al-), 1986, p. 110]. From left to right intervals of 6 7 5 13 4 9 9 commas.

[244] [Bacha, s.d. (199x), p. 1].

[245] [Chabrier, 1995, p. 67].

As a conclusion to this section, let us remember that, not far from Greece and still within the Ottoman Empire, Mīkhāʾīl Mashāqa's[246] comparative approach had no possibility of establishing a connection between two theoretical systems one of which – the Byzantine – was still embedded in the "Oriental" practice formalized, notably and in the 13th century, by Ṣafiyy-a-d-Dīn al-Urmawī while the second – the so-called "Arabian" theory of the "quarter-tone" – was already inspired by the Western theoretical system, if not artificially created by its promoters such as Bourgault-Ducoudray for Byzantine chant[247]. As seen above, the contents of Mashāqa's treatise were implemented a few decades later in the theory – and maybe in the practice – of Arabian *maqām* music notably, at the turn of the 19th-20th centuries, with the book of the musician and theoretician Kāmil al-Khulaʿī in Egypt.

It may well be that the mere existence of a simplified diastematic notation for Byzantine chant[248] towards the beginnings of the 19th century helped preserving this chant longer than Arabian – notably Urban – music, the Arabian society having failed in producing a theoretician such as Chrysanthos Madytos who would have paved the way for an endogenous modernization of Arabian *maqām* theory.

The Turkish notation system[249]

At the dawn of the 19th century the 17-intervals per octave system of Ṣafiyy-a-d-Dīn al-Urmawī was slowly becoming inadequate both quantitatively and structurally. Urmawī's scale could not describe the exact intervals of Ottoman music at a time when the comparison with Western music – in which the octave division is structurally different – was demoting it to an accident of history.

Urmawī's system was not conceived for a *description* of the intervals, but for the *identification* of those intervals.[250] It was also conceived as a *zalzalian*[251] system, based on "neutral" seconds that Ṣafiyy-a-d-Dīn called *mujannab*(s).[252]

***

Contemporary Turkish theories of the scale are influenced by Rauf Yekta Bey's theories in the *Encyclopédie du Conservatoire*.[253] Further developments by Suphi Ezgi and Sadettin Arel[254] led to what became the "Yekta-Ezgi-Arel" theory taught notably in Turkish conservatoires.[255]

Yekta's General scale of Turkish music (FHT 31 and FHT 32: 227) is transposed a fifth higher to fit it in a staff in treble clef. As for all Ottoman theories of the scale, it is inspired by Ṣafiyy-a-d-Dīn al-Urmawī's Pythagorean division of the octave.

Urmawī's theory is based on an unequal division of the octave in 17 intervals (FHT 33: 227) in a Pythagorean formulation.

The essence of Urmawī's scale is, however, *qualitative* as his intervals have an identifying function before all (the measure of the interval is only indicative of its function in the scale).[256] It is radically different from the

[246] Mīkhāʾīl Mashāqa was an offspring of Greek immigrants in what are today called Lebanon and Syria, or the Bilād a-sh-Shām of the Ottoman Empire. He was an ophthalmologist, a historian and a theoretician of Arabian music – see more in the first chapter of [Beyhom, 2015].

[247] See [Beyhom, 2015 ; 2016a].

[248] Apart from Byzantine chant being a religious chant, which generally leads to a better conservation of its characteristics with time.

[249] This section is partly translated from [Beyhom, 2014].

[250] See [Beyhom, 2018ap].

[251] The *Zalzalian system* is the main *maqām* system based on the scale of *maqām Rāst*.

[252] It is worth reminding here that many systems for the division of the octave have co-existed in the countries or regions of *maqām* music, from the trivial division in 7 intervals to the divisions in 14, 17, 21 (probably) and also 28 intervals – not forgetting the 22-*śruti* division of Indian music. More refined divisions include the 53-commas Turkish system with the 68 and 72-*moria* systems of Byzantine chant. All these systems have theoretical foundations that make them legitimate, and all should be looked at closely for a better understanding of how autochthonous theoreticians have tried to explain – and sometimes to teach – their music.

[253] [Yekta, 1922]. Yekta Bey also published numerous articles in Turkish – see [Borrel, 1935 ; Wikipedia Contributors, 2014] – as well as the seminal [Yekta, 1924] – republished as [Yekta, 1986].

[254] [Signell, 1977]. This original Ph.D. thesis was further published as [Signell, 1986 ; 2004 ; 2008].

[255] The main references for this section remain Signell's book with an abundant bibliography in [Signell, 2004, p. 188 sq.] as well as Yekta's article [Yekta, 1922] – Other useful reference are [Feldman, 1996], [Signell, 2001], and [Borrel, 1922 ; 1923a ; 1923b]. Alternate or complementary contributions to the Yekta-Ezgi-Arel theory include [Karadeniz, 1965] and [Karadeniz, 1983] – "Hardly known in Turkey" according to [Signell, 2004, p. 191] and an "obscure writer" in note n° 8 of [Signell, 2004, p. 37] – or the developments by [Tura, 1988], not to forget contributions by young authors such as [Yarman, 2008a ; 2008b].

[256] See [Beyhom, 2018ap] for more details on the different functions of intervals in *maqām* music.

Pythagorean scale in its conception (FHT 33: 227) as it follows an *additive* concept (Fig. 51 – Right) – and not imbricated for the sharp and flat accidentals as with Pythagorean theory as implemented by Western music theorists (Fig. 51 – Left).[257]

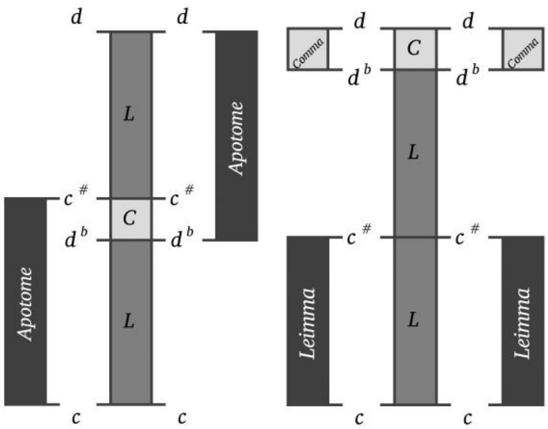


Fig. 51 To the left: Accidentals in Pythagorean theories adapted to the Common practice scale of western music are divisive: intervals $c\_c^{\#}$ and d_d^{b} intersect. To the right: Conjunct intervals and consecutive action of the accidentals with Urmawī: intervals $c\_c^{\#}$ and d_d^{b} are independent from one another, and separated by $c^{\#}\_d^{b}$ which is one *leimma*.[258]

This is even more apparent with Fig. 52, which reproduces the effect of accidentals in the case of a *L C L* tone for Urmawī, in which d^{flat} would be equivalent to $c^{\#}$ in the Pythagorean system (Fig. 51 – Left), and *vice versa*.

In modern terms, altering an interval[259] is different from altering a note of the scale. Whenever altering an interval means adding or removing a measuring (or small conceptual) interval from it, altering a note in western – Pythagorean based – theories is a divisive concept,[260] from which we deduce that d^{flat} is one *comma* lower than $c^{\#}$, whenever an "augmented" b_c interval (or $b\_c^{\#}$ – or its equivalent) with Urmawī will always be below the "diminished" c_d interval (or $c^{\#}\_d$).[261]

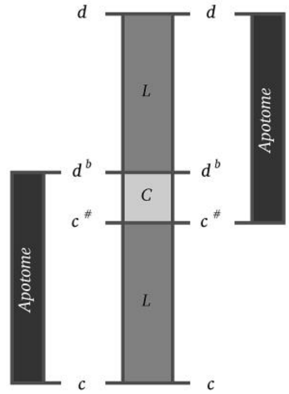


Fig. 52 Alternate formulation (*L C L*) of Urmawī's tone and accidentals.

Furthermore, and in addition to being a *linear* theory of the scale, Urmawī's theory encloses three successive levels of conceptualization, namely the structuring of the octave in (Just) fourths and disjunctive tones, the division of the fourth in three *emelic* intervals (of second) *and* the division of the tone in three further intervals (Fig. 53, and FHT 33: 227).

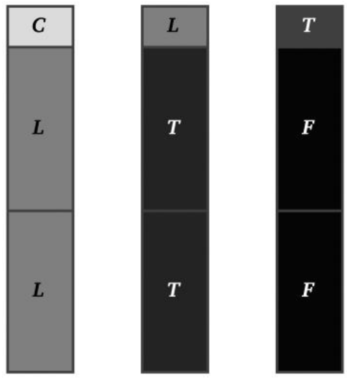


Fig. 53 Similar concepts by Urmawī for the construction of the tone (left), the fourth (center) and the octave (right).[262]

These *emelic* intervals – the whole tone composed of three elementary intervals and the two *mujannab*(s) composed of two elementary intervals[263] or the *baqiyya*

[257] This reasoning, which is essential for the understanding of the modifications of the scale in Ottoman-Turkish theories, is taken from [Beyhom, 2017, p. 27 *sq.*].

[258] Adapted and translated from Fig. 16-17: 115 in [Beyhom, 2014]; *L* stands for *leimma*, *C* for *comma*, both Pythagorean. Previously published as separate figures in [Beyhom, 2018ap, p. 28].

[259] A common characteristic in "Oriental" theories of the scale, including Byzantine chant – see [Azar Beyhom, 2012] for the explanations of Mīkhā'īl Mashāqa (who compares the "Arabian scale", according to him, with Chrysanthos Madytos' scale) about Arabian modes in the first half of the 19th century, and [Beyhom, 2015] for more explanations on the alterations in Byzantine theories of the scale (19th to 21st centuries).

[260] Intervals $c\_c^{\#}$ and d_d^{b} intersect – see Fig. 50.

[261] This can also be understood as a consecutive action of the accidentals: intervals $c\_c^{\#}$ and d_d^{b} are independent from one another, and separated by $c^{\#}\_d^{b}$ which is one *leimma* – see Fig. 51. (One *comma* in Fig. 52.)

[262] Previously published in [Beyhom, 2018ap, p. 29]. Note that while the tone might take a different form from the one shown in the figure – for example *L C L* as in Fig. 52 – in Systematist literature, it is always composed of three *elementary* intervals, which are always two *leimmata* and one *comma*. (Note also that some formulations of the tone may deviate from this norm – see for example [Schulter, 2013], notably fn. 40, with a possible interpretation of a Systematist "tone" with ratio 8:7.)

[263] The two *mujannab*(s) in Urmawī's theory are equivalent con-ceptually. They are identified through their internal composition – this

(*leimma*) – lie at the heart of misunderstandings which cripple today's theories of the scale in *maqām* music. The main reason for these misunderstandings is that Urmawī's theory was incorrectly assimilated by his successors and was transformed in a practical canon which determined a profound change of the intervals used in Ottoman music.[264]

The decline of the Ottoman Empire and the evolution of the balance of power in the 19th and 20th centuries precipitated the foundation of the main alternate (*maqām*) theory of the 20th century, the Yekta-Ezgi-Arel theory cited above.

* * *

While closely based on Urmawī's Pythagorean division – extended to 24 intervals – Yekta's "General scale" (FHT 31 and FHT 32: 227) uses, besides the usual *leimma* and *comma* intervals (Fig. 38: 173), an accidental in superparticular ratio 24/25 (Fig. 37: 173) which allows for *zalzalian* intervals to become part of the scale. This is the closest possible (simple) approximation of the 17th of the octave[265] and a possible indication that this author wished to avoid a practical drift from traditional performance to the theoretical – Pythagorean – values in his scale.

The extension of the number of intervals and the refinement of the accidentals became necessary because – notably – of the growing use of transposition in Ottoman music.[266] It was also dictated by the necessity – as with the 2nd Byzantine Reform of the 19th century – to reconcile Turkish (Urmawī's) theories with both Western theory, and with Arabian (?) theories of the quarter-tone which are based on it. Yekta's formulation, however, and due to his conflicting desires of retaining Pythagorean theory – a pre-eminent currency of prestige with Western musicologists – and of preserving the traditional characteristics of Ottoman-Turkish music, led to deep misunderstandings. (Fig. 54 and corresponding footnote)

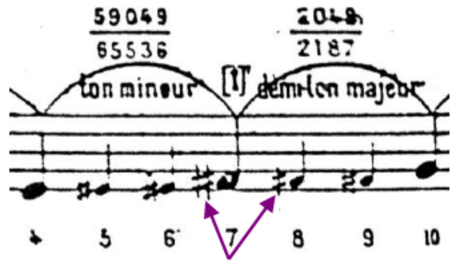


Fig. 54 One misunderstanding in the notation of Yekta Bey.[267]

This is the probable cause why his successors waived some of Yekta's refinements in favor of a more straightforward formulation of the scale division (FHT 37: 229 and FHT 38: 229).

However, and while Yekta's notation retains much of the characteristics of the original *zalzalian* scale of *maqām* music,[268] the Ezgi-Arel notation system consecrated the rapprochement of Turkish and Western music. This notation, while using a Pythagorean form, imposes in fact an arithmetic system of notation based on the Holderian comma (FHT 37). Furthermore, the inclusion in the scale of structural intervals of 3 commas means that they are composed of two elementary intervals, two *leimmata* or one *leimma* + one *comma*.

264 See [Feldman, 1996] and [Olley, 2012].

265 $(25/24)^{17}$ (the ratio of 25 over 24 to the power 17 – or 17 intervals in a row) = 2,001654134 which is 1,43 c greater than the octave (= 2).

266 For example [Ḥilū (al-), 1972, p. 96]: "Transposition was not in use among the Arabs – it is a Turkish invention [in *maqām* music]". (See also [Beyhom, 2014, p. 100].)

267 Detail from FHT 31: 226 (see Fig. 37: 173 for the accidentals. The altered f degrees following $f^{\#}$ are "lower" than this degree according to the code of accidentals provided by Yekta in Fig. 37. This "error" can only be explained by reminding that Yekta's notation is transposed to the (upper) fifth of Western notation. The degrees of the General scale of Yekta (FHT 31: 226) must then be read $g\ a\ b\ c\ d\ e\ f\ g_2$ instead of $d\ e\ f\ g\ a\ b\ c\ d_2$. This means that $f^{\#}$ in this scale is equivalent to b^{-1c} (b – 1 *comma*), as f in Yekta's scale is equivalent to $b^{\flat}$ – in fact "b - 1 *apotome*". In this case, the "Main" scale of Yekta (delineated by the upper ratios and circle segments) is to be understood as $g\ a\ b^{-1c}\ c\ d\ e^{-1c}\ f\ g_2$ instead of $d\ e\ f^{\#}\ g\ a\ b\ c$. Knowing that b^{-1c} and e^{-1c} in the Turkish scale correspond to e^{hf} (e "half-flat" – or e lowered by a quarter-tone) and b^{hf} in Arabian *maqām* theories of the scale, Yekta's General scale becomes thus equivalent to the Arabian scale of mode *Yākā* – on (equivalent Western) g with e^{hf} and b^{hf} (b and $f^{\#}$ with Yekta). While this means that implicit one-*comma* accidentals are included – for these two degrees – in Yekta's scale, the author explains notably, in a footnote (see [Yekta, 1922, p. 2997]): "This $f^{\#}$, as well as all the others that we shall use in our transcriptions, are at an interval of one *leimma* 243/256 from f ['natural'], […]. Whenever the $f^{\#}$ is at an interval of one *apotome* 2048/2187 from $f^{natural}$, we shall use a sharp sign topped by a dot".

268 These – be they implicit or explicit – are detailed in [Beyhom, 2014]: see also [Signell, 2004, p. 22–26].

(FHT 38) restores the notation to its symmetrical status[269] – compatible with Western theories of the scale as with the "Arabian" quarter-tone division.

Consequently, the resulting "Turkish" scale is structurally equivalent to the "Arabian" quarter-tone division while retaining the possibility of a finer description of the intervals which compose it.[270]

The intrinsic asymmetry of the *zalzalian* scale with an unequal division of the octave in 17 intervals[271] leads however to misunderstandings – such as seen above for Yekta – and discrepancies, notably for transpositions of scales and tetrachords.

Problems of transposition in the asymmetric formulations of *maqām* scales

The *zalzalian*– "medium" ("neutral") – seconds of Urmawī or *mujannab*(s) bear two formulations (Fig. 55). The difference between the two *zalzalian* seconds, *i.e.*, the difference between two *leimmata* and one *leimma* plus one *comma*, is about 67 cents, almost three Pythagorean *commata*. As the General scale of Urmawī is asymmetric,[272] he is compelled to use two different theoretical formulations for some tetrachordal configurations – for example the *bayāt* tetrachord on *d* or *a* in FHT 34: 228.

Transposing this tetrachord on different degrees of the scale imposes also – for example in a transposition on $d^{\#}$[273] – the inversion of the *mujannab*(s) to remain within the scope of the predefined division of the General scale.

Similar problems arise for the *ḥijāz* ("chromatic") tetrachord in this scale (FHT 36: 228).

However, and while the internal differences between *mujannab*(s) may well mirror actual practice,[274] the undifferentiated – and theoretical – use by Urmawī of these two forms enforces the equivalence between them and minimizes the importance of the actual sizes of the intervals. In which case a 17th of the octave equal division of the octave, which has the advantage of allowing for all transpositions without theoretical modifications of the intervals (FHT 35: 228), would have been much more convenient for both musicians and theoreticians of *maqām* music.

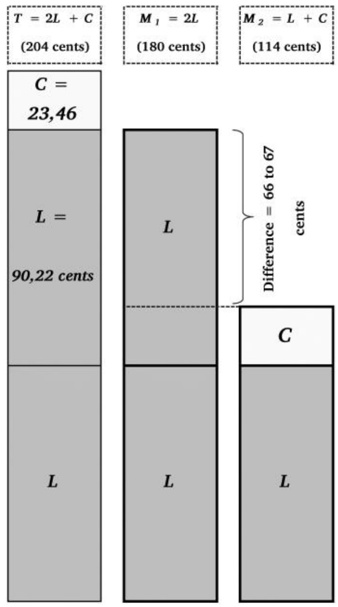


Fig. 55 Urmawī's tone (left) and two expressions of the *mujannab* (center and right): *T* = tone, *M* = *mujannab*, *L* = *leimma* and *C* = *comma*.[275]

However, in such a division the whole tone as well as – but to a lesser extent – key intervals such as the just fourth and fifth would no more correspond to the sacrosanct Pythagorean values,[276] and the concept of a theory which would merely structure – but not dictate – the intervals and music seems to be foreign to the thought of Modern *maqām* theoreticians.[277]

[269] Because it is divided in an even number of intervals (24) which, the moreover, structurally correspond to the Arabian quarter-tone (theoretically) equal-division of the octave.

[270] This could be debated, but would lead us to unnecessary – in this dossier – extended explanations. Note however that the differences between theoretical and practical values of the intervals of Turkish music are the subject of hot discussions among musicians and theoreticians, as explained throughout [Signell, 2004].

[271] The 17-intervals division of *maqām* music from its – known – origins is documented in [Beyhom, 2010c].

[272] *i.e.* not based on an equal – and even – division of the octave.

[273] *d* + one *leimma* when using Urmawī's additive conception.

[274] See [Beyhom, 2018ap, p. 14, Fig. 5] for explanations on the problematic of the *mujannab*(s) in *maqām* music – see also [Beyhom, 2003b; 2004].

[275] Previously published as [Beyhom, 2018ap, p. 11, Fig. 1].

[276] Pythagoreanism has always been fashionable with Arabian theoreticians since Urmawī. Note that even al-Kindī (9th century) cheerfully propagated Pythagorean theories among the Arabs (as I explain in [Beyhom, 2010c]). Very few authors questioned Pythagorean absolute "truth" – but one of them was the greatest of all: al-Fārābī who is first cited in the epigraphs to this dossier.

[277] Turkish musicologists have mostly been longing for a rapprochement with Western music on the base of temperament (as documented in [Signell, 2004]). A musical temperament being, by definition, a freeze – even temporary – of the intervals of the scale, "elastic"

Anyhow, one conclusion that can be reached here is that Urmawī's scale is not strictly fit for transpositions. The extension of the number of intervals,[278] whenever not based on an equal-division of the octave, brings no practical solution – as with the Yekta-Ezgi-Arel scale. (FHT 37: 229 to FHT 39: 230)[279]

In fine, the use of such theoretical intervals in a fixed temperament, while raising specific problems of transposition, rubbed off only very slowly on practice as, as late as in the 1970s, practice still didn't coincide with theory.[280]

Nevertheless, the Yekta-Ezgi-Arel theory is still taught today and considered as the base division of the Turkish scale, with specially programmed (standard) accidentals in dedicated music notation softwares (Fig. 56) which also allow for additional – non standardized – accidentals[281] and notations for which an example is provided – for Byzantine chant – in Fig. 57[282].

When comparing however the (theoretical and computerized) mechanical performance of this chant (see Fig. 87: 194 and Fig. 88: 194 – and the corresponding videos) with the actual performances by proven cantors proposed in the accompanying video-animations (in Part III), the overall conclusion for Western notations as applied to *maqām* music is that all the refinements brought to it[283] can still not describe the actual performed music and that these notations remain, in this aspect, mere caricatures of this music.

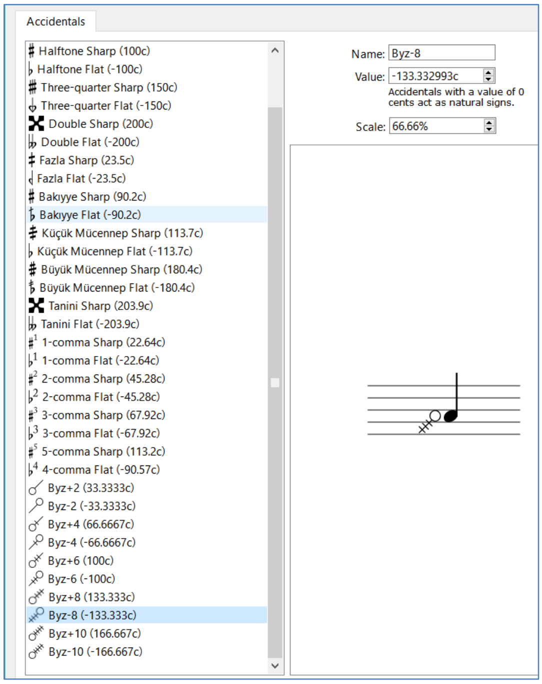


Fig. 56 Detail from a window snippet of the standard accidentals proposed in MUS2 (V 2.1) and the Byzantine accidentals implemented by the author (below – 2nd Reform), with the "Byz-8 (-133.333c)" accidental highlighted.[284]

As for the *prescription* of this music, Western notations are, in what concerns traditional *maqām*, practically useless for prescribing it without actual, prior and aural knowledge of the tradition as will be shown in the third part of this dossier.[285]

– even if theoretical – intervals were for these musicologists – and in particular for Yekta, Ezgi and Arel – simply absurd.

278 As with Karadeniz' 41-intervals per octave system mentioned in [Signell, 2004, p. 42]. Note that even with the "limited" Yekta-Ezgi-Arel theory, Signell reports – according to the explanations of Necdet Yaşar in the 1970s – that some of the *dik*(s) [the Arabian *tīk*(s)] are not used in the classical Turkish repertoire, which confirms that theory and practice barely coincide in *maqām* music, a simple truth that I try to remind my readers of in most – if not all – of my writings.

279 [Signell, 2004, p. 41] notes the existence of a few "uncommon" *mujannab*(s) used in some modes such as a 6-comma *mujannab* for *Ṣabā* (Arabian transliteration), and other, 7-comma *mujannab*(s) – whenever the Turkish theoretical norm is an 8-comma *mujannab* (*di-leimma*). Otherwise, further examples of transposition problems can be found in [Signell, 2004, p. 37–47].

280 Signell explores these discrepancies at length in the aforementioned reference, and notably – in [Signell, 2004, p. 38]: "Sometimes, the literal value of the accidentals can deviate at least one comma (23 cents) from common practice". See also Slides nos. 16-17 in the accompanying Power Point show of [Beyhom, 2014] (reproduced as Slides nos. 7-8 in the current dossier), in which the intervals of the *ṭunbūr* of Necdet Yaşar follow strictly the Yekta-Ezgi-Arel theory of the scale – with considerable refinements of tone-color, while Murat Aydemir's performance features intervallic variations. As I have expounded in [Beyhom, 2014], the aesthetics of Turkish music have constantly evolved between the traditional aesthetic – based on interval and rhythm variations – and the "Modern" – in fact Western – aesthetic of sound based on the variations and the mastery of tone-colors.

281 Refinements of the scale divisions – based on various theoretical grounds – are something of a national sport in Turkey.

282 Which is a detail of FHT 52: 240 – See also the notation of the First Byzantine Mode in FHT 40: 230.

283 Western notation evidently doesn't stop at the standardized version widely in use today, and has been further improved – notably for composition purposes (see for example the recent – however undated and in French – [Couprie et al.]). Its lacunae for the description of subtleties of *maqām* music persist, however, not speaking of the other problems raised in this and in the previous parts of this dossier.

284 Standard accidentals include equal-temperament (quarter-tone as a common denominator) accidentals together with the accidentals put forward in the Yekta-Ezgi-Arel theory, along with commatic (numbered) accidentals.

285 As Cem Behar explained in [Behar, 2014] – personal communication: "A mode does not exist because it is defined; it is the practice which defines it".

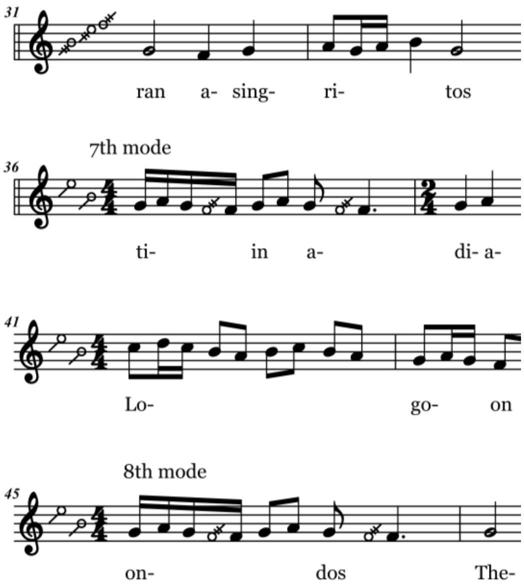


Fig. 57 Detail from the transnotated score of *Axion Estin* by Anonymous (FHT 52: 240) with hybrid Western/Byzantine notation using both Byzantine key signatures and in-score Byzantine accidentals.

***

I would like, finally for this Second part, to remind of one statement used by Bruno Nettl as a conclusive argument for keeping Western notation as the main analytical tool of ethnomusicology:

> "Western notation is being adopted by musical cultures throughout the world, modified to account for diversity, a reasonably adequate prescriptive system; this is leading to a kind of vindication of Western notation for purposes of transcription".[286]

In addition to the profound contradiction which arises from the use of a "prescriptive" notation for description purposes, or even for analytical purposes for musics which it cannot help analyze, knowing that its use in autochthonous musics has, more often than not, led to profound changes in the performance of these musics should alone prevent ethnomusicologists from using it further.

So, instead of using the adoption of Western notation by autochthonous musicologies as a justification of the continuous and persisting use of this notation in ethnomusicology – and indulge in some sort of intellectual laziness – should we not further explore other, old or new means for the analysis of these musics?

***

Part III. A tool for the analysis and teaching of *maqām* music

Graphic representation of sound can be found in (relatively) early research in phonetics (FHT 42: 232). Its application to melodic music is best explained in Van der Meer and Rao's publications[287] as well as on the SEEM website[288] – which are perfect introductions – and "by-documents" – for this third part of the dossier.

Few examples of graphic analysis of melodies today

At the very beginning of my musicological studies at the Sorbonne University, score notation seemed for me to be far from adequate to describe and explain *maqām* music.

I have therefore looked for alternatives and found them quite rapidly in the writings of Wim van der Meer and his explanations about the use of Praat for music analysis, which I tried to apply for *maqām* and other musics. (Fig. 58 to Fig. 63)

While the graphs provided through Praat can be as versatile and detailed as needed (Fig. 60 to Fig. 63),[289] some – major – structural limitations[290] restrict the types of music that can be analyzed to mono-instrumental music,[291] as well as to reduced time lapses (approx. 30 seconds as a maximum – see Fig. 62).

[286] [Nettl, 1983, p. 80].

[287] Mostly [Meer and Rao, 2006] and the same with video-examples at [Meer, 2018b], together with [Rao and Meer]. Many other articles of Meer are cited in this dossier, and few others are available at the author's latest website (http://thoughts4ideas.eu/), which are all interesting for the reader.

[288] In French – [Anon. "Notation musicale et visualisation du son - SEEM"]. See also [Picard, 2011].

[289] The only limitation is by the capacity of the computer – and the readiness of the analyst to wait for time-consuming calculations in the case of the use of a computer with an outdated processor – which is what most musicologists can afford.

[290] As with other speech – or sound – analysis programs to the current date.

[291] This difficulty can be overcome in specific cases.

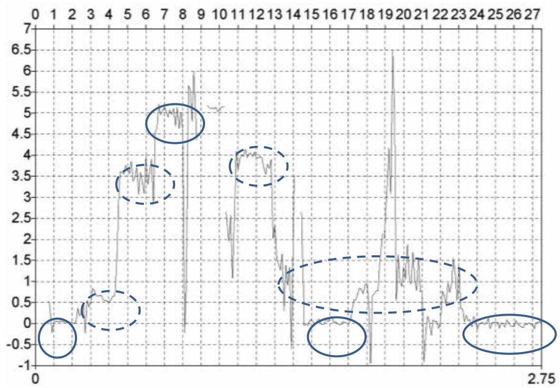


Fig. 58 *Jins* (*genos*) *ḥijāz* performed by Hamdi Makhlouf. Pitch (in semi-tones) / Time (in seconds) diagram.[292]

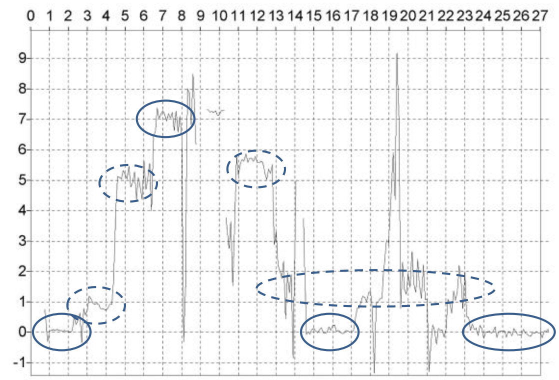


Fig. 59 Same *jins ḥijāz* as in the previous figure on a 17th of the octave basis.[293]

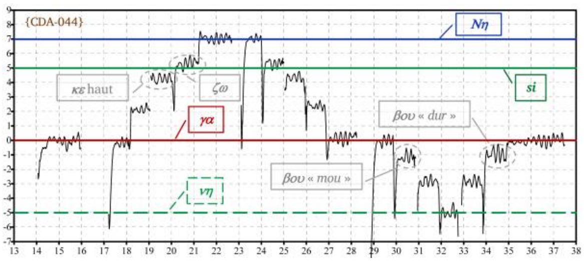


Fig. 60 Annotated (in French and Greek names of notes) example of scale analysis (3rd "enharmonic" mode of Byzantine chant performed by an Anonymous cantor) with Praat.[294]

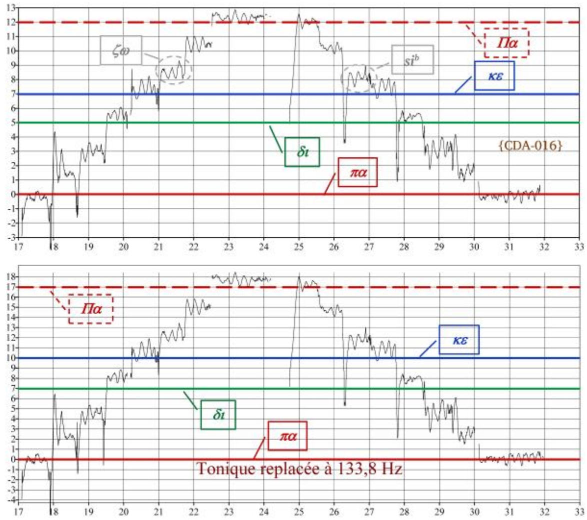


Fig. 61 Annotated (in French and Greek names of notes) example of scale analysis with Praat.[295]

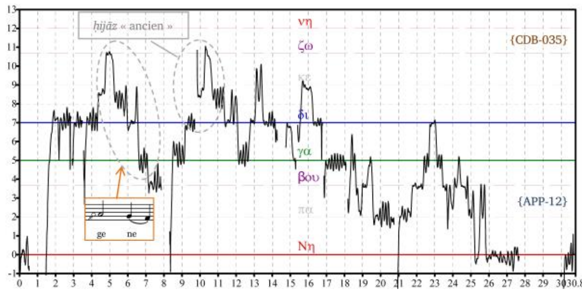


Fig. 62 Annotated (in French) example of a melodic phrase (from *Kyrie Ekekraxa* by Petros Byzantios – performed in Greek by fr. Nicolas Malek) analyzed with Praat in [Beyhom, 2015, p. 408, Figure 393] and featuring a "diatonic" scale (horizontal lines – in parallel with the semi-tones/time grid) and note names added with Praat as well as an inclusion of score detail from MUS2 (see Fig. 56).

Within these limits Praat can be a very powerful tool for music analysis, especially when the results are expounded with the help of an animated cursor with, when deemed useful, the parallel down-speeding of the music.

[292] Originally published in [Beyhom, 2007, p. 219] – graphic anno-tations are modified in the current figure.

[293] Pitch (in 17th of the octave) / Time (in seconds) diagram. Originally published in [Beyhom, 2007, p. 220] – graphic annotations are modified in the current figure.

[294] Taken from [Beyhom, 2015, p. 355, Figure 293]. Semi-tone (vertical axis) / time (in seconds – horizontal axis) grid drawn with Praat. The additional color-graphic code (horizontal lines – also drawn with Praat) is: Red for the tonic (dashed line for the upper octave – when relevant), Green for the fourth (dashed lines below the tonic) and Blue for the fifth.

[295] 1st "Diatonic" mode of Byzantine chant performed by fr. Makarios Haidamous – taken from [Beyhom, 2015, p. 333, Figure 263]. Above: Semi-tone (vertical axis) / time (in seconds – horizontal axis) grid drawn with Praat; below: 17th of the octave (vertical axis) / time (in seconds – horizontal axis) grid. See fn. 294 for the color-graphic code.

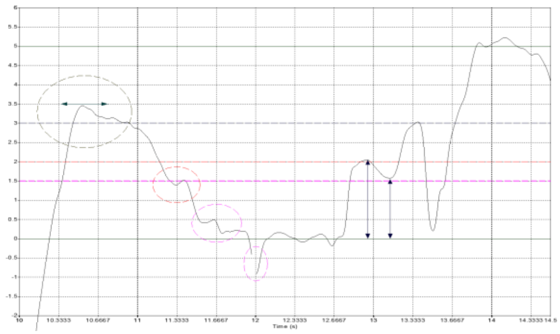


Fig. 63 Analysis of the first 4 seconds of the incipit of a chant in the 1st mode (new Stichiraric style) performed by Giorgios Tsetsis with a quarter-tone (as half of a semi-tone)/time grid and annotations – Used in various presentations by the author.

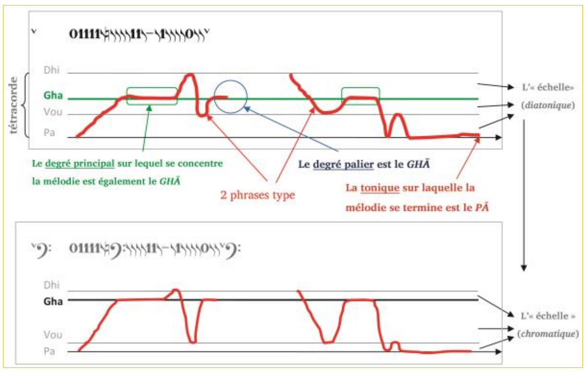


Fig. 64 Analysis from writings by Joseph Yazbeck (Lebanon) on Byzantine chant showing the transformation of two melodic phrases from the "diatonic" (1st) Byzantine mode to the "chromatic" (6th) mode.[296]

Of course, other programs (applications?) do provide today with graphics of the melodic contour (Fig. 65 & Fig. 66), each having its pros and cons but, to the author's knowledge, none is as versatile – and as adapted to pitch analysis of *maqām* music – as Praat *and*, in the same time, multi-platform and freeware[297].

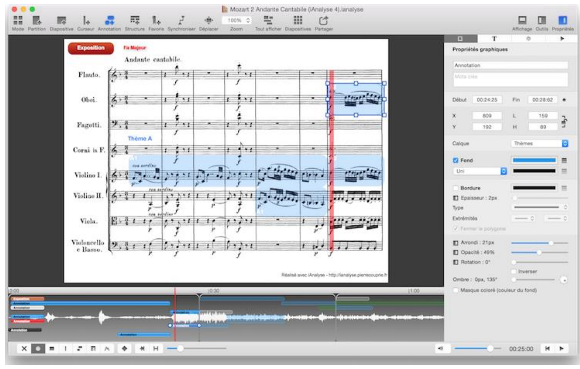


Fig. 65 Excerpt (window snippet) from the Analysis program *iAnalyse* developed by Pierre Couprie.[298]

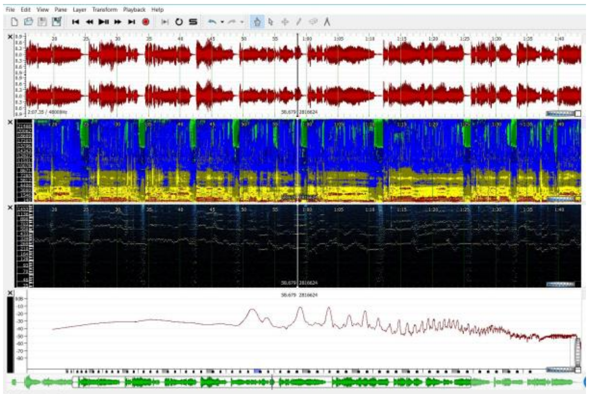


Fig. 66 General view of 4 panes (from top to bottom: Wave form, Spectogram, Peak frequency spectrogram, Spectrum, with a fifth – lowest – navigation pane in green) analyzing the central part of *7 maqāmāt* performed by Muḥammad al-Ghazālī in the main window of *Sonic Visualiser*.[299]

***

[296] Added comments (in French) by the author – taken from [Beyhom, 2015, p. 329, Figure 260]. Freely adapted from [Yazbeck, 2012a]: the upper line in each graph reproduces the notation put together by Joseph Yazbeck.

[297] Whenever the aim of the author is to provide the analyst with the most performing *and* accessible tools – and the least expensive as autochthonous musicologists rarely have the financial means for expensive computer programs, the choice of Praat for such analyses is nearly inevitable. See also the dossier of the author [Beyhom, 2007] on Interval measurements and on the testing of Praat for the analysis of melodic contours.

[298] [Anon. "iAnalyse 3 & 4 | Pierre Couprie"]: see also (same reference) *eAnalysis* and [Anon. "Pierre Couprie | Logiciels"]. Note that while Couprie does provide source codes on the *github* platform [Anon. "pierrecouprie (Pierre Couprie)"], these are not the source codes of his showcase programs. Another problem is that whenever the program is free of charge, it only works with specific Apple products, which restricts its use to (generally) musicologists willing to – and financially capable of – limit(ing) themselves to this material and software platform. The grand majority of autochthonous musicologists use PCs and generic programs on the latter. They have neither the will, nor the financial capabilities, to buy Apple products which may be incompatible with all the material and software available in their milieu. Note that Praat not only works on both platforms (PC and Mac) but also under Linux and few others, and provides the source code free of charge. See also http://liceu.uab.es/~joaquim/phonetics/fon_anal_acus/herram_anal_acus.html – accessed 05/07/2018 – for a comparison of speech analysis softwares – with Praat being used primarily for such analyses.

[299] See [Anon. "Sonic Visualiser"; Cook and Leech-Wilkinson] for more information on this program. (See notably the performance analyses in the latter reference.)

It is worthwhile here to note that graphic representation of (perceived) pitch is not the same as the graphic representation of the fundamental tone. As musicologists studying the representation of sound, we should first bother about the perceived pitch(es) of the melodic line.[300] While the shift in focus of acoustic research from the search for the fundamental to the search of the perceived pitch is relatively recent,[301] let us stress that, unlike most other programs which simply try to extract the *fundamental*, Praat algorithms allow for the graphic reproduction of the perceived pitch, which is much more effective in pitch determination.[302]

Animated analyses

Animations with a horizontally moving cursor synchronized with the music are of common use today, with many examples provided in the ethnomusicological field at the SEEM[303] website of the Université Paris-Sorbonne, and at Wim van der Meer's[304] websites.

The author uses power-point animated slides[305] with a moving cursor, of which a few examples are provided in the accompanying PPS file to this dossier, and to the making of which a manual[306] was dedicated. The usefulness of such animations is obvious, as these provide detailed information on the analyzed music. Their limitations are also evident: only short extracts can be thus analyzed, and only so much information as the (static) screen can contain can be conveyed by a moving cursor with a static graph.[307] Successful attempts to overcome the time limitation were made by multiplying the number of animations (joined together in a flash movie in the case of Picard[308]). These implied however the segmentation of the song in successive slides[309] and did not show the effective flow of the melody.[310] The next step was the use of moving graphs and fixed cursors, or moving graphs and moving cursors, in which the flow of the music appears in its entirety.

Introduction to video-animated analyses of the melody – The VIAMAP

Using animated analyses with moving graphs and (moving or) fixed cursors seems to be, on the face of it, a superfluous step towards a better understanding of *maqām* music as the animations with a moving cursor (and fixed graph) seem to be already rich in teachings. The main lacuna of the latter – apart from the general deficiency of these methods for polyphonic music – lies however in the often too short extracts that can be analyzed following this procedure; analyzing a whole piece or song thus would be time consuming and would require a considerable amount of written explanations with, paradoxically, at least some (or much more) notated musical passages which would lead back to the use of inadequate tools for the analysis of *maqām* music.

Another limitation of the moving cursor with a static graph method is the technical difficulty in explaining tonic shifts and interval variations with time, as well as identifying intervals for *tajwīd*[311]-type chanting in which the use of very ample vibrato seems to be the rule.

[300] See for example [Houtsma and Smurzynski, 1990], see also [Haynes and Cooke, 2001], notably: "Pitch is determined by what the ear judges to be the most fundamental wave-frequency of the sound".

[301] A good retrospective of the shift from the extraction of the fundamental to the determination of the perceived pitch can be found in [Plomp, 2002, p. 25–29], not forgetting the seminal [Plomp, 1976]. Note also these explanations from Wim van der Meer (personal communication), who raised the subject while reviewing this dossier: "I had learnt most [...] from my French friend/colleague Bernard Bel, who was a computer engineer and programmer. But it was after we met A.J.M. Houtsma (sound perception from TU Eindhoven) that we realized that the fundamental was not necessarily the perceived pitch. My programs took into account those ideas, but later in Leiden and Amsterdam better solutions were created (first LVS in Leiden and then PRAAT in Amsterdam)".

[302] Moreover, the source code of Praat is – as already stated above – freely available so anyone can check the way it functions (which is essential in scientific work).

[303] "*Séminaire d'Études Ethnomusicologiques*" – see http://seem.paris-sorbonne.fr/.

[304] Mostly http://thoughts4ideas.eu/.

[305] See the accompanying PPS for a few examples notably for Cypriot and Greek music in Slides nos. 9-15.

[306] [Miramon-Bonhoure and Beyhom, 2010].

[307] *cf.* Nettl: "Melographic analysis […] has been used for the solution of special problems. […] these studies [are] based on a small amount of music, as little as a few seconds, and in most cases the purpose was to analyze rather minute differences within or among pieces. The kinds of findings one may expect in this type of studies are illustrated by those of Caton (1974:46) on a type of vocal ornament, the Persian *Takiyah*: It is 'distinctly simpler in tone quality than the melody notes'" – [Nettl, 1983, p. 80]. The next section may prove Nettl wrong – at least as for the future of such analyses…

[308] See two examples at http://seem.paris-sorbonne.fr/IMG/swf/barbara_allen_molly_jackson.swf and http://seem.paris-sorbonne.fr/IMG/swf/nasori_no_kyu.swf (accessed 12/07/2018).

[309] See for example Slides nos. 10-15 in the accompanying PPS.

[310] This seems to be a decision made by Picard, and not a limitation of the program (Acousmographe) used to create these animated analyses.

[311] Melismatic recitation.

Once again, and after having nearly abandoned the idea of analyzing whole songs or music pieces, the answer came from Meer's work, this time for the *Music in Motion* program – developed jointly with Suvarnalata Rao, Rustom Irani and Salil P. Kawli – which is concerned with "The Automated Transcription for Indian Music (AUTRIM)".[312] The aim of the program is

> "to develop a system of notation that would be specifically fit to describe, analyse and even reproduce Indian music with all its fine nuances and inflections".

While watching the videos, I was stunned at the convenience of the technical handling of the graphs and animation, which made it very easy to follow the (analysis of the) melody and, in parallel, to be able to compare the current passage with preceding or following ones.[313] Small literal additions in the video help, at key passages, underline a peculiarity of the analyzed music.

The first video-animation produced by the CERMAA followed these principles loosely[314] by using a fixed semi-tonal grid to delineate the intervals used in the *Hurrian Song No. 6* in Lara Jokhadar's interpretation of 2012 (Fig. 67).[315] The color code used by the author for previous graphic analyses[316] gives the possibility of identifying intervals (and pitches) at different phases of the song. Small differences in intervals – supposedly between the same pitches in semi-tonal score notation[317] – can be identified and loosely estimated.[318] Slight variations of the tonic (and of the pitches in parallel) or of the main acoustic intervals – the fourth, the fifth and the octave – can also be identified.

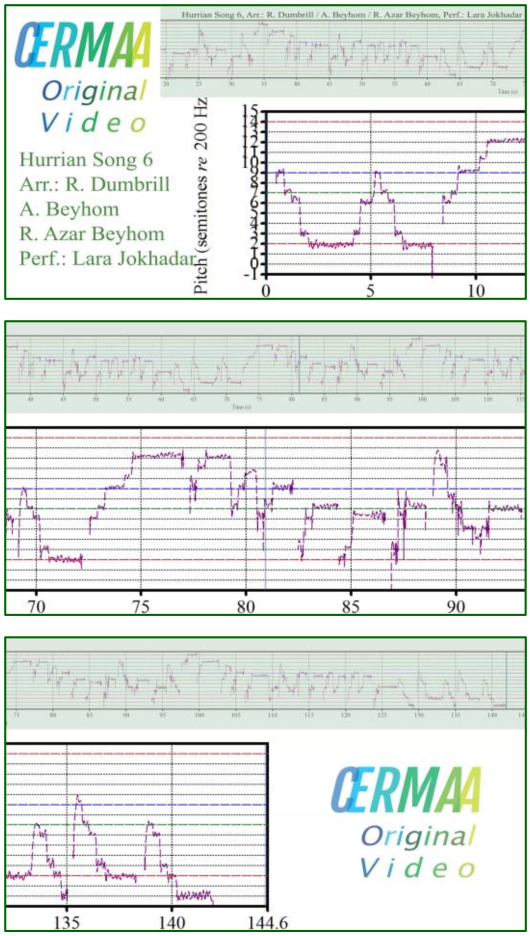


Fig. 67 Three frames (from top: First, Middle, Last) from the video-animated analysis of *Hurrian Song No. 6* in Lara Jokhadar's interpretation of 2012. The lower strip shows the detailed analysis while the upper strip shows a more general view of the same analysis.[319]

[312] See https://autrimncpa.wordpress.com/. Earlier attempts at video-animated representation of melodic music, by the same author or others, existed already but did not reach the degree of refinement achieved in the *Music in Motion* program.

[313] The videos of *Music in Motion* (as well as the videos of the CERMAA which were inspired by them) are divided vertically in two lateral stripes, the lower one containing the detailed analysis while the upper stripe shows a more general view of the analysis.

[314] The main difference lies in the animation of the upper lateral stripe, in which both the cursor and the graph are animated – at a slower pace than for the detailed analysis and with a wider scope – constantly, and in opposite directions. This is one of the secondary differences for technical solutions that can be used in this type of video-animated analyses.

[315] [Beyhom, 2018c] – Composed according to the corresponding cuneiform text by Richard Dumbrill, Amine Beyhom and Rosy Azar Beyhom. (Watch the video at https://youtu.be/U8Yr6mKc550 or at http://foredofico.org/CERMAA/analyses/other/hurrian-song-h6 – [Beyhom, 2018a].) Note also that the recordings analyzed with Praat for these video-animated analyses were treated for broadcasting (by adding a reverb and, for some of the recordings, by modifying the dynamics – by compression) when (later) included in the animations. (Praat analysis was undertaken for the "dry" – un-treated – sound.)

[316] Reminder: Red lines for the tonic and its octave, Green for the fourth and Blue for the fifth.

[317] See the original score of the song in Dumbrill's/Beyhom's/Azar Beyhom's interpretation in [Dumbrill, 2017], reproduced in this dossier as FHT 41: 231.

[318] The main aim of such video-analyses is not the measurement of the intervals, but (notably) to show the variations in both absolute pitch and intervals with the passage of time.

[319] Figures are given here as examples of particular frames and illustrations of particularities of the analysis. It goes without saying that the video-animated analyses are intended as self-explanatory entities, while the comments and explanations in this dossier are intended as a help for understanding the need, purpose and usefulness of such analyses in the particular domain of *maqām* music.

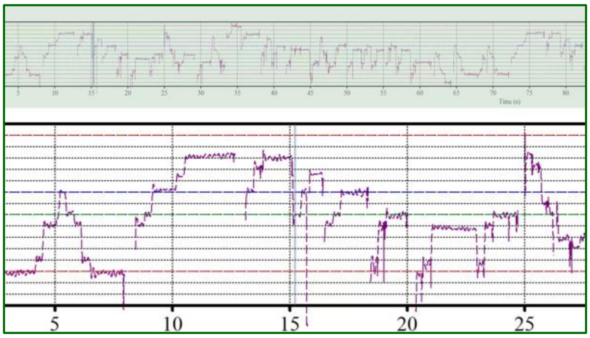


Fig. 68 Rise of the fifth (and upper pitches) then reversion to the semi-tonal grid between 9 s_a and 15 s_a of the video animated analysis by the CERMAA of *Hurrian Song No. 6*, with an ascending *mujannab* around 16 s_a in Lara Jokhadar's interpretation of 2012.

The analysis is in itself pretty much self-explanatory: for example the fifth rises just before 10 s_a[320] shifting the two upper pitches above while the next three pitches (from 13 s_a to 15 s_a) are nearly exactly located at their semi-tonal values (Fig. 68). Such small variations, which may take place either by accident or consciously, do not call for a special technical treatment of the analyzed material as the singer[321], although performing *a capella*, maintains a stable tonic – with the aforementioned slight variations – till the end of the song[322].

While this first analysis concerned itself with a song based on a fixed score – with no variations or interpretations allowed – and on a (near-) semi-tonal grid, it soon became clear that traditional melodies, while based also on a score such as in Byzantine chant, would necessitate a particular treatment for the scale – which in such case should not be based on a semi-tonal division of the octave.

We chose at the CERMAA[323] to gradually enlarge the scope of the application of such analyses for what we termed "Video-Animated (Music, *maqām* or Melody) Analysis" – or (the) VIAMAP when adding the caudal "Project".[324]

Video-animated analyses of Byzantine chant(s)

The first attempts at such analyses were made for the first set of video-animations of the song *Kyrie Ekekraxa* by Petros Byzantios[325], including 8 variations of this song – 4 in Greek and 4 in Arabic – by 4 Lebanese cantors previously recorded for the book of the author on Byzantine chant[326]. The videos are self-explanatory and based on the 1881 Byzantine (Second) Reform "diatonic"[327] scale with a dedicated color code. (Fig. 69 and Fig. 70)

[320] "s_a" is used for "seconds of analysis" to differentiate analysis time (s_a) from video time (farther used as "s_v" – or "seconds of the video").

[321] Lara Jokhadar trained in the Lebanese conservatoire and is an experienced performer.

[322] See the very regular positioning of the end pitches in the last frame shown in Fig. 67; compare if needed with the score provided in FHT 41: 231 and with the following by-publications of the same:

- Mixed score (Tonogram reproduction of the intonations in parallel with the score) of Hurrian song H6 (http://nemo-online.org/wp-content/uploads/2017/08/Hurrian-H6-intonation-120902-12-mixed-scoreS.pdf)
- Midi reproduction of Hurrian song H6 including intonations (http://nemo-online.org/wp-content/uploads/2017/08/H6-intonated-Dumbrill-Beyhom-Azar-Beyhom.mp3)
- Recording of Hurrian song H6 with singer Lara Jokhadar (http://nemo-online.org/wp-content/uploads/2017/08/H6-Lara-Jokhadar-121021-04-Dumbrill-Beyhom-Azar-Beyhom.mp3)

[323] Reminder: the research center of the FOREDOFICO foundation in Lebanon.

[324] Notably to avoid any connotation with the notion of "entertainment" as conveyed by the following websites – which all use "Music in Motion" as a motto: http://www.djmim.com/, https://www.facebook.com/mimskate/ and http://www.musicinmotionentertainment.com/.

[325] See http://foredofico.org/CERMAA/analyses/byzantine-chant/kyrie-ekekraxa nos. 1-8. These eight videos can also be directly streamed:

1. *Kyrie Ekekraxa* in Arabic by fr. Makarios Haidamous (published 16/02/2018 – original recording [Haidamous, 2010a]): https://youtu.be/j8w9I9CfF0c [Beyhom, 2018b]
2. *Kyrie Ekekraxa* in Greek by fr. Makarios Haidamous (published 19/02/2018 – original recording [Haidamous, 2010b]): https://youtu.be/8SSETdJWC8o [Beyhom, 2018d]
3. *Kyrie Ekekraxa* in Arabic by an Anonymous Cantor (published 19/02/2018 – original recording [Anonymous, 2011a]): https://youtu.be/Uek_AD_aRQg [Beyhom, 2018e]
4. *Kyrie Ekekraxa* in Greek by an Anonymous Cantor (published 19/02/2018 – original recording [Anonymous, 2011b]): https://youtu.be/ush88CvgQYk [Beyhom, 2018c]
5. *Kyrie Ekekraxa* in Arabic by fr. Nicolas Malek (published 22/02/2018 – original recording [Malek, 2011a]): https://youtu.be/wIhyN30y-qc [Beyhom, 2018f]
6. *Kyrie Ekekraxa* in Greek by fr. Nicolas Malek (published 22/02/2018 – original recording [Malek, 2011b]): https://youtu.be/w6YWloCd2Do [Beyhom, 2018g]
7. *Kyrie Ekekraxa* in Arabic by Joseph Yazbeck (abridged – published 26/02/2018 – original recording [Yazbeck, 2012b]): https://youtu.be/QvKcoi7LdVI [Beyhom, 2018h]
8. *Kyrie Ekekraxa* in Greek by Joseph Yazbeck (abridged – published 26/02/2018 – original recording [Yazbeck, 2012c]): https://youtu.be/uvElBc7-3-4 [Beyhom, 2018i]

[326] [Beyhom, 2015].

[327] Understand "diatonic" in its original, Ancient Greek use, *i.e.* as in a tetrachord having no *pycnon*.

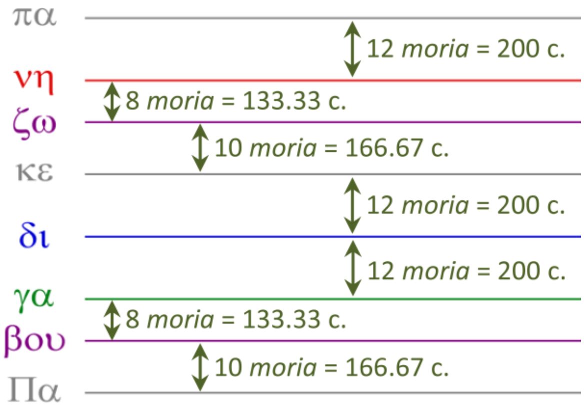


Fig. 69 Graphic scale of the 1st Byzantine mode ("diatonic") – used in the video-animated analyses, with the theoretical values of intervals (2nd Reform of 1881) given in "minutes" ("*moria*") and cents.[328]

Note that the scales in the videos – be they graphic or in score notation – are only shown to give a reference for the viewer (and listener), and to mark the discrepancy between theory and practice – which is obvious in all the analyses.

A further improvement concerns the upper stripe which has been simplified (no grid but only the red tonic line and – whenever deemed necessary or useful – its upper octave).

Readers who practice score notation can compare the interpretations (and the differences between the latter) of the 4 Lebanese cantors with the tentative adapted score provided in FHT 45 and FHT 46, or with the original 1820 Byzantine notation (FHT 43 and FHT 44) – if familiar to the reader.

Strikingly enough, and despite the differences in styles and interpretations for these 4 cantors, the tonic remains mostly stable from the beginning to the end of the song, as shown in Fig. 72 to Fig. 75.[329]

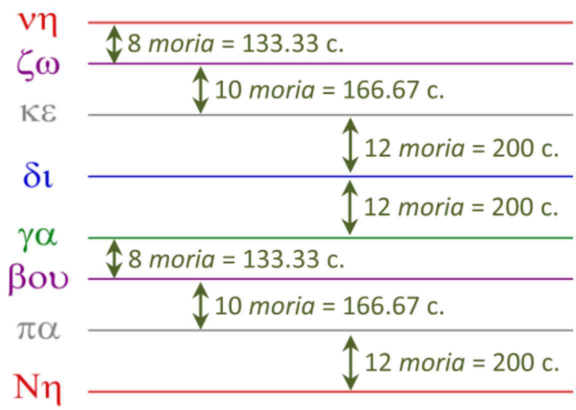


Fig. 70 Graphic scale of the 8th Byzantine mode ("diatonic") – used in the video-animated analyses, with the theoretical values of intervals (2nd Reform of 1881) in "minutes" ("*moria*") and cents.

In-video comments (Fig. 76) were added to help the viewer understand the different changes occurring but these soon seemed a little overwhelming – as too much information was provided in very short periods of time – which triggered the idea[330] of producing a half-tempo version[331] complementing the full-tempo version.[332]

In order to be, however, less directive[333] for the analyses, and while the inlayed comments were kept within the main (lower) stripe, a pair of dashed gray lines was added for the analysis of the Greek version of the same song – to show the positions of the original tonic and octave (Fig. 77). These are also reproduced in the form of two fine red lines[334] in the upper stripe.[335]

[328] 1 "*moria*" = 1200 c / 72 = 200 c / 12 = 16.67 c.

[329] And as can be easily deduced from watching the corresponding videos. Note that recordings made – of his own performances – by fr. Makarios Haidamous included heavy – added – reverb which necessitated a special treatment of the recording prior to the analysis by Praat. This was also the case for the recording of Muḥammad al-Ghazālī's *Seven Maqāmāt* (explored farther) which was extracted from the corresponding video uploaded on YouTube (the address of the original YouTube video figures at the beginning and at the end of the video-animated analysis).

[330] As used already for previous animated analyses (animated cursor with fixed graph) using Power Point presentations.

[331] Note that video-hosting providers – such as YouTube chosen for the hosting of the video-animated analyses by the author – do propose different speeds (up to quarter-tempo for YouTube) and resolutions to the viewer/listener, but the quality of the audio is generally degraded.

[332] At this stage, notated versions of the scales of the modes used in the chant were added at key moments to complete the analyses. Note that the terms "half-tempo" (or "reduced tempo", or "Xth part of the original tempo") are more adequate than "slow motion" used by Meer (in http://thoughts4ideas.eu/what-you-hear-isnt-what-you-see/ [figures 6a and 6b] – accessed 12/07/2018), with the latter terms being even inaccurate when applied to motionless videos (see for example https://youtu.be/wodNQzUEOCc from the same author, embedded in the same page); note however that Meer uses further the caption "Fig. 8B: Fig 8A slowed down by a factor 2 (=3 x slower than the original)" for https://youtu.be/LSSCjZ-D6tg, which seems to me more accurate.

[333] I dare not write here "less prescriptive"…

[334] Either solid or dashed.

[335] A half-tempo version was also produced for this analysis – See next footnote.

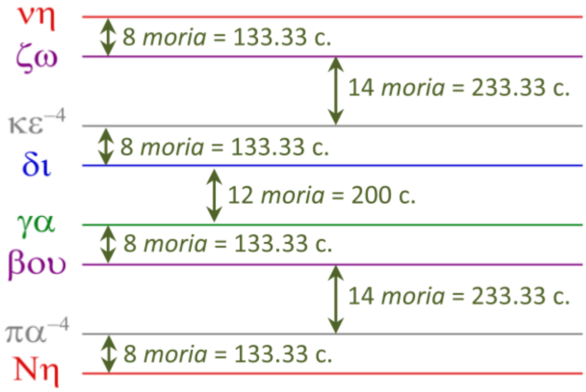


Fig. 71 Graphic scale of the 2nd Byzantine mode – used in the video-animated analyses, with the theoretical values of intervals (2nd Reform of 1881) in "minutes" ("*moria*") and cents. (1 "*moria*" = 1200 c / 72 = 200 c / 12 = 16.67 c)

Fig. 72 Beginning and ending tonics in fr. Haidamous' interpretation of *Kyrie Ekekraxa* (Arabic version).[336]

Traditional singing is, however, often more dynamic in what concerns variations of intervals and tonic pitch(es). This happened for the next analysis of the Arabic version of the same chant as performed by Bachir Osta.[337]

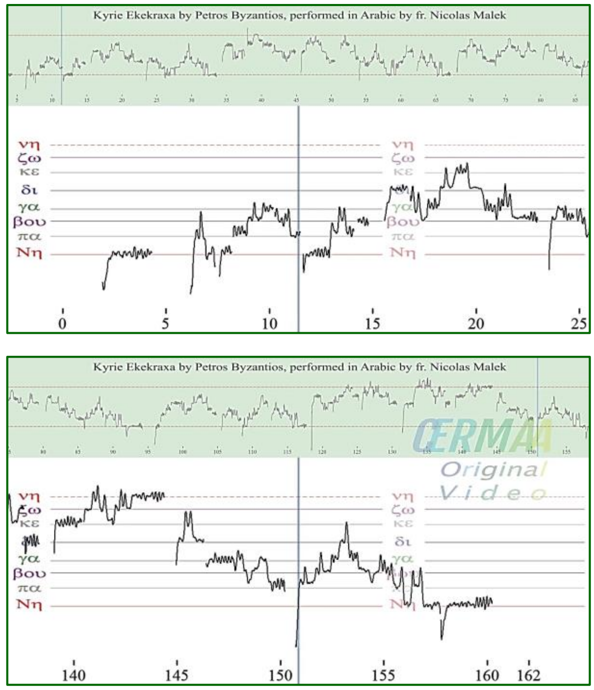


Fig. 73 Beginning and ending tonics in fr. Nicolas Malek's interpretation of *Kyrie Ekekraxa* by Petros Byzantios in the Arabic version.

The tonic (FHT 47 to FHT 50) and the intervals in the interpretations of this cantor change constantly which makes it difficult for the viewer to understand the progression of the melody without an appropriate treatment of the scale.

The most simple remedy – and technical solution – for such an analysis is to use a (vertically) moving scale which is adapted to the pitch of the tonic or to either note of the scale which can help identifying the melodic contour at a given time.[338]

This analysis featured also the use of two different scales for each of the modes in use in this chant (the

336 Father Makarios Haidamous declared to me that he used, for this recording, an *ison* (drone) which he could listen to through headphones. All other recordings are *ison*-less and – except otherwise stated – made by Rosy and Amine Beyhom.

337 These can be found at http://foredofico.org/CERMAA/analyses/byzantine-chant/kyrie-ekekraxa nos. 13-16 and can also be directly streamed:

13. *Kyrie Ekekraxa* in Arabic by Bachir Osta (uploaded 10/10/2018 – original recording [Osta, 2013a]): https://youtu.be/hAicecu12TI [Beyhom, 2018j]
14. *Kyrie Ekekraxa* in Arabic by Bachir Osta in Half tempo (uploaded 10/10/2018): https://youtu.be/gHfSkqOzJio [Beyhom, 2018k]
15. *Kyrie Ekekraxa* in Greek by Bachir Osta (uploaded 10/10/2018 – original recording [Osta, 2013b]): https://youtu.be/WQVd-SqLh1v4 [Beyhom, 2018l]
16. *Kyrie Ekekraxa* in Greek by Bachir Osta in Half tempo (uploaded 24/10/2018): https://youtu.be/2QYvuEAOhWE [Beyhom, 2018m]

338 In the case of Byzantine chant, the *βου* – or even the *Ζω* – can sometimes play this role (watch mainly the versions of *Axion Estin* mentioned farther) – which contradicts the "movable", or "fluctuating" status of these notes in *maqām* music.

8th Byzantine chant mode – Fig. 70 – with an incursion in the 2nd mode – Fig. 71). Let us remind that such a special treatment is only needed in the case of multiple variations in the scale, of the tonic and of intervals.

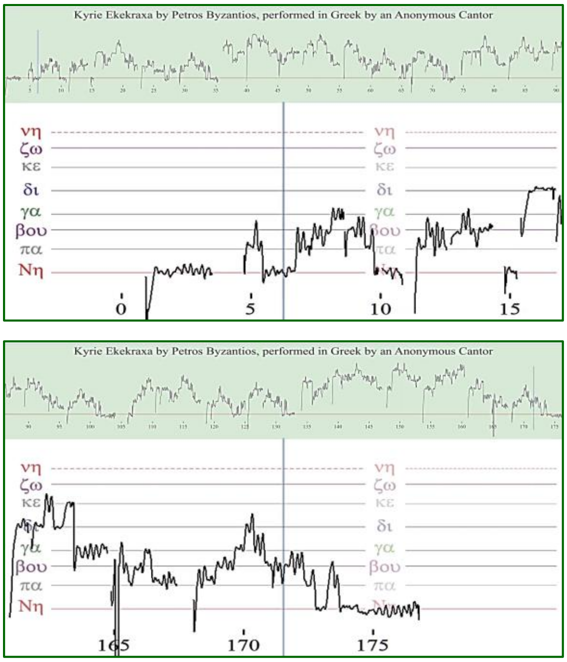


Fig. 74 Beginning and ending tonics in the interpretation by an Anonymous cantor of *Kyrie Ekekraxa* by Petros Byzantios in the Greek version.

In a remake of the analysis of these chants (in both Arabic and Greek languages) as interpreted by an Anonymous cantor[339], the use of a special marker for the original tonic in the main analysis stripe was deemed superfluous.[340]

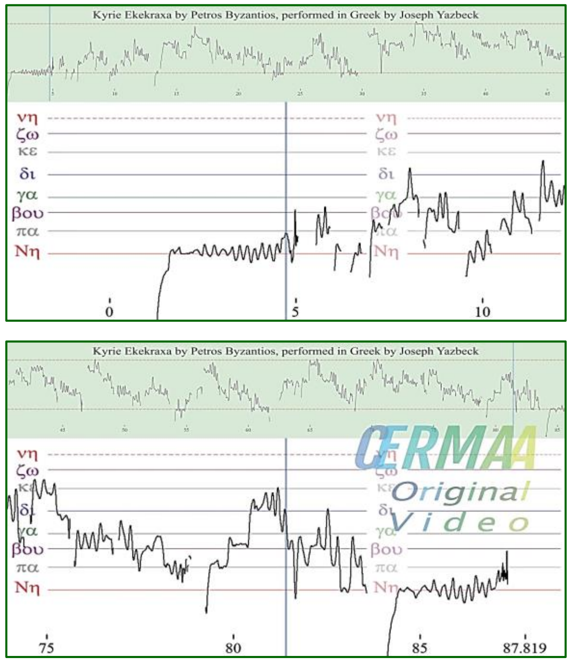


Fig. 75 Beginning and ending – considerably rising at the end for the latter – tonics in Joseph Yazbeck's interpretation of *Kyrie Ekekraxa* by Petros Byzantios in the Greek version.

This series of analyses was completed by another series of the same chant performed by four Greek cantors.[341] (Fig. 78) These analyses[342] included some technical improvements, the most important of which was the use of vectorized graphic output from Praat which allows for a more precise – and smooth – reproduction of the melodic line and of the superimposed scales[343] (Fig. 79, Fig. 80 and Fig. 81).

[339] See http://foredofico.org/CERMAA/analyses/byzantine-chant/kyrie-ekekraxa nos. 9-12 or:

9. *Kyrie Ekekraxa* in Arabic by an Anonymous Cantor (V2 uploaded 10/10/2018): https://youtu.be/uGL8PtgNH1Y [Beyhom, 2018n]
10. *Kyrie Ekekraxa* in Arabic by an Anonymous Cantor (V2) in Half tempo uploaded 10/10/2018): https://youtu.be/2-zsuOXtFsU [Beyhom, 2018o]
11. *Kyrie Ekekraxa* in Greek by an Anonymous Cantor (V2 uploaded 10/10/2018): https://youtu.be/f-QHaMJ5138 [Beyhom, 2018p]
12. *Kyrie Ekekraxa* in Greek by an Anonymous Cantor (V2) in Half tempo uploaded 10/10/2018): https://youtu.be/cVvwFtQE8Dc [Beyhom, 2018q]

Note that the last two videos feature a finer graphical analysis expounded farther.

[340] Note that these dashed lines were included systematically as part of a tentative – generalized – template for further analyses.

[341] The four cantors were recorded in parallel to a conference on Psaltic chant in Volos from the 29th of May to the 1st of June.

[342] See http://foredofico.org/CERMAA/analyses/byzantine-chant/kyrie-ekekraxa nos. 17-20 or:

17. *Kyrie Ekekraxa* in Greek by Emmanouil Giannopoulos (recorded 31/05/2018 by Rosy Beyhom with Zoom H2 in Volos - Greece; uploaded 10/10/2018): https://youtu.be/7_DawlHFeOk [Beyhom, 2018r]
18. *Kyrie Ekekraxa* in Greek by Ioannis Tomas (recorded 31/05/2018 by Rosy Beyhom with Zoom H2 in Volos - Greece; uploaded 10/10/2018): https://youtu.be/ettIzTmrlpw [Beyhom, 2018s]
19. *Kyrie Ekekraxa* in Greek by Mikhail Stroumpakis (recorded 01/06/2018 by Rosy Beyhom with Zoom H2 in Volos - Greece; uploaded 10/10/2018): https://youtu.be/Ije3EdE9bws [Beyhom, 2018t]
20. *Kyrie Ekekraxa* in Greek by Nikolaos Siklafidis (recorded 31/05/2018 by Rosy Beyhom with Zoom H2 in Volos - Greece; uploaded 10/10/2018): https://youtu.be/AvNz2oUYSHY [Beyhom, 2018u]

[343] A few – up to nine for the latter videos – different computer programs are used for the production of such video-animated analyses, with Praat being one single – but essential – component of the whole.

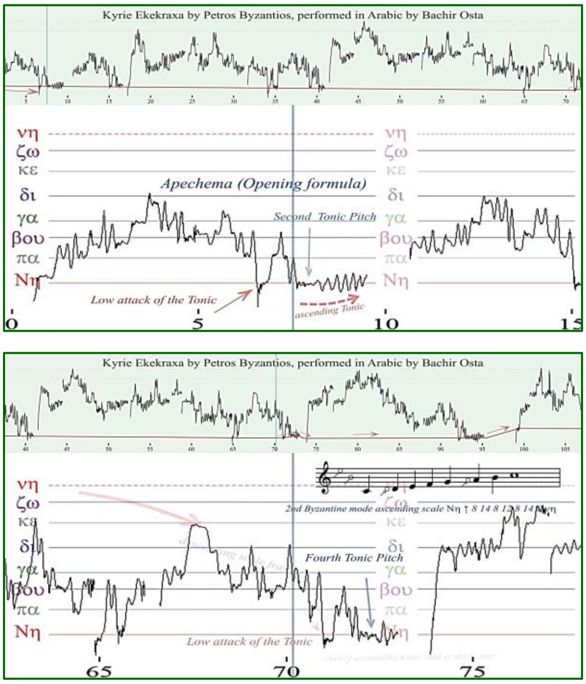


Fig. 76 Additional embedded comments with a (vertically) moving scale used in two frames extracted from the video-analysis of Bachir Osta's interpretation of *Kyrie Ekekraxa* in Greek.[344]

The finer delineation of the melodic line made it also possible to systematize the use of the dashed lines indicating the original positions of the tonic and its upper octave, which proved useful for interpretations such as by Ioannis Tomas for example, but also for the other Greek cantors.[345]

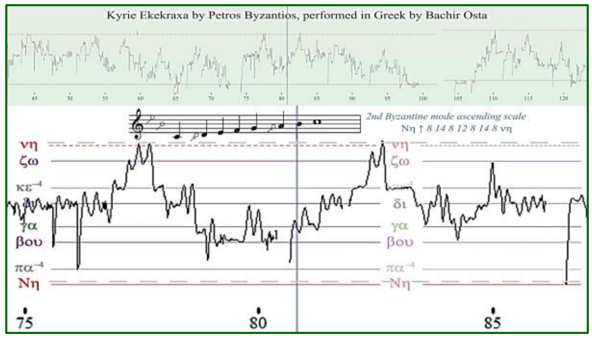


Fig. 77 Additional gray dashed lines show the positions of the original (beginning) tonic and its (upper) octave in the video-analysis of Bachir Osta's interpretation of *Kyrie Ekekraxa* in Arabic.[346]

Fig. 78 Five Greek cantors – Volos (Makrinitsa) 2018/05/31 (photo credit: Amine Beyhom).[347]

Further analyses were dedicated to one other Byzantine chant, namely *Axion Estin* in 8 modes by an anonymous composer.[348] (Fig. 82 and Fig. 83)

[344] The red line in the upper stripe shows the general movement (ascending or descending) of the tonic. Graphic scales are complemented at key moments with hybrid Western-Byzantine notated scales and accompanying literal notation in 2nd Reform Byzantine "minutes".

[345] I hypothesize farther – but this needs further research and analyses to be proven (or unproved) – that Lebanese cantors, being more impregnated with "Oriental" *maqām* music and *tajwīd*, have therefore less difficulties in maintaining a steady tonic throughout the chant – in the case of (Lebanese) Bachir Osta, Greek Psaltic may have influenced his style.

[346] The two fine red lines in the upper strip underline the positions of the same pitches. The superimposed scale reproduces the theoretical intervals of the 2nd Byzantine chant mode in the formulation of the Second reform (see also Fig. 71 above).

[347] Front row, left to right: Ioannis Tomas, Nikolaos Siklafidis and Michalis Stroumpakis. 2nd row, left to right: Conference host Konstantin Karagounis with Emmanouil Giannopoulos.

[348] See http://foredofico.org/CERMAA/analyses/byzantine-chant/axion-estin nos. 1-9. These eight + one – alternate for fr. Nicolas Malek – videos can also be directly streamed:

1. *Axion Estin* by fr. Makarios Haidamous (recorded 06/06/2018 by the performer in Dayr al-Mukhalliṣ - Lebanon; uploaded 09/10/2018): https://youtu.be/aWnwPvG0Ri8 [Beyhom, 2018v]
2. *Axion Estin* by an Anonymous Cantor (recorded 25/06/2018 by Rosy Beyhom with Zoom H2 in Broummana - Lebanon; uploaded 09/10/2018): https://youtu.be/DWsRxCih8hM [Beyhom, 2018w]
3. *Axion Estin* by fr. Nicolas Malek (recorded 24/06/2018 by Rosy Beyhom with Zoom H2 in Broummana - Lebanon; uploaded 09/10/2018): https://youtu.be/UNYUlFNwHuM [Beyhom, 2018x]
4. *Axion Estin* by fr. Nicolas Malek – Alternate take (recorded 24/06/2018 by Rosy Beyhom with Zoom H2 in Broummana - Lebanon; uploaded 09/10/2018): https://youtu.be/JYZAj-DYjj60 [Beyhom, 2018y]
5. *Axion Estin* by Joseph Yazbeck (recorded 08/06/2018 by Rosy Beyhom with Zoom H2 in Broummana - Lebanon; uploaded 09/10/2018): https://youtu.be/_Cpyf9hqUEc [Beyhom, 2018z]
6. *Axion Estin* by Emmanouil Giannopoulos (recorded 31/05/2018 by Rosy Beyhom with Zoom H2 in Volos - Greece; uploaded 09/10/2018): https://youtu.be/4VpOchjbEZA [Beyhom, 2018aa]
7. *Axion Estin* by Nikolaos Siklafidis (recorded 31/05/2018 by Rosy Beyhom with Zoom H2 in Volos - Greece; uploaded 09/10/2018): https://youtu.be/gyxoviJs1aU [Beyhom, 2018ab]

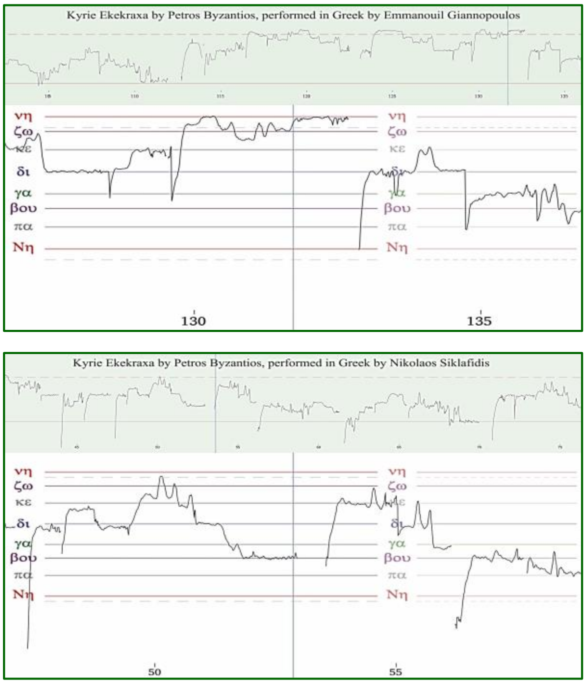


Fig. 79 Frames extracted from the video-animated analyses of *Kyrie Ekekraxa* by Petros Byzantios in, from top to bottom, the interpretations of Emmanouil Giannopoulos and Nikolaos Siklafidis.

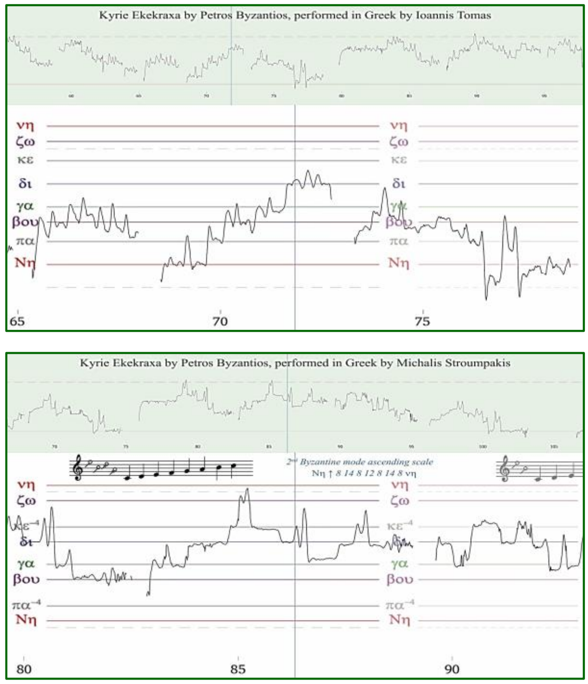


Fig. 80 Frames extracted from the video-animated analyses of *Kyrie Ekekraxa* by Petros Byzantios in, from top to bottom, the interpretations of Ioannis Tomas and Michalis Stroumpakis.[352]

Besides this chant being a challenge for any cantor in the field of Byzantine chant,[349] these analyses contributed as a test for the procedures already in use and triggered new developments such as the delimitation of the modes (between brackets) together with a more elaborate grid[350] in the upper stripe and/or the use of additional indicators for peculiarities of the chant[351].

Moreover: a set of identified "attractions" was searched for in the interpretations and underlined (Fig. 81 – upper frame at 112.5 s_a) for each cantor.[353]

One of the lessons to be drawn from these analyses concerns the factual difference between the intervals used in Byzantine chant by cantors impregnated by the 2nd Reform theory and the same intervals as performed by the school of "Oriental" singing represented here by fr. Nicolas Malek (third from top in Fig. 83, then Fig. 85)

8. *Axion Estin* by Ioannis Tomas (recorded 31/05/2018 by Rosy Beyhom with Zoom H2 in Volos - Greece; uploaded 09/10/2018): https://youtu.be/QICHWCaOfQA [Beyhom, 2018ac]
9. *Axion Estin* by Mikhail Stroumpakis (recorded 01/06/2018 by Rosy Beyhom with Zoom H2 in Volos - Greece; uploaded 09/10/2018): https://youtu.be/qM34JswCUZo [Beyhom, 2018ad]

349 Most of the recorded Greek cantors had for example difficulties in holding the intervals in the seventh mode – or "diatonic" on *Zω*. I would like to express here my heartfelt thanks to fr. Romanos Joubran who helped us at the CERMAA seek and find this chant, the particularities of which greatly enriched the observation of the resulting analyses.

350 Using once again the color code for main intervals (red solid and dashed horizontal lines for the tonic and octave, green for the fourth and blue for the fifth) and helping thus the viewer identifying the melodic course.

351 Notably the "attractions" particular to the modes of Byzantine chant – in the lower stripe – and the literal delimitation of the first tonic and its octave (*Πα* and *πα*) – in the upper stripe.

352 The first frame (top) illustrates the considerable discrepancies for the positions of the tonic pitch in the cantor's interpretation. The styles of the cantors vary also considerably which contradicts the theory of standardized Byzantine chanting put forward by the Music Committee of 1881 – see Chapter III in [Beyhom, 2016b] – even when limited to Greece as such.

353 These attractions are the use of the "diatonic" (in the Byzantine sense of the word) *βου*(s) in the 3rd mode (measures 14 and 16 in the score of FHT 52: 240), of the lowered two *Ζω*(s) in the 5th mode (measure 27 in the same figure), the use of upper "diatonic" *βου* in the 6th mode – the two *βου*(s) in measure 30, and the two raised *γα*(s) at the beginning of the 7th and of the 8th mode (measures 36 and 45). Note that the attractions were not underlined for the analysis of this chant as performed by Joseph Yazbeck due to the particular style – notably characterized by ample variations and constantly changing pitches – of this cantor.

and, as a tentative experiment to include an extraneous element in the analyses, by Rosy Beyhom (Fig. 84)[354].

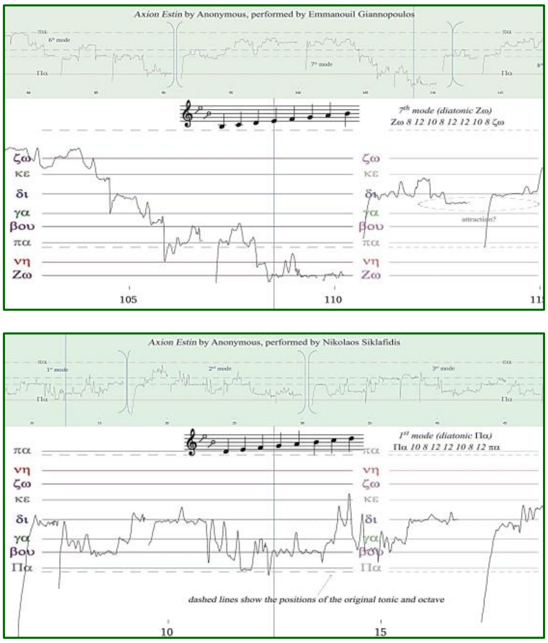


Fig. 81 Frames extracted from the video-animated analyses of *Axion Estin* in, from top to bottom, the interpretations of (Greek) Emmanouil Giannopoulos and Nikolaos Siklafidis.

Both have trouble in choosing the pitches of the *βου* and the *Ζω*, which leads to slight (localized) scale disruptions. This also applies (mainly for the *Ζω*) for the Anonymous cantor (Fig. 86).

More generally, and surprisingly enough, most of – if not all – the cantors have had difficulties in keeping coherent intervals in the 3rd mode which is the "enharmonic" ("ditonic" – supposedly equivalent to the "Western") on *Νη* = *c*[355] (examples are provided in Fig. 82 – bottom frame – and Fig. 83 – 2nd and 4th frames from top).

Further: all these analyses confirm that the notated scores are but a guide, and that these are interpreted more or less freely according to each performer.

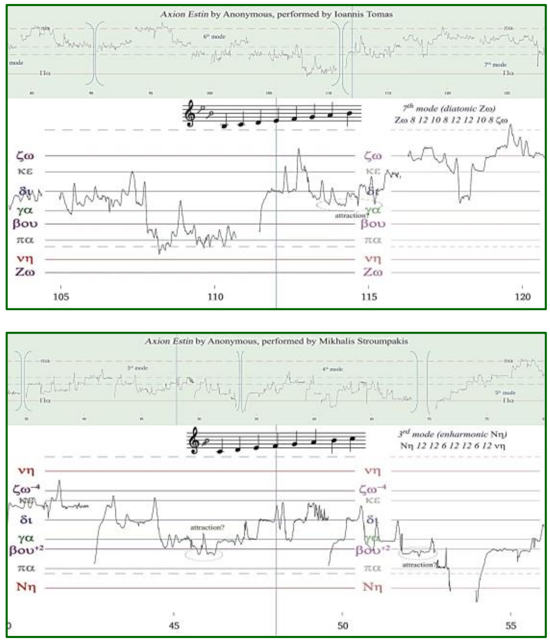


Fig. 82 Frames extracted from the video-animated analyses of *Axion Estin* in, from top to bottom, the interpretations of (Greek) Ioannis Tomas and Michalis Stroumpakis.[356]

Other developments for *Axion Estin* include a template analysis (Fig. 87)[357] based on the westernized score as transnotated by fr. Romanos Joubran and the author, (FHT 51 and FHT 52: 239-240).

This definitely shows the discrepancy between notated music[358] and its interpretation in Byzantine chant.[359]

[354] See http://foredofico.org/CERMAA/analyses/byzantine-chant/axion-estin no. 10 (this video can also be directly streamed):

10. *Axion Estin* by Rosy Beyhom (recorded 14/06/2018 by Rosy Beyhom with Zoom H2 in Broummana - Lebanon; uploaded 09/10/2018): https://youtu.be/lDhi2g6dPkY [Beyhom, 2018ae]

[355] All pitches are relative. The Second Reform *enharmonic* mode on *Νη* (= *c*) is equivalent to a western ("ditonic" – as with "having two whole tones in the Fourth") mode of *g* on *c*, or *c* 2 2 1 2 2 1 2 *C* in multiples of the semi-tone.

[356] The styles of these cantors (their graphic "signature" in these videos and analyses), together with the styles of the two cantors in the previous figure and as for *Kyrie Ekekraxa* by Petros Byzantios, vary considerably.

[357] See http://foredofico.org/CERMAA/analyses/byzantine-chant/axion-estin nos. 11-12. These – original and half-tempo – videos can also be directly streamed:

11. *Axion Estin* by Anonymous, template analysis of audio output by programs MUS2 & Cubase (uploaded 09/10/2018): https://youtu.be/YuRD6G4PTuE [Beyhom, 2018af]
12. *Axion Estin* by Anonymous, template analysis of audio output by programs MUS2 & Cubase – Half-tempo (uploaded 09/10/2018): https://youtu.be/MiRuhUt_tMQ [Beyhom, 2018ag]

[358] And, here, its computerized interpretation by the program MUS2 for score notation which produced the midi score, then by Cubase which reproduced the pitches according to digitalized violin samples.

[359] While the wife of fr. Nicolas Malek (Orthodox priests can be married and have children) was visiting the CERMAA in July 2018, we showed her – among others – this template video-animated analysis. Her main reaction to the beginning of the piece was "This sounds so much like a Minor scale – it has nothing to do with the chanting as such!".

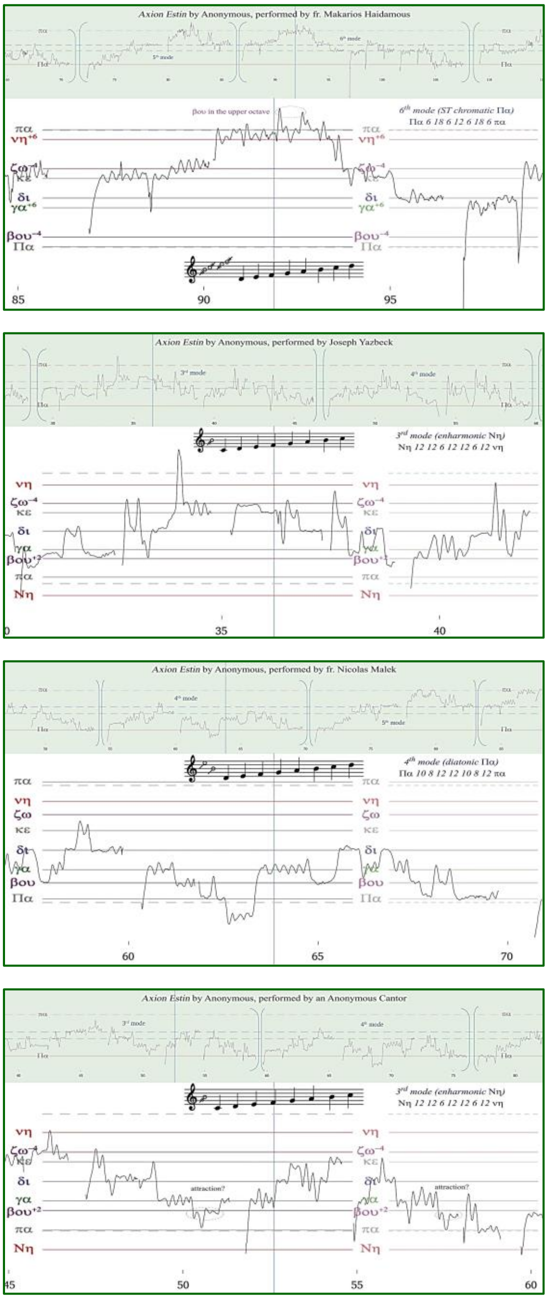


Fig. 83 Frames extracted from the video-animated analyses of *Axion Estin* by an Anonymous composer (in the eight Byzantine modes).[360]

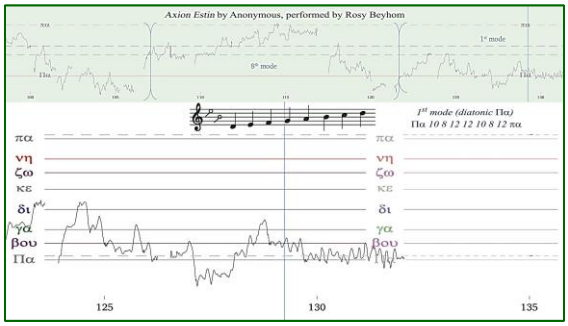


Fig. 84 One frame towards the end of the video-animated analysis of *Axion Estin* as performed by Rosy Beyhom. The performer has visible trouble choosing between the lower, "Oriental" *βου* and the higher, "Byzantine" *βου*.

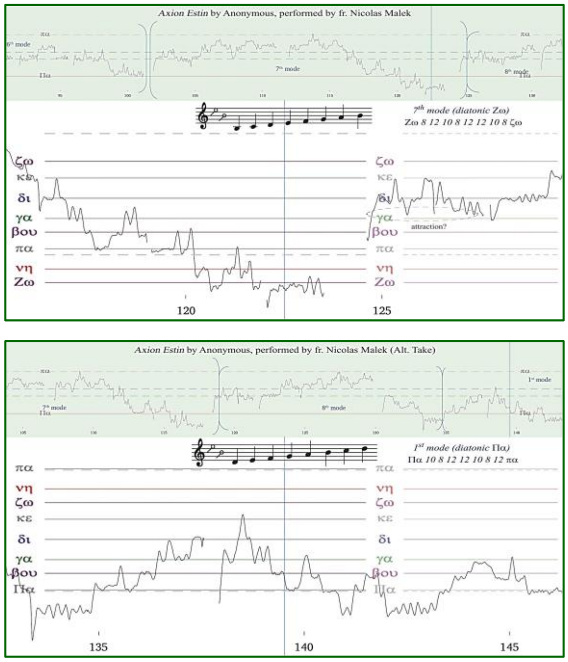


Fig. 85 One frame (top) to the end of the 7th Byzantine mode in the video-animated analysis of *Axion Estin* performed by fr. Nicolas Malek, and one frame (bottom) towards the end of the analysis of the second (alternate) take.[361]

An Arabic language version[362] (from right to left – Fig. 88) was also produced in order to verify the feasibility of such videos for Arabic-speaking (or likewise right to left reading) countries.

[360] In, from top to bottom, the interpretations of (Lebanese) fr. Makarios Haidamous, Joseph Yazbeck, fr. Nicolas Malek and an Anonymous cantor, also with different styles. Father Makarios Haidamous declared that he didn't use, for this recording, an *ison*. As stated above, all other recordings of Byzantine chant reviewed in this dossier – for the video-animated analyses – were made by me or by Rosy Beyhom: all these recordings were made without the use of an *ison*.

[361] The first analysis was undertaken for the third audio take – which was the choice of the author. As fr. Malek inclined towards the second take, it was also analyzed and named "Alternate Take". Note that in the upper frame, the performer has visible trouble choosing between the lower, "Oriental" *Zω* and the higher, "Byzantine" *Zω*. This also applies – in the lower frame – to the lower "Oriental" *βου* and the higher "Byzantine" *βου*.

[362] As well as a half-tempo version – see http://foredofico.org/CERMAA/analyses/byzantine-chant/axion-estin nos. 13-14. These – original and half-tempo – videos can also be directly streamed:

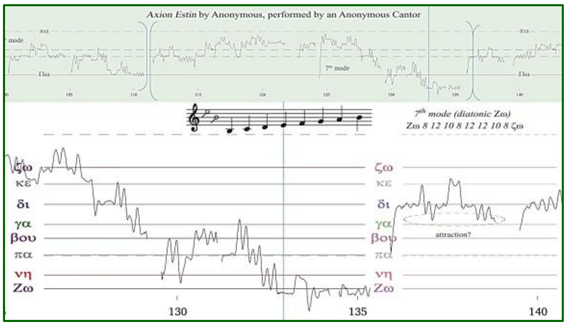


Fig. 86 One frame to the end of the 7th Byzantine mode in the video-animated analysis of *Axion Estin* performed by an anonymous cantor. The performer has visible trouble choosing between the lower, "Oriental" *Ζω* and the higher, "Byzantine" *Ζω*.

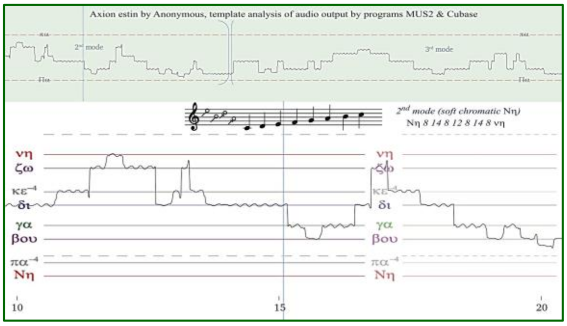


Fig. 87 One frame extracted from the Template analysis of Axion Estin by an anonymous composer. The audio was produced by a Cubase violin VST on the base of a midi score extracted with MUS2 from the transnotated score (FHT 52).

As a final addition to these – Byzantine – analyses, a synthetic table of the 9 *Axion Estin* commented Praat analyses[363] was assembled and used as a poster by the author (FHT 53: 241).

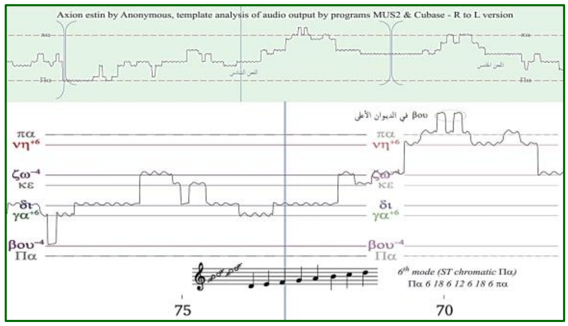


Fig. 88 One frame extracted from the template analysis of *Axion Estin* (Anonymous) from right to left, including incrustations in the Arabic language.

Video-animated analyses of two *tajwīd*-like songs by the *shaykh* ʿAlī Maḥmūd and the *qāriʾ* Muḥammad al-Ghazālī

In the case of the two analyzed Byzantine chants, the score – whether in Byzantine or in westernized notation – provided a guide for both the performer and the analyst[364].

In the particular case of Arabian *maqām* music, which is rich in both ornamentations and modulations[365] – and is partly or mainly improvised in its traditional interpretations, undertaking a correct analysis could be much more of a challenge.

Indeed, Byzantine chant analyses may seem relatively simple when compared to analyses of *tajwīd*[366] and *ādhān*[367] in which ample variations of the pitch are consciously – and often – performed (Fig. 89).[368] These difficulties are sometimes magnified by either a broader use of the vertical space (as for example in the chants by sheikh ʿAlī Maḥmūd) or, to the contrary, by a downsizing of this space – as with Muḥammad al-Ghazālī –

13. *Axion Estin* by Anonymous, template analysis of audio output by programs MUS2 & Cubase (R to L) – (uploaded 09/10/2018): https://youtu.be/j3lyDA-IFPE [Beyhom, 2018ah]
14. *Axion Estin* by Anonymous, template analysis of audio output by programs MUS2 & Cubase – Half-tempo (R to L) – (uploaded 09/10/2018): https://youtu.be/tDXJkXGO8fo [Beyhom, 2018ai]

[363] To which were added the template analysis and the alternate-take analysis for fr. Nicolas Malek – which makes it 11 analyses in all.

[364] The video-analyses of these (Byzantine) chants would have been, in some cases, much more difficult to undertake without prior knowledge of the modes – and of the "attractions".

[365] *i.e.* much more versatile.

[366] See [Denny, 2012] for a complete definition – and description. Note also: "***Tajweed*** (Arabic: تجويد *tajwīd*, IPA: [tædʒ'wi:d], meaning 'elocution'), sometimes rendered as ***tajwid***, refers to the rules governing pronunciation during recitation of the *Quran*. The term is derived from the triliteral root *j-w-d* meaning 'to make well, make better, improve'. *Tajweed* is a *mustahab* (preferred, but not an obligation) when reciting the Quran to the best of one's ability" – in [Wikipedia Contributors, 2018d].

[367] See [Juynboll, 2012]. Note also: "The ***adhan***, ***athan***, or ***azaan*** (Arabic: أَذَان [ʔaˈðaːn]) (also called in Turkish: *Ezan*) is the Islamic call to worship, recited by the *muezzin* at prescribed times of the day. The root of the word is *ʾadhina* أَذِنَ meaning 'to listen, to hear, be informed about'. Another derivative of this word is *ʾudhun* (أُذُن), meaning 'ear'. *Adhan* is called out by a *muezzin* from the mosque five times a day, traditionally from the minaret, summoning Muslims for mandatory (*fard*) worship (*salat*)" – in [Wikipedia Contributors, 2018e].

[368] See also examples of *tajwīd* and *ādhān* in the animated powerpoint slides proposed as an accompaniment to [Beyhom, 2014], and in FHT 47 (Analysis of *ḥijāz* performed by Hafiz Hâni Karaca) and FHT 48 and 47 (analyses of *ḥijāz* by Bekir Sidqi Sezgin) – [p. 148-149] of the same reference. See also Slides nos. 2-6 in the PPS accompanying this dossier.

which create both specific needs and necessitate particular techniques of analysis. In such cases, a static – or semi-static[369] – analysis is often unsatisfactory while a video-animated analysis can often provide more complete information on the performance.

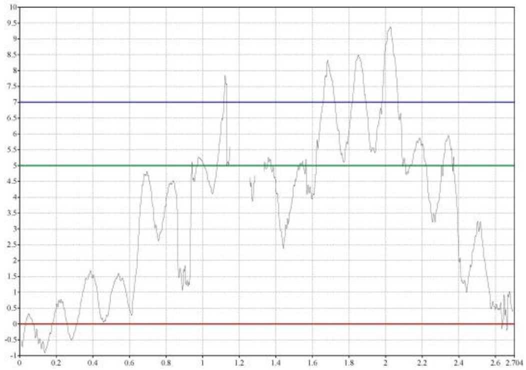


Fig. 89 Graphic analysis with Praat of a *ḥijāz genos* performed by *sheikh* ʿAlī Maḥmūd – from [Beyhom, 2014].[370]

In the particular cases of the two performances analyzed here,[371] Al-Ghazālī is a *qāriʾ*[372], and ʿAlī Maḥ-mūd a *shaykh*[373]. Both use a very melismatic style, while both can equally hold notes with virtually no vibrato.

Fig. 90 Photograph of sheikh ʿAlī Maḥmūd.[374]

To be able to analyze these chants a special set of graphic scales was created (examples provided in Fig. 91 and Fig. 93) based on the theoretical – quarter-tone – division of the vertical space[375].

[369] The same way as for the "Animations with moving cursors and fixed graphs" seen above.

[370] Analysis available in Slide no. 2 of the accompanying PPS.

[371] The two video-animated analyses of these chants – with a half-tempo version for each – are available at (http://foredofico.org/CERMAA/analyses/maqam-analysis), and directly streamable as:

1. *Seven Maqāmāt* by Muḥammad al-Ghazālī (uploaded 10/10/2018): https://youtu.be/Uc22jh65r0M [Beyhom, 2018aj]
2. *Seven Maqāmāt* by Muḥammad al-Ghazālī – Half-tempo (uploaded 10/10/2018): https://youtu.be/6TvK2keRZe4 [Beyhom, 2018ak]
3. *Ahlan bi-Ghazālin* by sheikh ʿAlī Maḥmūd (uploaded 09/10/2018): https://youtu.be/s_Nsm4mzFns [Beyhom, 2018al]
4. *Ahlan bi-Ghazālin* by sheikh ʿAlī Maḥmūd – Half-tempo (uploaded 09/10/2018): https://youtu.be/3pbprgsRuRA [Beyhom, 2018am]

[372] "A ***qāriʾ*** (Arabic: قارئ, plural قُرَّاء *qurrāʾ*; English: 'reader') is a person who recites the Quran with the proper rules of recitation (*tajwid*)" – in [Wikipedia Contributors, 2018c].

[373] See [Geoffroy, 2012]. Note also: "***sheikh*** (ʃeɪk) *or* ***sheik*** (in Muslim countries) *n*[:] **1.** (Government, Politics & Diplomacy) the head of an Arab tribe, village, etc. **2.** a venerable old man **[…]** **4.** (Islam) a high priest or religious leader, esp a Sufi master" – in [Anon. "sheikh"]. In general, [a] learned Islamic sheikh is a *ḥāfiẓ*: "*Sheikh*, also spelled *Sheik*, *Shaikh*, or *Shaykh*, Arabic *Shaykh*, Arabic title of respect dating from pre-Islāmic antiquity; it strictly means a venerable man of more than 50 years of age. The title *sheikh* is especially borne by heads of religious orders, heads of colleges, such as Al-Azhar University in Cairo, chiefs of tribes, and headmen of villages and of separate quarters of towns. It is also applied to learned men, especially members of the class of *ulamas* (theologians), and has been applied to anyone who has memorized the whole *Qur'ān*, however young he might be" – in [Anon. "Sheikh | Arabic title"].

[374] The provenance of this photograph is unknown. Extract from the biography of *Shaykh* ʿAli Maḥmūd (translated in 2006 by Rosy Azar Beyhom from the *Wikipedia* corresponding entry in Arabic – further checked and translated to English by the author): "*Shaykh* ʿAli Maḥmūd was born in 1878 in Cairo. He became blind due to an accident, when he was still young. He studied Koranic memorization under *shaykh* Abū Hāshim a-sh-Shibrāwī then the *tajwīd* and Koranic reading with *shaykh* Mabrūk Ḥusnayn. After learning Koranic Sciences under *shaykh* Abd al-Qāder al-Maznī, he became famous in Egypt as a *qāriʾ* (reader of the Koran). He acquired his musical knowledge under *shaykh* Ibrahīm Al-Maghribī, and with the great singer ʿAbd a-r-Raḥīm Maslūb who taught him the *muwashshaḥāt*, performance on instruments and music composition. He also studied with *shaykh* ʿUthmān al-Mawṣilī, of Turkish origin, who also taught him Turkish (Ottoman) music and its peculiarities. ʿAlī Mahmūd's celebrity as a *muṭrib* (profane singer), a *munshid* (religious singer – cantor) and a *qāriʾ* (see fn. 372 and 373) can be ascribed to his very complete background in music and Koranic studies, however also to the fact that he was extremely gifted. It is said that he would perform the call to prayer on Fridays at the Al-Ḥusayn mosque in a mode that he would not use again before the year after. As First *munshid* in Egypt, he also had many students some of which became well known such as *shaykh* Muhammad Rifʿat, *shaykh* Ṭah al-Fishnī, *shaykh* Kāmil Yūsif al-Bahtīmī, *shaykh* Zakariyya Aḥmad as well as singers such as Muḥammad Abd al-Wahhab, Um Kulthūm and Asmahān. He died on the 21st of December 1946 leaving few recordings after him".

[375] Most probably the result of the influence of Western music (theory) on *maqām* theoreticians.

The author's solmization[376] (Fig. 92) was extended (FHT 57:245), inspired by the denominations of the degrees of the "Modern Arabian" scale (FHT 54: 242 to FHT 56: 244).

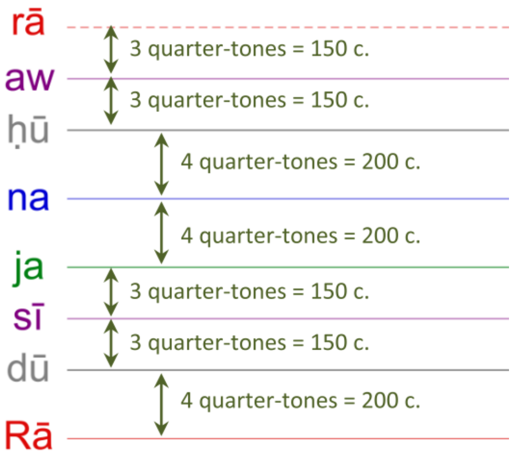


Fig. 91 Simplified octavial graphic – and theoretical – scale of *maqām Rāst* implemented in the video-animated analyses – with intervals in quarter-tones and equivalents in cents.[377]

KARDĀN	↔	***rā*** $_2$	***c'***
AWJ	↔	***aw*** $_2$	***b*** ^{hf}
ḤUSAYNĪ	↔	***ḥu*** $_2$	***a***
NAWĀ	↔	***na*** $_2$	***g***
JAHĀRKĀ	↔	***ja***	***f***
SĪKĀ	↔	***sī***	***e*** ^{hf}
DŪKĀ	↔	***dū***	***d***
RĀST	↔	***rā***	***c***

Fig. 92 Solmization proposed for the middle octave of Arabian music by the author in 2012 – and Western equivalents. ("*hf*" stands for "half-flat".)[378]

It is systematically used in the following analyses in order to simplify the process of pitch identification, together with the use of equivalent western (literal, relative and altered as needed for the equivalence) degrees of the scale (to the right in Fig. 93).

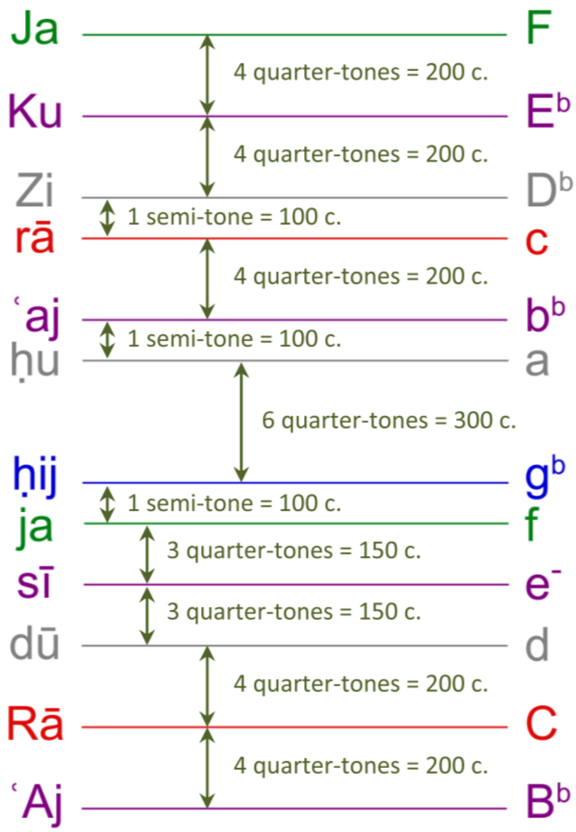


Fig. 93 (Non-dimmed) Right-side of the graphic non-octavial (based on *d*) – and theoretical – scale of *maqām Ṣabā-Nahawand*[379] as implemented in the video-animated analyses with intervals in quarter- (or semi-) tones and cents.[380]

* * *

[376] The limited (to 7 notes per one octave) solmization was first proposed in [Beyhom, 2012].

[377] Names of notes (to the left – originally *RĀST* = *c*, *DŪKĀ* = *d*, *SĪKĀ* = e^{-}, *JAHĀRKĀ* = *f*, *NAWĀ* = *g*, *ḤUSAYNĪ* = *a*, *AWJ* = b^{-} and *KIRDĀN* = *c'*) follow the solmization proposed by the author in [Beyhom, 2012] with the "minus" ("-") sign indicating an approximate quarter-tone lowering of the note. (1 equal-tempered quarter-tone = 1200 c / 24 = 200 c / 4 = 50 c.)

[378] Previously published as [Beyhom, 2012, p. 68, Fig. 3].

[379] *Ṣabā-Nahawand* is a neologism used to describe the (scale of) *maqām Ṣabā* when a *nahawand* tetrachord is inserted on the upper b^b (as happens in the course of the performance of sheikh ʿAlī Maḥmūd at approx. 47 s_a in Fig. 98: 200 – see also Fig. 101: 200), instead of a *ḥijāz* tetrachord (*262*) on *d*. This case is described theoretically in [Erlanger, 1949, v. 5, p. 282] as a *ʿajam* on b^b, which shows the differences of interpretation in *maqām* analysis. The scale with upper *ḥijāz* tetrachord of the *maqām* could be termed – to differentiate it from the *Ṣabā-Nahawand* – as *Ṣabā-Ḥijāz*. (See also the analysis of *Ahlan bi-Ghazālin* by sheikh ʿAlī Maḥmūd next.)

[380] Names of notes (to the left – originally *QARĀR-ʿAJAM, RĀST, DUKĀ, SĪKĀ, JAHĀRKĀ, NAWĀ, ḤIJĀZ, ḤUSAYNĪ, ʿAJAM-ʿUSHAYRĀN, KIRDĀN, SHAH-NĀZ, SUNBULA and MĀHŪRĀN*) follow the solmization proposed by the author in [Beyhom, 2012] and expanded in FHT 57: 245. Theoretic equivalents in Western notation are provided to the right, with the "minus" ("-") sign indicating a quarter-tone lowering of the note.

Al-Ghazālī's *Seven Maqāmāt*[381] can readily be considered as an exercise of style in which the reciter shows his mastery of the complex modulations commonly used in Arabian *maqām* chant.

The video-animated analysis of this chant opens on an overall graphic description of the performance (approx. from 5 s_v to 11 s_v[382] – see also FHT 58) with the names and delineation of the scales of the different *maqāmāt* (in fact *ajnās*[383] or *geni*).

The first observation is that – when relying on the conservatoire terminology in Arabian countries – the reciter uses the term *maqām* for *ajnās* and that he often announces a *maqām* but performs a variant or singles out a tetrachord in a scale. This happens with "*maqām*" *Sīkā* which is in conservatoire terminology a *Sīkā-Huzām*, *i.e.* a *Sīkā* with an insertion of a *ḥijāz* tetrachord on *na* (*g* – see Fig. 94: 198, second frame from top), and with a "*maqām*" *Nahawand* (from 49 s_a to 52 s_a) which is in fact the upper *jins nahawand* of *maqām Kurd*.

A literal description of the performance could be:

The performer begins by announcing *maqām Rāst* on its (relative) tonic *RĀST* (*C*) then (from 2 s_a to 14 s_a) develops a *jins rāst*[384] (*C 433* in relative – and approximate – multiples of the quarter-tone) then modulates (15 s_a to 25 s_a) to *maqām Sīkā-Huzām* on its original tonic *SĪKĀ* starting with the sub-tonic *d* then developing a limited part of the scale *E⁻ 3426243*, namely *E⁻ 34[2]* in which the initial trichord *34* corresponds to a *sīkā* on *E⁻* and the *[2]* initiates the upper *jins ḥijāz g 262* of the scale. The next step (26 s_a to 42 s_a) consists of a modulation *and* a transposition, namely to *maqām Ṣabā* (originally on *DŪKĀ* or *D 3326244* in its octavial form) on the degree *SĪKĀ*, with a development of *jins ṣabā 332* including occasional inceptions of *jins ḥijāz 262* on the lower[385] g^b or *c* (34 s_a). Although the performer announces a "*Nahawand*" between 42 s_a and 48 s_a, this announcement is also undertaken in the scale of *maqām Ṣabā* – equally limited to the main (lower) tetrachord – with ample vertical descending variations (reaching the *ḥu* or central g^b) while concluding on the (transposed) tonic *DŪKĀ* (=*D*) on *AWJ* = *B⁻*. In the following 33 seconds (49s_a to 72s_a) the performer develops *maqām Kurd D 24444244* transposed on original *SĪKĀ* (*E⁻*), the scale of which consists in a *kurd* pentachord *D 24444* and a *nahawand* tetrachord *g 424[4]*. The following part (72 s_a to 108 s_a) is a WIAIWYG[386] and consists in developments within the scale of *maqām Ḥijāz* (*D 2624244*) transposed on *ʿAJAM*[387] = B^b. The performance is concluded by the development of the lower part of *maqām Bayāt* transposed also on *ʿAJAM*[388].

As expounded above, the range of the performance is limited to one octave – with occasional limited leaps as (for example) at approx. 116 s_a – in the vertical space[389], and with intricate modulations due to transpositions of the modes.

Obviously, such a literal description – which could correspond to aural teaching of *maqām* music[390] – will not suffice for the purpose of complete analysis of the melody.

The video-animated analysis provides, on the other hand, a compact and complete description of the melodic contour[391] of the performance along with the listening to the performance itself.[392]

[381] "Seven modes", with the original video available at https://www.youtube.comatch?v=w1OYvFfpjeE.

[382] "s_v" is used for video-time (time as given by the video-player) while "s_a" is used for analysis-time (time as shown on the graphic analysis).

[383] The *ajnās* correspond to particular performances of polychords in a given repertoire. The range of the *jins* (singular of *ajnās*) is generally wider than the range of the polychord as such; this is why, in the following video-animations, a *jins ṣabā* can be described as composed from the successive (rising) intervals *332[6]* meaning that the *ṣabā* tetrachord on *d* – scale notes are all relative to the current tonic – is composed from the initial intervals 3, 3 and 2 (quarter-tones) and uses the upper one-and-half-tones interval "6" – initially the central interval of the *ḥijāz* tetrachord on *f* ("*ja*" in the Arabian solmization recommended by the author) as a complement in the realization of the *jins*.

[384] The upper and lower cases lettering differentiates (the scale of) *maqām Rāst* (initial uppercase) from the tonic (pitch) *RĀST* (uppercase) and from the polychord (or *jins*) *rāst* (lowercase).

[385] The vertical space for the description of this performance of *ma-qām* music is divided in three parts: the central octave (or near-octave in this case), the lower octave and the upper octave.

[386] "What Is Announced Is What You Get".

[387] In fact on *AWJ* = *b⁻*, but it seems to the author that the intended transposition pitch was on *ʿAJAM*.

[388] See previous footnote.

[389] In practice this would be the octave from lower *ʿAj[am]* = *A* to its octave *ʿaj* = *a* if the initial *Rā* = *C* is to be taken as the reference pitch.

[390] And which could be developed in such a way as to include most of the details of the performance – but this would be very time consuming as well as not as efficient as the video-animated analysis itself.

[391] With comments added in parallel to help with the identification of the *ajnās* used in the performance.

[392] The mastery of this *qāriʾ* for these modulations and transpositions cannot be described by the analysis, but only appreciated by listening

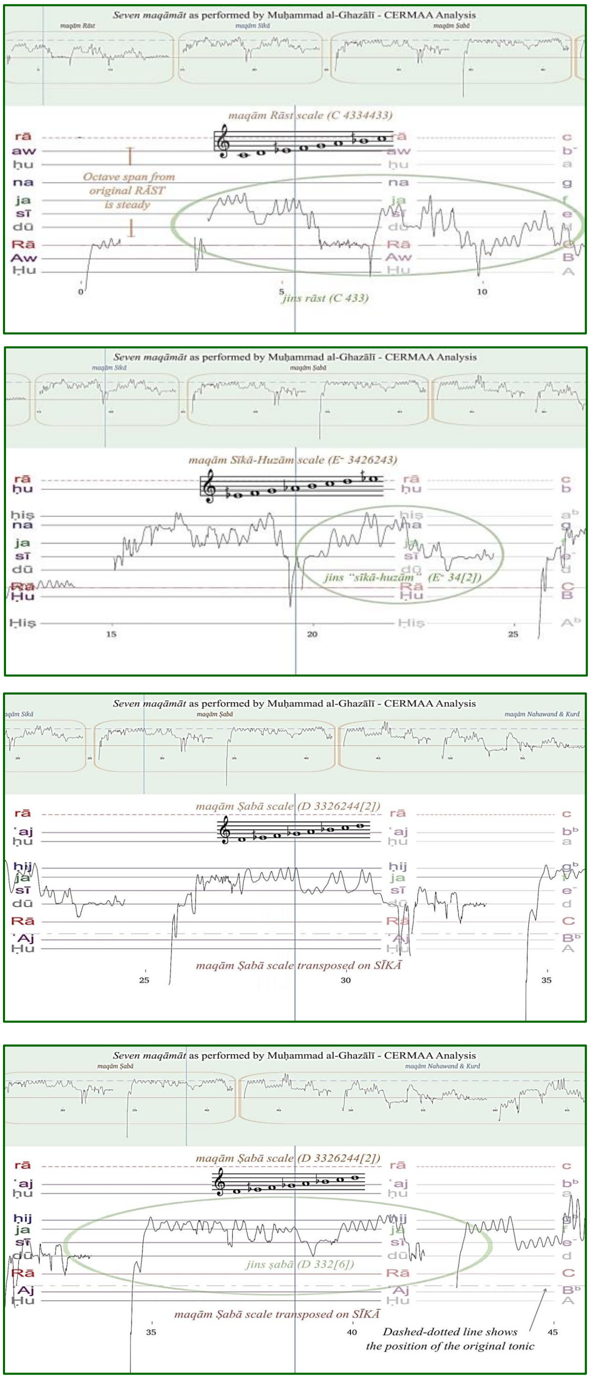


Fig. 94 Four frames from the video-animated analysis of *7 maqāmāt* as performed by the *qāriʾ* Muḥammad al-Ghazālī.

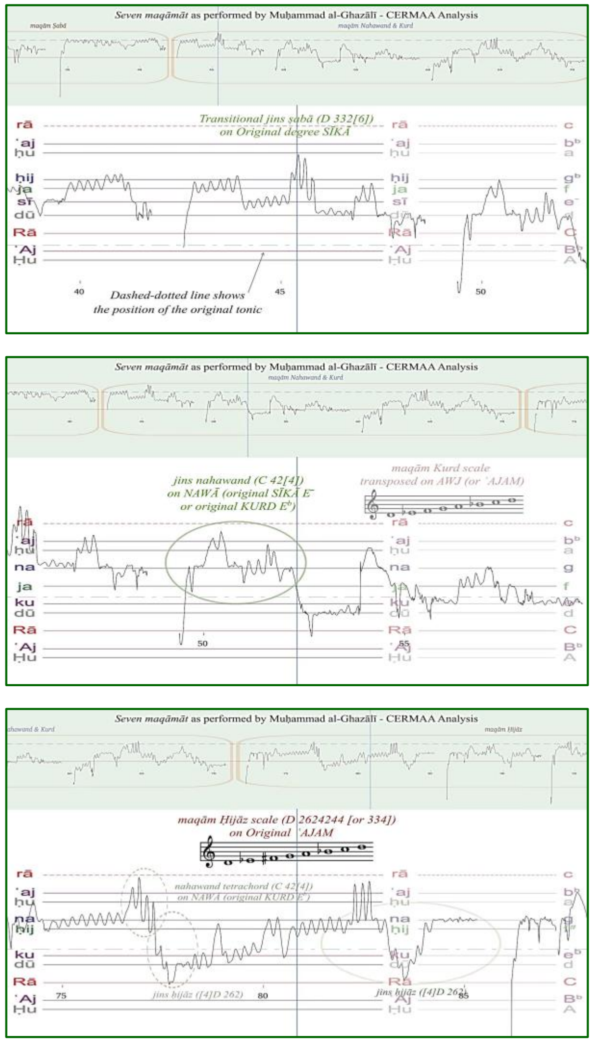


Fig. 95 Three frames from the video-animated analysis of *7 maqāmāt* as performed by the *qāriʾ* Muḥammad al-Ghazālī.[393]

*
* *

Ahlan bi-Ghazālin by sheikh ʿAlī Maḥmūd[394] is the first – solo – part of a hymn performed by a choir. The date of the recording is unknown[395] and the bad quality of the recorded copy – as with most old recordings of Islamic cantors – compelled the author to undertake a light clean-up of the recording prior to the analysis with Praat in such a way as to lower the background noise without, however, altering the melodic line.

to the performance and understanding what happens in its course: the video-animated analyses are of great help for such a purpose. Note also that, as for the aforementioned video-analyses of *Kyrie Ekekraxa* performed by Bachir Osta, a half-tempo version – with quality audio – is proposed for al-Ghazālī's *7 maqāmāt*.

393 The near-leap of fourth (descending) at 52.5 s_a (central frame) is in fact structured in five different pitches when listening to the excerpt at decreased speed – namely at 16th tempo, which necessitates a specific handling of the audio recording.

394 https://youtu.be/3pbprgsRuRA.

395 Evidently to the author, but it is before (or till) 1946, year of the death of Maḥmūd.

The interpretation of the results of the analysis by Praat took some time as no prior knowledge of the structure of the performance was known to the author except that it was performed in *maqām Ṣabā*.[396]

The performance starts directly with *jins ṣabā* (till 11 s_a) then with an inception of *jins ḥijāz* on $ja = f$ (14.5 s_a to approx. 19 s_a – Fig. 96). It is followed by an extended development of *jins ṣabā* till 28 s_a with a second inception of *ḥijāz* then *ṣabā* till approx. 37 s_a (Fig. 97).

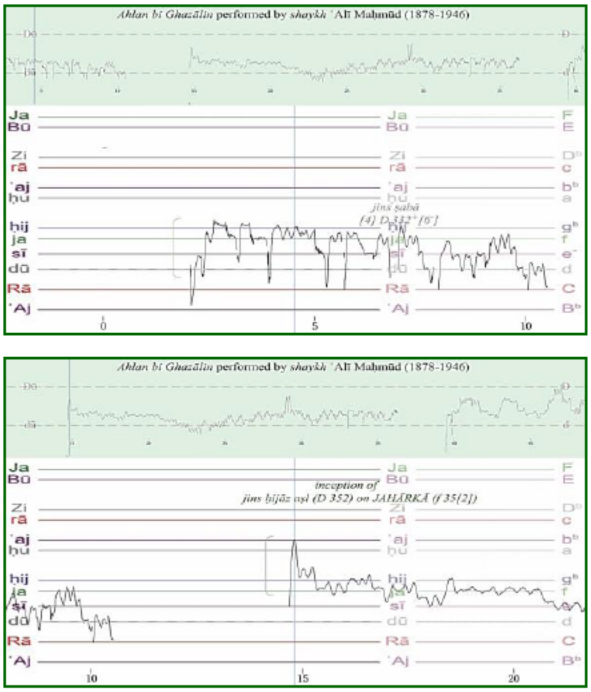


Fig. 96 Two frames from the video-animated analysis of *Ahlan bi-Ghazālin* performed by sheikh ʿAlī Maḥmūd, showing the initial *jins ṣabā* followed by *jins ḥijāz* on $ja = f$.

This is followed by the development of (what the author names) a *jins ḥijāz-mazmūm* – due to the use of somewhat "inwards" extended bordering "semi-tones" of the tetrachord – then by the inception of a *jins nahawand* on $ʿaj = b^b$ followed in descent by alternated *ḥijāz* on $ja = f$ and *ṣabā* on $dū = d$ (ending around 53.5 s_a – Fig. 98).

Having thus developed the (non-) octavial scale of *maqām Ṣabā* (Fig. 99), Maḥmūd reminds the auditor of the importance of *jins ḥijāz* (by singling it out as shown in Fig. 100 – around 60 s_a) and undertakes then a long development of *jins nahawand [4]424[4]* on *g* initiated with a leap of octave – at 64.5 s_a – between (lower) $ʿAj[am] = B^b$ and (upper) $ʿaj[am] = b^b$ (Fig. 101).[397]

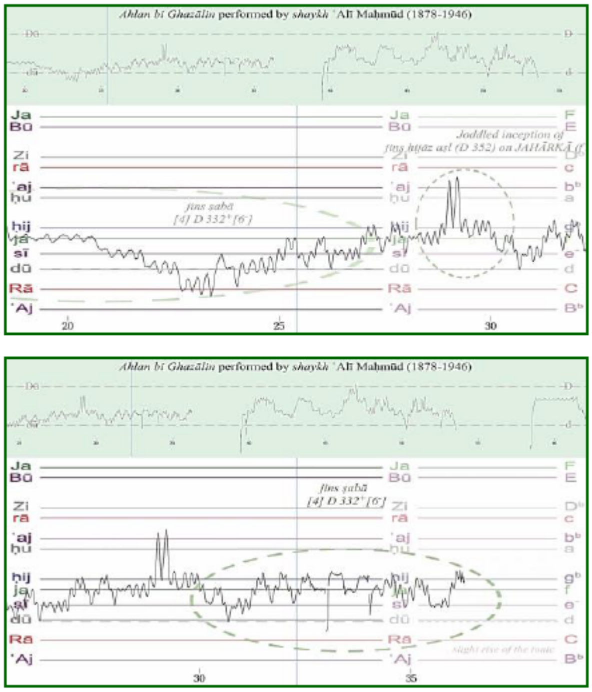


Fig. 97 Two frames from the video-animated analysis of *Ahlan bi-Ghazālin* performed by sheikh ʿAlī Maḥmūd.[398]

The next *jins ʿajam* is also initiated by a (nearly imperceptible) leap of octave between $ʿAj = B^b$ and $ʿaj = b^b$ immediately followed by a downwards leap of fifth to $ja = f$ while, between 87.5 s_a and 91 s_a, the performer uses the upper $rā = c$ as a temporary rest note paving the way to the inception of an upper *ḥijāz* on the same degree (Fig. 102) and reaching the (upper) $Ja = F$, which completes the scale of *maqām Ṣabā* as such (Fig. 103).[399]

Note that the range of the whole performance appears clearly on Fig. 102 and Fig. 103 – from (lower) $ʿAj = B^b$ to (upper) $Ja = F$ (one octave plus fifth).

[396] The author relied on a loose analysis by Rosy Beyhom for her Master Thesis in 2006 and on the help of *maqām* connoisseur and *ʿūdist* – as well as friend and Director of the department of musicology in the Music Institute of Tunis (ISM de Tunis) – Hamdi Makhlouf from Tunisia. Note however that the conclusive analysis was established by the author, which relieves both Makhlouf and (Rosy) Beyhom from any responsibility in possible errors of interpretation (analysis).

[397] Tetrachord *nahawand* ("minor") is 424, here based on *g*. The added bordering [4](s) indicate an extension of (at least) one whole tone of the tetrachord (in both directions), during the development of the *jins*, beyond its tetrachordal borders.

[398] These show the extended development of *jins ṣabā* till 28 s_a with a second inception of *ḥijāz* then *ṣabā* till approx. 37 s_a.

[399] This is further explained in the synthesis of this analysis.

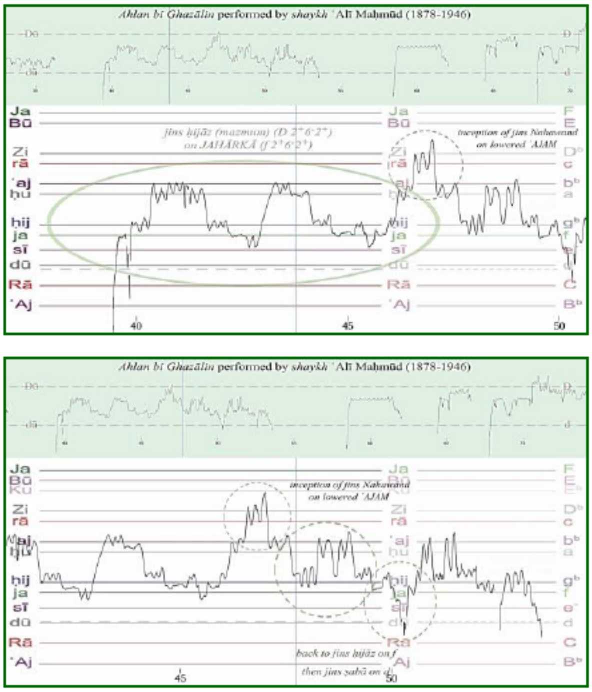


Fig. 98 Two additional frames from the video-animated analysis of *Ahlan bi-Ghazālin* performed by sheikh ʿAlī Maḥmūd.[400]

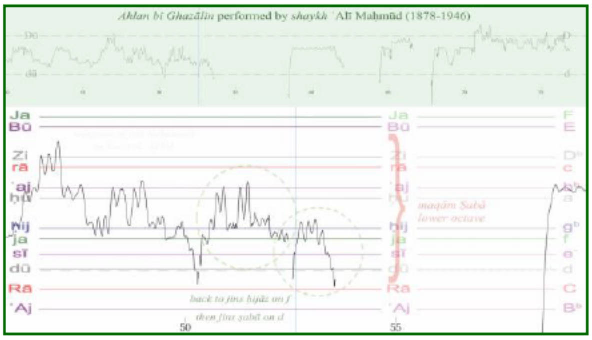


Fig. 99 Frame from the video-animated analysis of *Ahlan bi-Ghazālin* performed by sheikh ʿAlī Maḥmūd, showing the effective use of the non-octavial scale (from *dū* = *d* to *Zi* = D^b) of *maqām Ṣabā*.

This is followed (centered on 95 s_a – Fig. 103 and Fig. 104) by another double leap of (1) octave (still from *ʿAj* = B^b to *ʿaj* = b^b) then (2 –"minor") third (*ʿaj* = b^b to *Zi* = D^b) then by the complete descent of the scale till the tonic *dū* = *d* (at approx. 116.5 s_a – Fig. 104 and Fig. 105).[401]

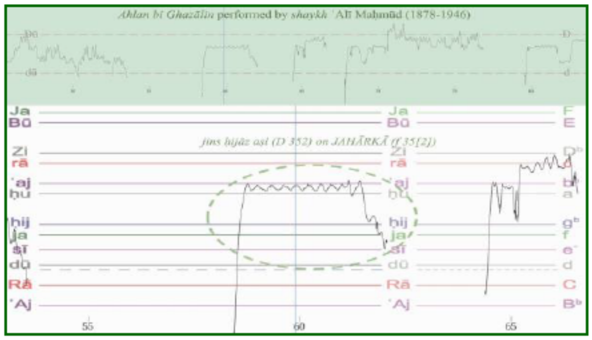


Fig. 100 Frame from the video-animated analysis of *Ahlan bi-Ghazālin* performed by sheikh ʿAlī Maḥmūd in which the performer singles out *jins ḥijāz* to remind the auditor of its importance in the performance of *maqām Ṣabā*.

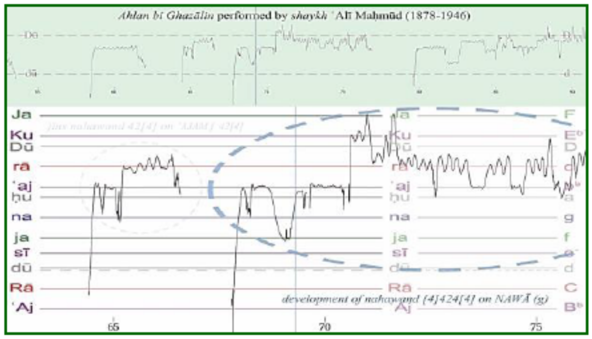


Fig. 101 Frame from the video-animated analysis of *Ahlan bi-Ghazālin* performed by sheikh ʿAlī Maḥmūd, showing a (nearly imperceptible) leap of octave.[402]

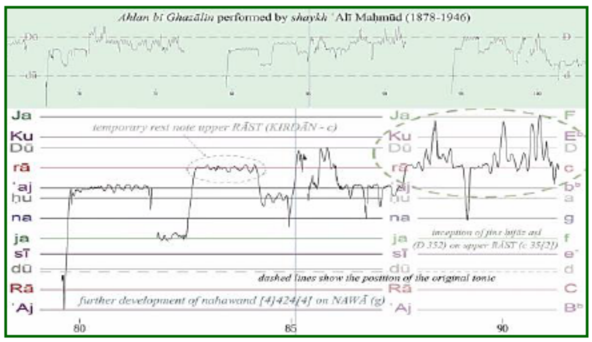


Fig. 102 Frame from the video-animated analysis of *Ahlan bi-Ghazālin* performed by sheikh ʿAlī Maḥmūd.[403]

[400] These show the development of *jins ḥijāz-mazmūm* followed by the inception of a *jins nahawand* on *ʿaj* = b^b followed in descent by alternated *ḥijāz* on *ja* = *f* then *ṣabā* on *dū* = *d*.

[401] Note the closing – near-instantaneous and descending – *jins ṣabā* (around 116 s_a) with a downwards leap of "augmented" fourth from *rā* = *c* to *ḥij* = g^b, and a "slip" below the *dū* at the end.

[402] This takes place between *ʿAj* = B^b and *ʿaj* = b^b and the beginning of the development of *jins nahawand [4]424[4]* on *g*.

[403] This frame shows the (nearly imperceptible) leap of octave between *ʿAj* = B^b and *ʿaj* = b^b followed by a downwards leap of fifth to *ja* = *f*, and the use of the upper *rā* = *c* as a temporary rest note paving the way to the inception of an upper *ḥijāz* on the same degree.

The next developments (120 s_a to 150 s_a) consist in subtle back and forths between *jins nahawand 424* on *na* = *g* and *jins ʿajam 442* on *ʿaj* = b^b (Fig. 106).[404]

A descending *nahawand* arpeggio (modulation) at 148-150 s_a, preceded by a leap of near-octave between *Rā* = *C* and *ʿaj* = b^b and by an ample *jins ʿajam* with double descent in thirds between 144 s_a and 146 s_a (Fig. 107), initiates finally the complete descent of the scale of (what the author terms) *maqām Ṣabā-Nahawand* until the tonic *dū* = *d*, with a closing slip – for this solo performance which precedes the choir performance – on *Rā* = *C* (end at 161 s_a – Fig. 108; compare with the closing *jins ṣabā* in Fig. 105).

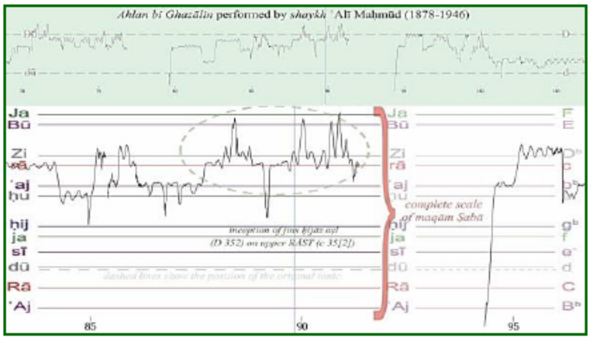


Fig. 103 Frame from the video-animated analysis of *Ahlan bi-Ghazālin* performed by sheikh ʿAlī Maḥmūd, showing the complete scale of *maqām Ṣabā*.[405]

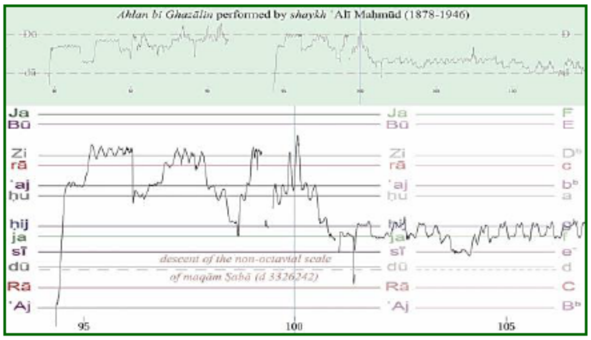


Fig. 104 Frame from the video-animated analysis of *Ahlan bi-Ghazālin* performed by sheikh ʿAlī Maḥmūd.[406]

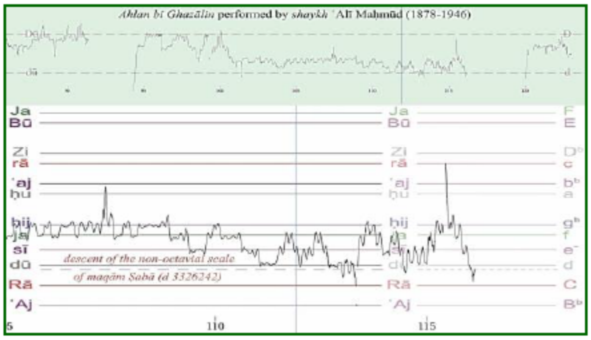


Fig. 105 Frame from the video-animated analysis of *Ahlan bi-Ghazālin* performed by sheikh ʿAlī Maḥmūd, showing the continuation of the complete descent of the scale till the tonic *dū* = *d* with the closing *jins ṣabā*.

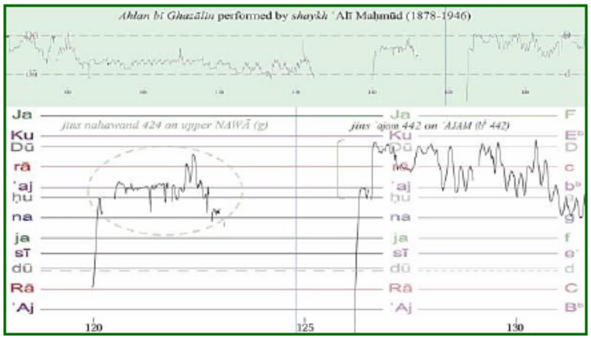


Fig. 106 Frame from the video-animated analysis of *Ahlan bi-Ghazālin* performed by sheikh ʿAlī Maḥmūd, showing the beginning of the process of back and forths between *jins nahawand 424* on *na* = *g* and *jins ʿajam 442* on *ʿaj* = b^b.

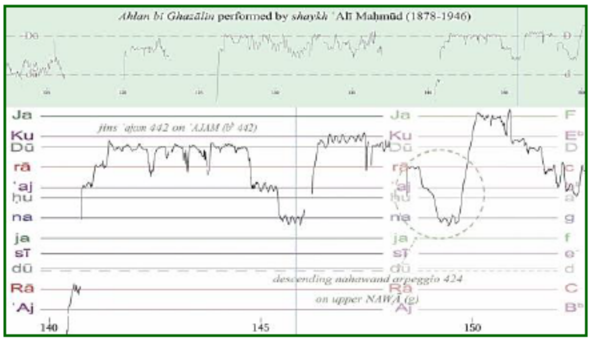


Fig. 107 Frame from the video-animated analysis of *Ahlan bi-Ghazālin* performed by sheikh ʿAlī Maḥmūd, showing the leap of near-octave between *Rā* = *C* and *ʿaj* = b^b and the descending *nahawand* arpeggio between 148 s_a and 150 s_a.

[404] The global scale (here of *nahawand on NAWĀ* or *na 424424[4]*) remains the same: the two *ajnās* are solely differentiated through the insistence on parts of this scale and formulaic turns.

[405] The scale is completed by the inception of the upper *ḥijāz* on *rā* = *c*.

[406] This frame shows the double leap of octave (from *ʿAj* = B^b to *ʿaj* = b^b) then (2–"minor") third (*ʿaj* = b^b to *Zi* = D^b) and the beginning of the complete descent of the scale till the tonic *dū* = *d*.

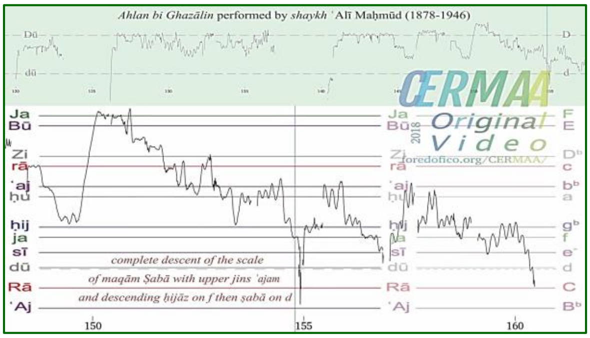


Fig. 108 Frame from the video-animated analysis of *Ahlan bi-Ghazālin* performed by sheikh ʿAlī Maḥmūd, showing the complete final descent of the scale of *maqām Ṣabā-Nahawand* until the tonic *dū* = *d*, with a closing slip on *Rā* = *C*.

***

There are many observations which can be made following this (slightly) detailed chronological analysis of the development of *Ahlan bi Ghazālin* by sheikh ʿAlī Maḥmūd.

The first observation is that "What You See Is [Not] What You Get".[407] Whenever the melodic line seems crystal clear when attentively listening to the performance and when scrutinizing in parallel – equally attentively – the sequence of events on the moving graphic, few details may seem difficult to grab – in the case of Maḥmūd and in this performance the octave (or near-octave) leaps. Repeated reviews of these excerpts are the rule, with occasional verifications of the analyst's interpretations in the half-tempo version provided with the original video-animated analysis.

The author wishes to underline here the fact that, although these characteristics of the performance were not clearly distinguishable at the beginning of the analysis (and without it), these became perceptible after the analysis when listening to the bare performance.[408]

The second observation is about the striking differences in the techniques used by this performer when compared to the techniques used by al-Ghazālī in the previous analysis, notably in what concerns the frequent use of ample leaps of octave, fifth, fourth and third by Maḥmūd whenever Al-Ghazālī, in the analyzed performance, uses mainly conjunct seconds[409] with frequent yodels of thirds and a very limited number of leaps of fourth[410].

The third observation concerns the nearly imperceptible[411] small slips from the tonic which are frequent with Maḥmūd, together with the near-instantaneous delineation of closing *jins ṣabā* as can be noted in Fig. 105: 201 and Fig. 108.

All these techniques underline the mastery of this performer and the complexity – and uniqueness – of each interpretation, far from the standardization and reduction of score notation.

Further perspectives for video-animated analyses

There remains here to answer Nettl's prediction about the future of ethnomusicological analyses of pitch, saying that "automatic analysis" did not become, at his time, as pervasive as it could have been predicted, and that it would merely be used in the future as an aid for aural transcription in western notation.[412]

While this seems to have become a self-fulfilling prophecy,[413] let us examine some facts.

Firstly: what we are dealing with here – video-animated analysis of the VIAMAP – has nothing to do with "automatic analysis": the only part that may elude the musicologist is the preliminary analysis with Praat, but this is far from being "automatized".

Secondly: before undertaking an analysis a complete survey of the musical piece is often necessary, with a preliminary analysis of the content – especially in what concerns other instruments or sounds not related to the melody as happens often in old *maqām* recordings. For the latter recordings, background noise is sometimes

[407] To paraphrase Wim Van der Meer in "What You Hear Isn't What You See…" – [Meer and Rao, 2006].

[408] This is precisely the process by which an amateur becomes a connoisseur of a certain music.

[409] Which is also the case with Maḥmūd.

[410] However, and as noted in fn. 393, even the descending leap of fourth from *na* = *g* to *dū* = *d* at approx. 52 s_a in Ghazālī's performance (central frame in Fig. 95) becomes structured by 5 different pitches when listening to the excerpt – as the author undertook for verification – in 16th tempo (16 times slower). This does not necessarily mean, though, that it was the performer's intent to perform this leap of fourth as separate pitches. Note also that such a treatment of the intervallic leaps performed by Maḥmūd was not undertaken for this dossier.

[411] But which amount to one whole tone according to the graphic analysis.

[412] [Nettl, 1983, p. 80–81].

[413] Nettl's closing argumentation for his chapter on transcription resembles a little too much to List's argumentation expounded in Part I of this dossier to exclude his total opposition to what he calls "automatic transcription".

also an issue, and may have to be reduced for Praat (or any other graphic pitch analyzer) to be able to handle the analysis properly.

Moreover, Praat provides the analyst with a mere educated guess: at some points, an octave – or fifth, octave + fifth etc. – error creates discrepancies and must be corrected – whenever possible.[414] Furthermore, some of the parameters of the program must sometimes be adapted for a particular analysis: the ear is the final judge of the pertinence of the computer analysis, and of the corrections brought by the analyst.[415]

Further improvements – such as the use of moving[416] (and different) scales according to the song or music, the type of motion and the scaling of the graphic etc. – are completely Man-made, meaning that decisions are in this process taken by the human analyst, not by the computer or the program.

Finally, in this complex process (which is an art as much as it is a science), the "automated" part is reduced to its bare bones: it is a simple basis on which the analyst constructs an interpretation of the results which reflects, eventually, his own – or his culture's – understanding of the music. However, and while this type of analysis can be as subjective as score notation, it is far more superior to it in terms of accuracy, reliability and – at least with *maqām* music – adequacy to the music culture it analyses.

So if Nettl meant by "automatic analysis" the results of the Melograph in his time, neither the analyses proposed here are automatic, nor is the graph the final result of the analysis. It is a tool, used in conjunction with other tools and means of representation in the aim of providing an integrated – and an immediately understandable by the musicologist[417] – analysis of a song or a melody.

However, and if by "automatic analysis" Nettl meant the replacement – or the adjacent use – of score notation with the graphic representation provided by tools such as the Melograph or Praat, there can be no doubt whatsoever that such representations are much more accurate, informative and convincing than score notation. Which raises the question, once again, of the misuse of this score notation for the analysis of *maqām* or other non-Western musics.

***

While it is clear that video-animated analyses, together with the handling – mainly the down-speeding – of the audio recording, provide a complete set of tools for understanding and – eventually – for teaching traditional[418] *maqām* music, one stunning observation is that this type of analyses mostly takes place in parallel to the production of the video, and that the technicalities involved in such approaches are necessitated by the analysis itself.

In other words, the amount of technological implementations in an analysis derives from the complexity and peculiarity of each analyzed song, melody or music piece. The corollary of the last statement is that one standard procedure cannot be applied to all types of performances – be they all acapella or not.[419]

Another – paradoxical – observation is that the technical knowledge involved in such analyses is far from excessive, although the use of a few different computer programs may be required at different steps of the analytical and production process.[420]

[414] Sometimes the program would not even give a hint of the possible pitch, which leaves the analyst with two choices: either to repeat the analysis with other parameters possibly more adapted to the specific song or music, or to accept the limitations of the program and proceed further on.

[415] All these steps are explained – and for some of them detailed – in aforementioned articles by the author, and were further expounded to the participants in the workshops he has directed for nearly two decades.

[416] Scales are displaced vertically "by hand": this means that it is the choice of the analyst when and how to displace them in order to follow the movement of the intervals. The computer or program has nothing to do with this process: they simply apply whatever position of the scale the analyst chooses.

[417] If he is ready to "hear" the music.

[418] And by this I mean non-westernized, non-polyphonic, non-tempered, etc. *maqām* music.

[419] One example of such differences is the different ranges of the analyzed music, as with Al-Ghazālī and Maḥmūd.

[420] This means that the amount of technicality needed to produce such video-analyses is, on the whole, surprisingly small, as it is limited to the basic understanding of the functionalities of each program needed for the said procedure. As for the programs in use, these are – until today – (1) a(ny) word processor (see https://alternativeto.net/software/libreoffice-writer/ accessed 12/07/2018 – as for all links below), (2) an(y) image editor (see https://alternativeto.net/software/krita/), (3) a versatile score maker such as MUS2 (see http://www.mus2.com.tr/en/) with an alternate possibility (see https://musescore.org/ and https://alternativeto.net/software/

The main requirement for such analyses remains, however, the understanding and the respectful approach of the music: as with the study of treatises from the past, the first assumption of the analyst must be that the author – be him a writer, a theoretician, a composer or a performer – knows what he is doing and is doing it in a certain way for a definite purpose.

It remains then for the musicologist (the "analyst") to identify the particular needs for a particular analysis of a particular musical piece. These needs determine the techniques which should be used in the analysis – which are today rather at hand for most musicologists.[421]

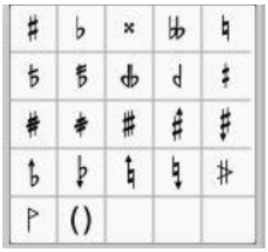
However, knowing that technical background is unfortunately far from being the first requirement for the enrolment of students – or for the teaching – in (ethno) musicology today, and that musicological requirements in many musicological institutes are limited to considering music as a science, and musicology as part of the humanities – so to say "not a science", it seems that a radical evolution in the way of understanding, teaching and promoting musicology must take place.

In what concerns the future of video-animated analyses as such, and while the scope of the VIAMAP is being slowly extended to cover other musics as *maqām*,[422] there are still a few – other – problems to be solved:

- The first – and most general – problem is the feasibility of graphic analyses of Multi-instrumental/voices music.

Although Praat and other programs allow for a limited separation of different "voices" (instruments) based on their characteristics – this being done mainly through the narrowing of the range of the analysis to fit the range of a particular instrument[423] – this solution is impractical whenever there are two or more instruments in the same range – not speaking of instruments in the same range and with similar tone-colors.[424] The author

musescore/) – which however, while proposing a rich palette of accidentals (see figure below), doesn't add non-conventional accidentals but allows for creating non-conventional key signatures.



To these first three programs we should add (4) a(ny) vector graphics editor (see https://alternativeto.net/software/vectr/), (5) an(y) audio production tool (see https://alternativeto.net/software/audacity/), (6) Praat (see http://www.fon.hum.uva.nl/praat/), (7) a video editor (see https://alternativeto.net/software/kdenlive/), (8) a(ny) digital visual effects, motion graphics, and compositing program (see https://alternativeto.net/software/audacity/) and (9) possibly a(ny) computer program for music production/recording with support for VST plugins (see https://alternativeto.net/software/lmms/). Note that while the author aims at not publicizing particular programs, the choice of Praat is expounded in this dossier and in previous – aforementioned – publications; as for MUS2, its low cost and its value for money is unmatched – including for the purpose of the video-analyses expounded in this dossier – from the point of view of the author since he first began to use it in the 2000s. This makes these two programs at least advisable although alternatives exist both as freeware and as commercial programs.

421 Technical difficulties can always be overcome as online help is ubiquitous today in the internet or – as in the famous song – "With a little help from my friends". In the case of the author initial help came willingly from Wim van der Meer and from Kabalan Samaha, a musician and graphic designer in Lebanon.

422 A new series of video-analyses was for example initiated for Breton music (Brittany – France) with the audio fund *DASTUM*, starting with the traditional song *Ar bern plouz* by Manu Kerjean, with two analyses up to date – numbered 1-2 – published at http://foredofico.org/CERMAA/analyses/breton-music, and featuring a third-tempo analysis:

1. "Ar bern plouz" chanté par Manu Kerjean à Bonen (22) éd. Dastum: *Manu Kerjean Chanteur du Centre-Bretagne* DAS153 (piste 15); uploaded 11/10/2018: https://youtu.be/IlERM9mEw9g [Beyhom, 2018an]
2. "Ar bern plouz" chanté par Manu Kerjean à Bonen (22) éd. Dastum: *Manu Kerjean Chanteur du Centre-Bretagne* DAS153 (piste 15 – Tempo = 1 :3); uploaded 11/10/2018: https://youtu.be/oslJy0P_snU [Beyhom, 2018ao]

To differentiate these analyses from other analyses by CERMAA which are more *Maqām*-oriented, the background and lettering colors have been changed to blue(ish) and yellow(ish), and the cursors colors to tones of red. Other analyses are underway for solo instruments and include for example graphs of the intensity of the sound in parallel to the graph of the pitch.

423 For example with two instruments playing an octave – or more – apart, provided that their ranges do not overlap; or for two instruments with a rather important difference in acoustic intensity, which allows also to filter some of the input.

424 While this is a technical question, note that instruments with resembling spectrums of sound (tone-colors) – such as the instruments of the symphonic orchestra – are the most difficult to differentiate one from another (unless by their range), and typically with mechanical or electronic means as explained in [Plomp, 2002, p. 12]: "The ear distinguishes between frequency components originating from different sound sources, as opposed to components from the same source. It separates out components according to the first category, but not the second. This calls for an extremely sophisticated process, exceeding by far the performance of any frequency analyzer designed for acoustical research, in that auditory perception involves *synthesis* as well as analysis".

hopes that further developments of pitch-measuring programs and sound-analysis softwares will allow for this type of analysis in the near future.[425]

- **In the case of multi-vertical space musics (with different registers of voices and/or instruments), a graphical solution must be found to show both (or more) instruments on the same video.[426]**

This is a technical complication that could be solved by integrating the different ranges in one pane, by changing the colors of the graphic analysis for each instrument, and by adding a visual marker for the range of each instrument.[427]

- **Video-analyses, although not complex technically, still require the practice of different programs that aren't necessarily connected between them, and which for most of them aren't even connected directly with pitch analysis of music.[428] This will still prevent students – especially those having no or seldom technical background – from taking interest in undertaking such analyses.**

Although workshops and training courses can be – and are – proposed to teach (ethno) musicologists to undertake a preliminary analysis of the music, then prepare the subsidiary tools for the video-analysis and put them together before editing the video as such, this is an unsatisfactory solution in the long run. The ideal solution would be to create (build, program) an integrated tool (computer program) which would help making such video-animated analyses a standard tool in ethnomusicology and in autochthonous *maqām* musicologies.[429]

Conclusions

Musicology as we know it today is probably the most conservative humanity in the world – be it for musicology itself or for ethnomusicology.[430] One first error of Western musicology was to consider score notation as a scientific tools for the analysis of music. One main second error was the use of this tool for the analysis of "Foreign" musics.

Whenever classical musicology may continue to go round in the same vicious circle, ethnomusicology cannot evolve without resolving its original sin, its inability to understand foreign musics otherwise than by examining them through the lens of Western notation and Pythagorean pseudo-science.

If we refer to Nettl's discussion of the problem of aural perception *versus* graphic analysis of music:

> "one of the issues [of graphic analysis of music] may be the degree to which the kind of distinctions that [we] could draw can be heard by the human ear. There is the typical dilemma: If the distinctions can be made by ear, why does one need the

[425] At a conference in Paris in the beginning of the 2000s, Simha Arom declared that scientists and programmers with which he worked were on the brink of succeeding at such analyses. Alas! I have never heard of such developments since, which could be caused by our present inability to reproduce the process of synthesis of the ear (see previous footnote).

[426] By this is intended live recorded music, and not only separately recorded instruments mixed together in a studio.

[427] A prototype of such an analysis is being prepared as this article is being edited for publication.

[428] The most striking example being Praat which is a program intended for phonetics, and not for music analysis.

[429] Wim van der Meer raised here two noteworthy questions (personal communication): "One thing that crossed my mind is the relation between the x and y axes. After all, this is something totally arbitrary, we can compress the melodic line in time or expand it. This is another aspect of how we see what we hear. [On the other hand,] [m]any people, including the musicians we worked with, had problems with the jittery melodic lines, where they would expect them to be more smooth—or if you like, because they hear them more smoothly. To this day I am not entirely certain about the jittery appearance of melodic lines. What happens there? Is it really there and do we smooth it out in the ear or the brain? Or is it an artifact of the computer?". The first question (about shrinking and expanding melodic lines with seemingly the same intervals – a frequent case in traditional acapella singing for example) can be solved by shrinking and expanding the scale accordingly (a technical – and practical – way for doing so while keeping trace of the original scale is still to be determined). As for the second question, different parameters (variables) can intervene in the process of jittering (be it as the result of our perception or because of the programming algorithms or their implementation): I have yet – as with Wim – no definite answer to this question.

[430] While there has been some progress in the analysis of "Foreign" musics since Hornbostel and Abrahams (and with them for the use of recorded music in comparative musicology), these advances are still limited to few specialized individuals. The discipline as such, as noted by Hood commenting the dismantling of Seeger's Melograph C, is still going in circles in what concerns graphic analysis of pitch and its further developments. Note also that while other aspects of analysis (paradigmatic, "sequencing", synoptic analyses) have also been developed, there has not been an effective (and generalized) further questioning of the role of score notation in ethnomusicology.

> melograph? And if not, are we justified in assigning significance to them?”[431],

the answer to this dilemma is simple: if one cannot “hear”, this occurs mainly because one has not trained his ears to hear subtleties or nuances of the melody – or did not wish to do so.[432]

However, and while our hearing is impaired by decades – if not centuries – of aural indoctrination, we are compelled to use a hearing aid in order to understand – and eventually learn to hear – these subtleties, which are an integral part of the art of the *maqām*, and of other musics around the world.[433]

While this is a question debated for centuries in Western music,[434] the persistent doubts of ethnomusicology, and its reluctance – if not its inability – to break away from its musicological womb and score notation have crippled the discipline on the long term.

It is vital today for both ethnomusicology and autochthonous musicologies to cut the umbilical cord with musicology.

In order to do so, even more effective replacement methods of analysis must be created to supersede it.[435]

Far from proposing a musicological “Atlanta compromise”, the author believes in the necessity of such an alternate way of understanding and analyzing autochthonous musics, to which the present dossier aims to be a contribution, a further stone for the foundation of an alternate analytical musicology which could be (or become) part of what Meer calls Cultural musicology.[436]

* * *

431 [Nettl, 1983, p. 80].

432 Nettl’s remarks – and commitment to score analysis – become even more surprising when remembering that he was a specialist of Iranian music – one of the main subdivisions of *maqām* music. It is also worthwhile here to remind of Cook’s reflection on the role of music education in the training of the hearing of musicians (and musicologists?) quoted in the conclusions of Part I of this dossier.

433 In a private communication, Wim van der Meer explained: “when we hear things in slowed down mode that we don’t hear in normal speed there may be a Nettl question raised. On the other hand, I am convinced that the musical mind of top musicians works 5 times faster and more accurate than that of the average listener and up to 10 times faster than that of the average ethnomusicologist”.

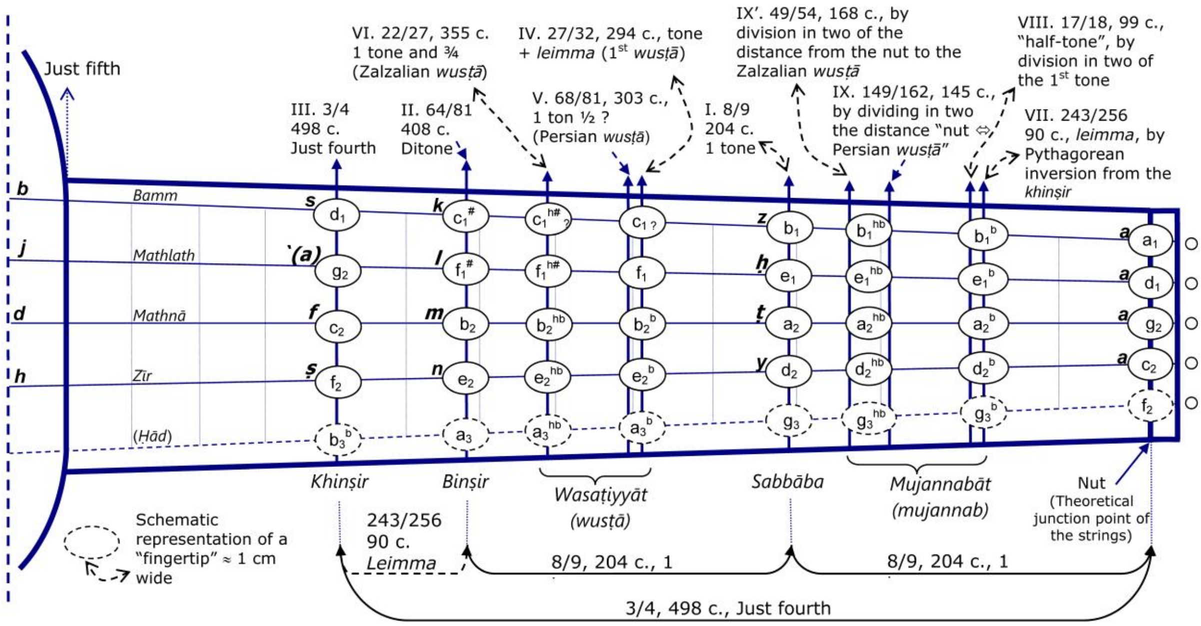
434 Remember Rousseau: “In order to put the Reader in a position to judge the various musical Accents of Peoples, I have transcribed a Chinese Tune taken from Father du Halde, a Persian Tune taken from the Chevalier Chardin, and two Chansons of the American Savages taken from Father Mersenne. A conformity of Modulation with our Music will be found in all these pieces which will possibly make some admire the goodness and universality of our rules, and for others will perhaps render suspect the intelligence or the fidelity of those who have transmitted these Tunes to us. (As translated in [Rousseau and Scott, 1998, p. 444–445] and quoted in [Meer and Erickson, R., 2014, p. 19].)

435 The first stage of renovation is always a stage of critique – of deconstruction – while the second stage of a successful reconstruction is to provide tools for it. We may compare the situation of autochthonous musicologies today with the situation of the former slaves in the south of the United States in the Post-Civil war period – in the former Confederacy: The post- (American) Civil war Reconstruction was a failure because, while civil and political rights were formally granted to the Freedmen, no effective alternative was proposed to integrate them economically. Giving *maqām* and others non-western musics their “political and civil rights” – the right to be considered as equals to western music or, as with ethnomusicology, the right to be considered as different from western music – without providing these musics with effective tools for their analysis would be another way for (ethno) musicology to postpone a necessary reevaluation of its methods, and another way to keep autochthonous musicologies under its influence. Needless to say, the first task of autochthonous musicologies today should be to find, and found, these alternate tools of analysis.

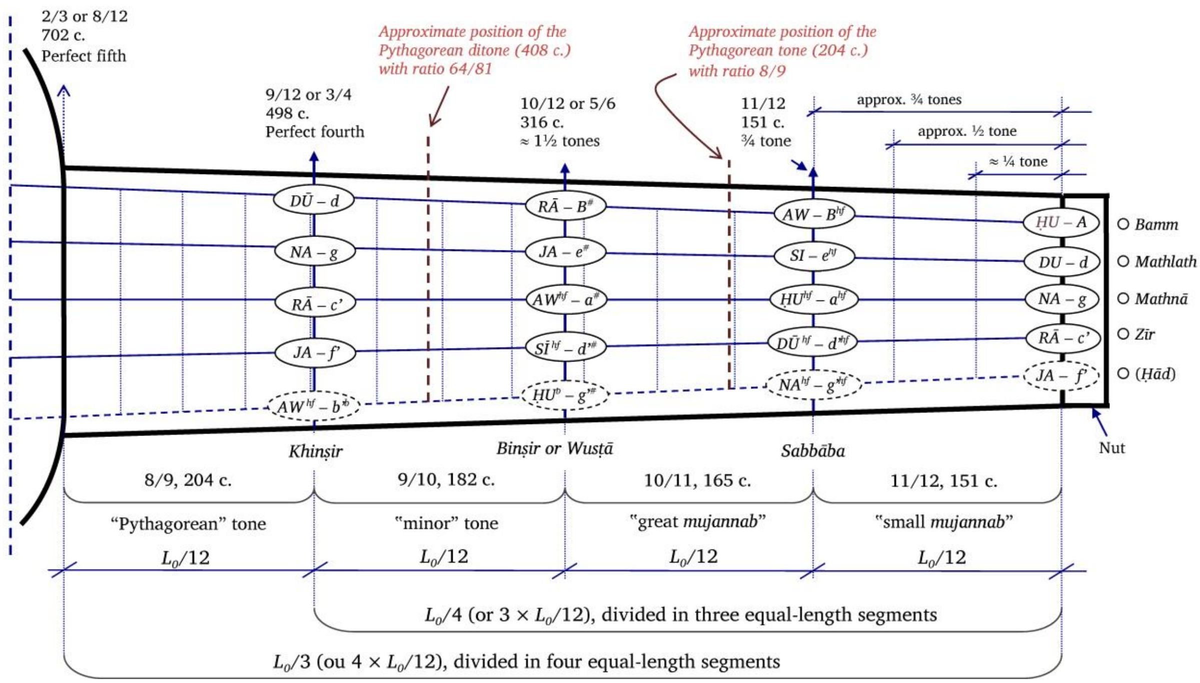
436 See the discussion of the definition of “Cultural musicology” in [Meer and Erickson, R., 2014], notably the characterization of Cultural musicology as the “the cultural analysis of music” [p. 20]. Note also: “music has unique powers as an agent of ideology. We need to understand its working, its charms, both to protect ourselves against them and, paradoxically, to enjoy them to the full. And in order to do that, we need to be able not just to hear music but to *read* it too: not in literal, notational terms, to be sure, but for its significance as an intrinsic part of culture, of society, of you and me” – [Cook, 2000, p. 129].

Plates

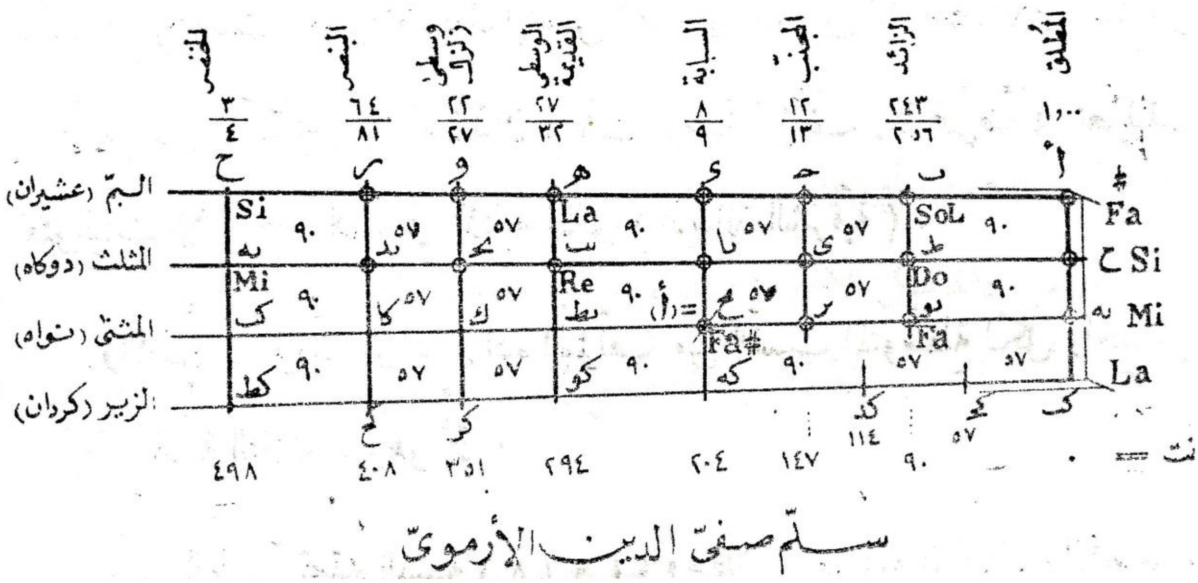
FHT 1 “A hand-drawn *lubok* featuring ‘hook and banner notation’ ” – from [Wikipedia Contributors, 2017b] (source file https://en.wikipedia.org/wiki/File:Kryuki.jpg) as an example of modified Byzantine (diastematic) notation.



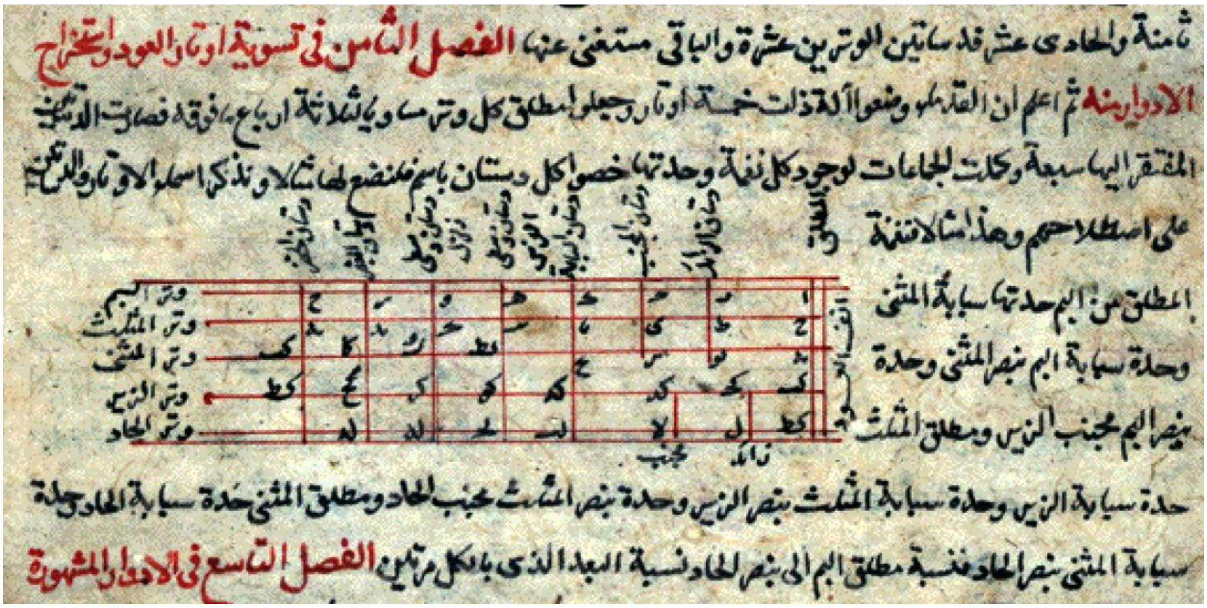
FHT 2 Fārābī's sequential construction in the *Kitāb al-Mūsīqī al-Kabīr* of the meshing of the fingerboard of the *ʿūd* using the *Abjad* alphabet (bold letters) for key notes – "h#" and "hb" are, respectively, "half-sharp" and "half-flat" accidentals in approximate quarter-tones. The column of letters to the utmost left corresponds to the junctions of the strings with the tailpiece, the right column (bold "***a***"s) reminds that the strings make their (theoretical) junction on the nut; the fifth (*Ḥād*) string is theoretical – adapted and translated from [Beyhom, 2010c, v. 1, p. 205 (Figure 75)].



FHT 3 Division of the fingerboard of the *ʿūd* on a 12 equal string-parts basis using the solmization proposed by the author. "*hf*" stands for "half-flat" – adapted from [Beyhom, 2012, p. 72 (Fig. 14)].



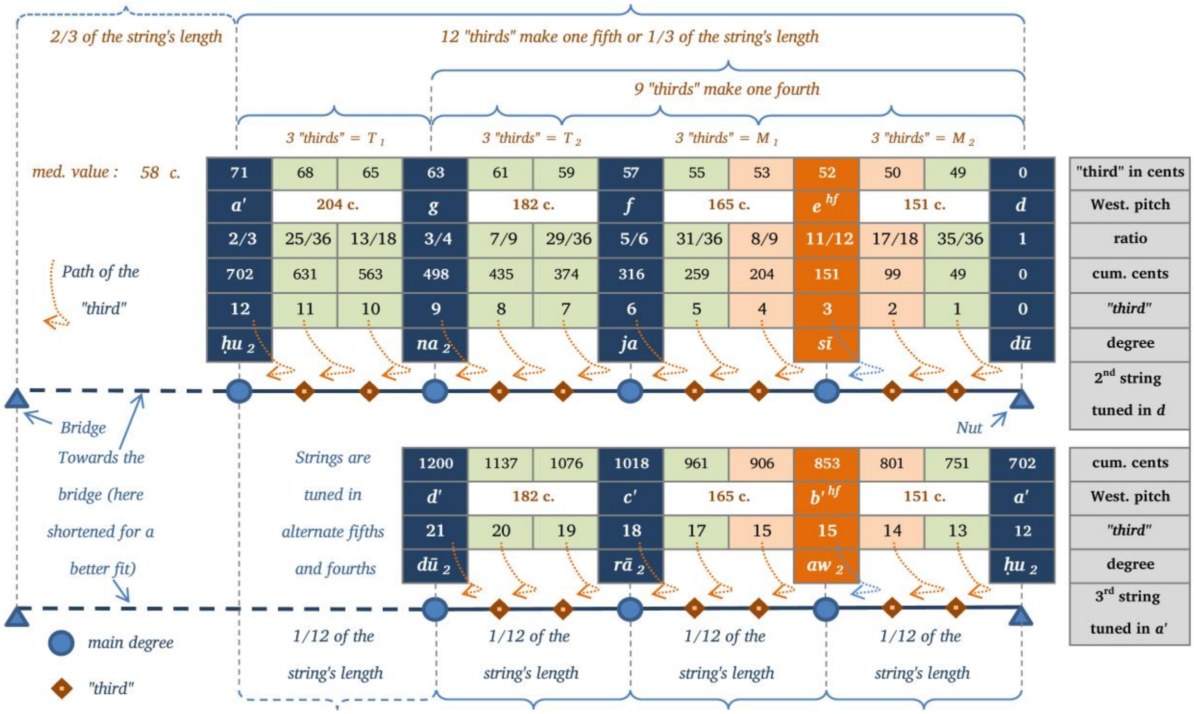
FHT 4 Use of the *Abjad* alphabet by Ṣafiyy-a-d-Dīn al-Urmawī in his description of the scale as proposed in [الأرموي, 1986, p. 44].



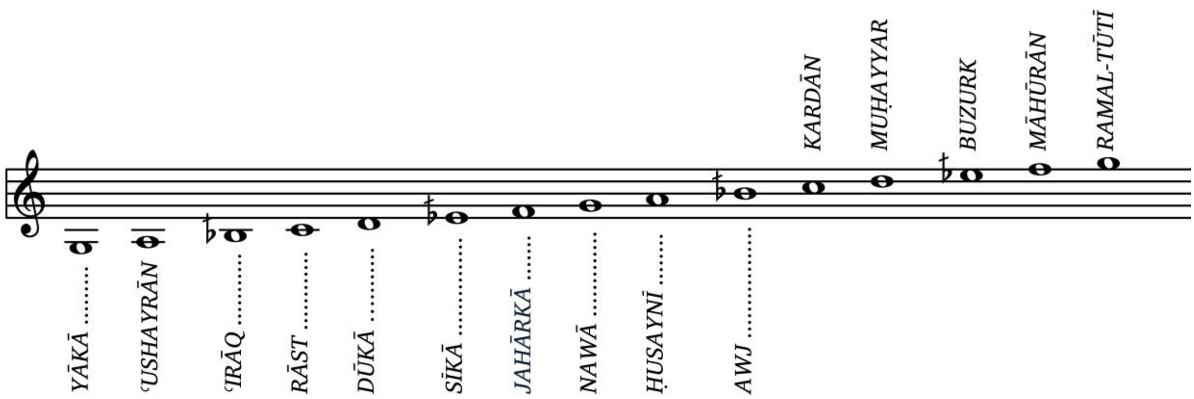
FHT 5 *Abjad* tablature in [Urmawī (d. 1294), 2001, p. 14].

Intervallic notations

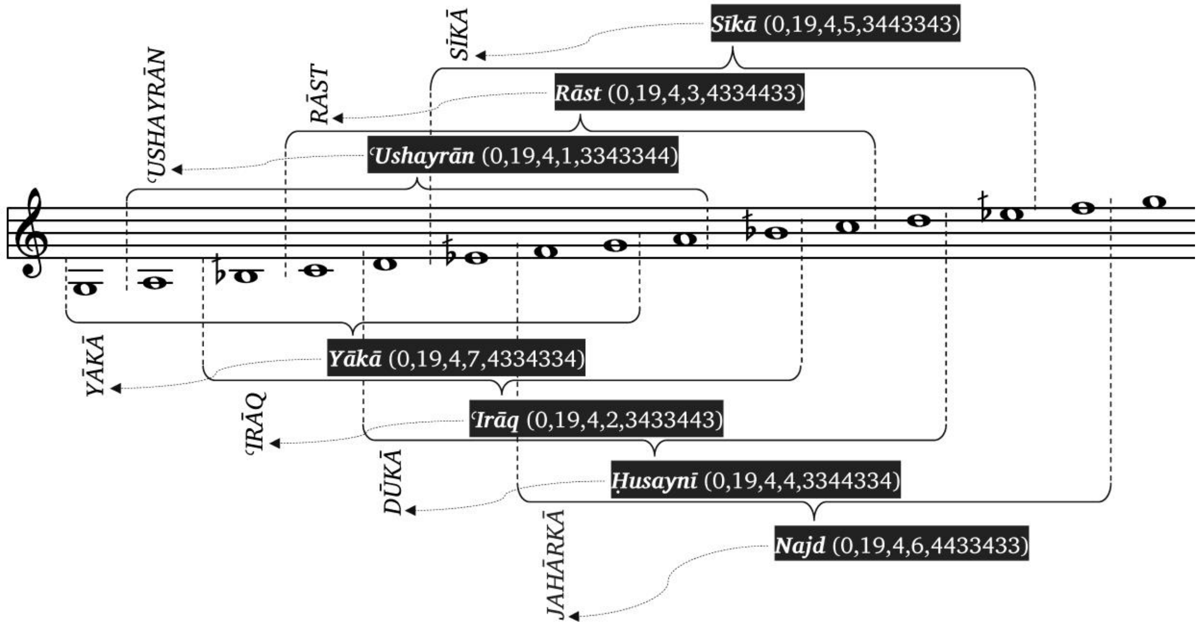
FHT 6 Intervallic representation of polychords in [Urmawī (d. 1294), 2001, p. 6]. The theoretical scale of Urmawī is based on a division of the octave in 17 *leimmata* and *commata*, with a whole tone *T* composed of two *leimmata* + one *comma*, and two "neutral" second ("medium tones") which can be either composed of two successive *leimmata* (M_1), or of one *leimma* + one *comma* (M_2).



FHT 7 Scale of the pseudo-Ṣafadī in the hypothesis of an equal-strings division on a *ṭunbūr* tuned in alternate fifths and fourths.



FHT 8 Arabian quarter-tone bi-octavial notation of the main scale of *maqām* music (mode *Rāst* with – exclusively – adjacent "whole-tones" and "three-quarter-tones" intervals) with usual names of the degrees.



FHT 9 Main sections (octavial scales) of the Arabian quarter-tone division of the bi-octave with corresponding *maqāmāt* and classification in *Modal Systematics*.[437]

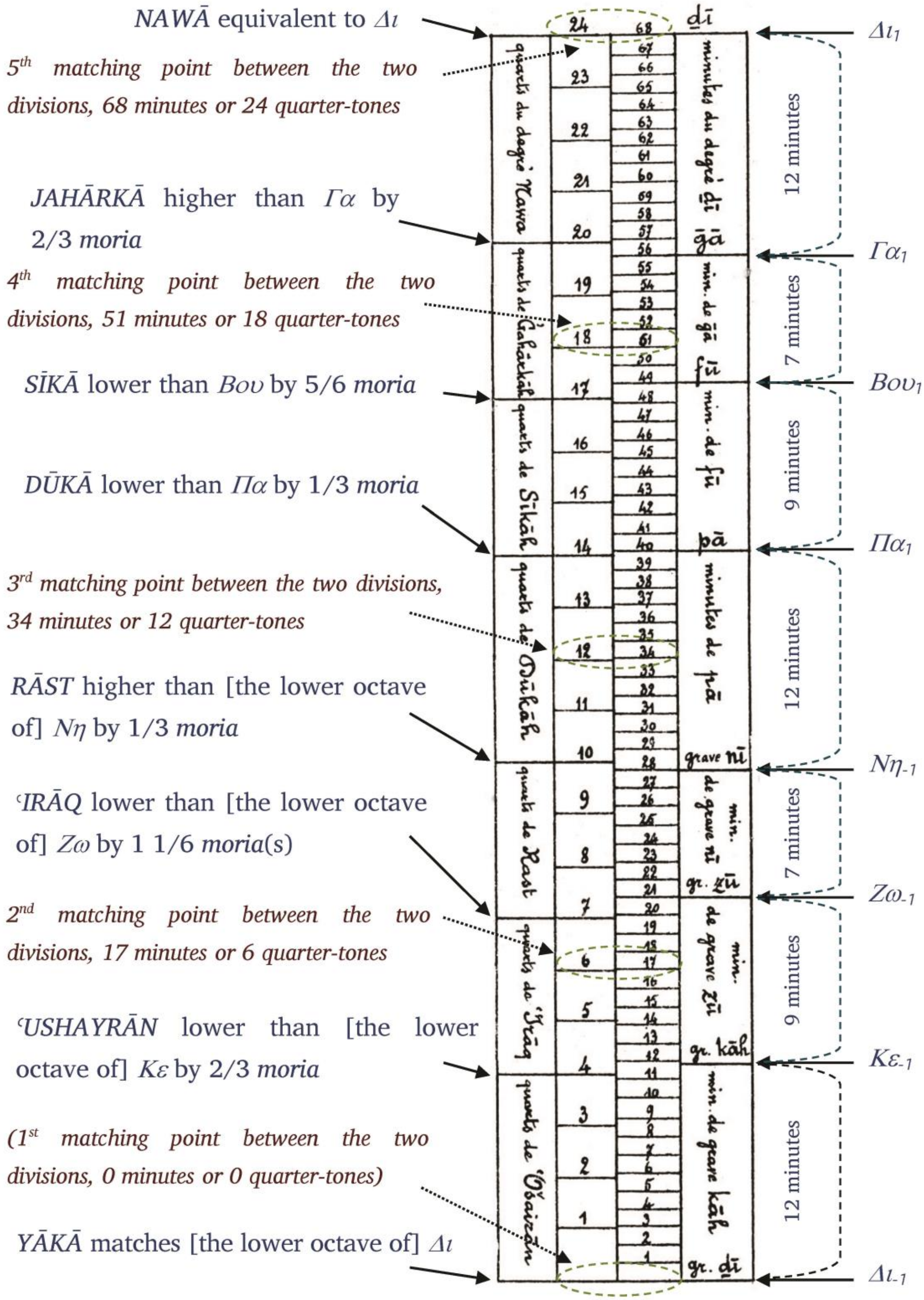
68 (Byz.) / 24 (Ar.)		g_1		a_1		b_1^{-}		c_1		d_1		e_1^{-}		f_1		g_2
"Byzantine" Division	Minutes		12		9		7		12		9		7		12	
	Cents		212		159		124		212		159		124		212	
	Total in cents	0		212		371		494		706		865		988		1200
"Arabian" Division	Quarter-tones		4		3		3		4		3		3		4	
	Cents		200		150		150		200		150		150		200	
	Total in cents	0		200		350		500		700		850		1000		1200
Difference in cents	Interval		**-12**		**-9**		**26**		**-12**		**-9**		**26**		**-12**	
	Note	**0**		**-12**		**-21**		**6**		**-6**		**-15**		**12**		**0**

FHT 10 Comparing the intervals of the "Greek scale" (of Chrysanthos – assuming equality between the 68 divisions of the octave – which is not the correct interpretation) and the intervals of the scale in equal quarter-tones embedded by the *Congrès du Caire* of 1932, for a *diatonic* (Byzantine) scale from g_1 to its octave (g_2) supposedly equivalent to the scale of *maqām Yākā* in Arabian music: the degrees of the two scales do not coincide except for the trivial cases of the unison and the octave.

72 (Byz.) / 24 (Ar.)		*sol*		*la*		*si-*		*do*		*ré*		*mi-*		*fa*		*sol*
Partition "grecque"	*Minutes*		12		10		8		12		10		8		12	
	Cents		200		167		133		200		167		133		200	
	Total en cents	0		200		367		500		700		867		1000		1200
Partition "arabe"	"Quarts"		4		3		3		4		3		3		4	
	Cents		200		150		150		200		150		150		200	
	Total en cents	0		200		350		500		700		850		1000		1200
Différence en cents	Intervalle		**0**		**-17**		**17**		**0**		**-17**		**17**		**0**	
	Note	**0**		**0**		**-17**		**0**		**0**		**-17**		**0**		**0**

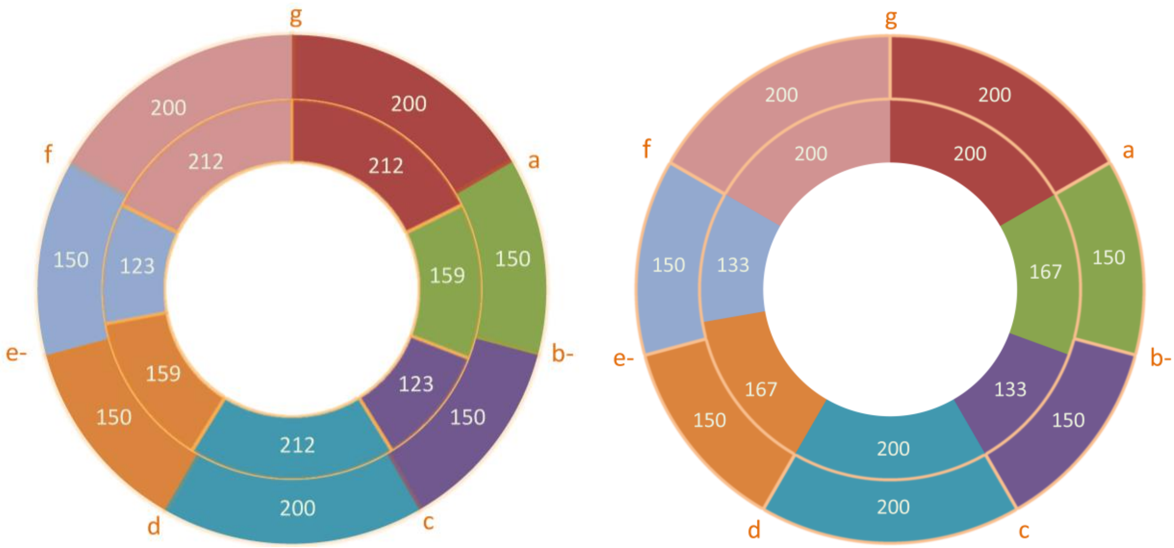
FHT 11 Comparing the intervals of the "Greek scale" (2nd Byzantine Reform of the 19th century) and the intervals of the scale in equal quarter-tones embedded by the *Congrès du Caire* of 1932, for a *diatonic* (Byzantine) scale from g_1 to its octave (g_2) supposedly equivalent to the scale of *maqām Yākā* in Arabian music: the two scales differ only by one *minute* (*moria* or one twelfth of the tone) for the degrees *si*˙ et *mi*˙ (*ʿIRĀQ* and *SĪKĀ* in Arabian music). Note that the 2nd Reform scale is based, in practice, on minimal steps in sixths of the tone which makes this difference ineffective. (See FHT 10 above for English equivalences.)

[437] Beginning degree for each mode added vertically, with *Modal Systematics* classification between brackets. (See [Beyhom, 2003a ; 2003c ; 2003d ; 2004 ; 2010a ; 2018ap] for more details on the *Modal Systematics* theory).

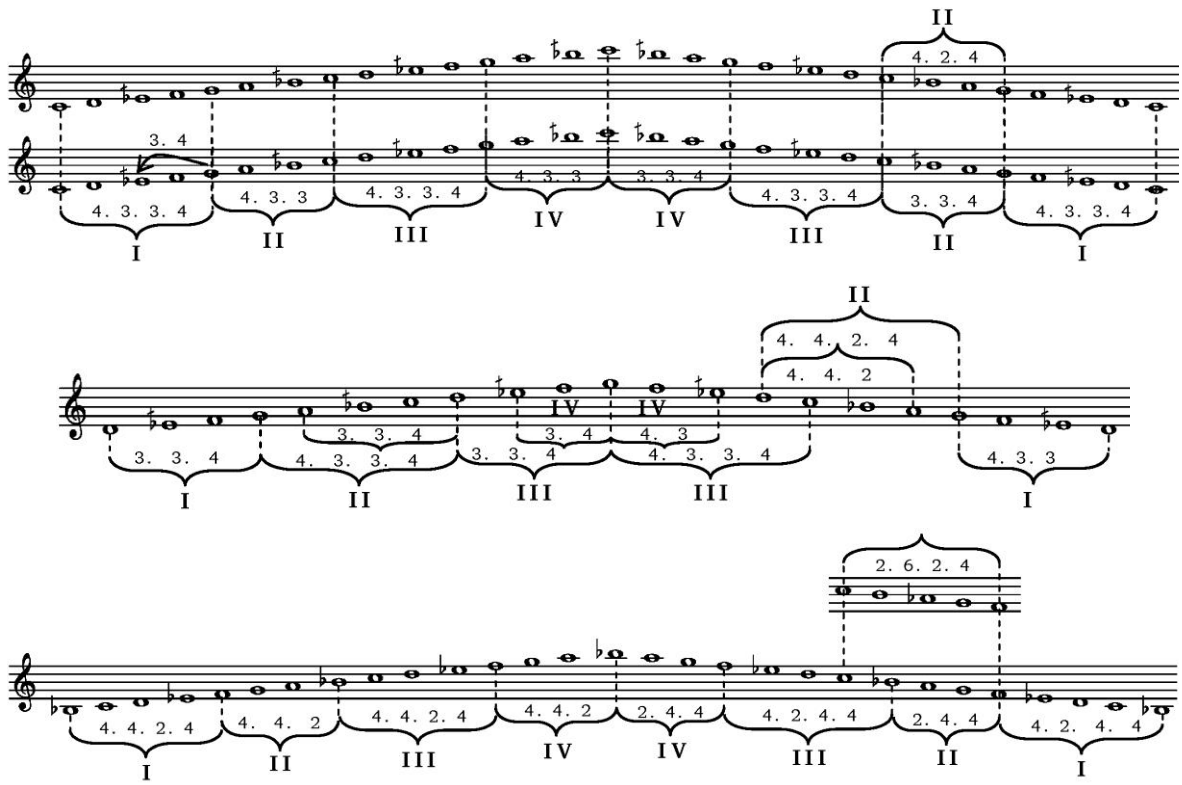


FHT 12 Mashāqa's diagram (here in Ronzevalle's French translation with added comments by the author) showing the discrepancies between the intervals of the "Greek scale" (of Chrysanthos – assuming equality between the 68 divisions of the octave – which is not the correct interpretation) and the scale in equal quarter-tones.[438]

[438] [Mashāqa, 1913, detail from Plate I between p. 14 and 15]: subscript indices in the comments show the octave position with "1" corresponding to the main octave and "-1" to the lower octave.



FHT 13 "Doughnut" versions of the comparisons in FHT 10 and FHT 11, with the "Arabian quarter-tone scale" shown in the outer rim. Chrysanthos diatonic division based on 68 "equal-*moria*" to the left, 2nd Reform intervals based on "sixths-of-the-tones" to the right.[439]



FHT 14 Scale and polychordal structure (with alternate formulations) – according to Erlanger – of, from top to bottom, *maqām Rāst, maqām Ḥawzī* and *maqām ʿAjam-ʿUshayrān*.[440]

[439] While cyclic representations of scales are easier to decipher for such comparisons, it must be however reminded here that cyclic scales do not apply for the majority of *maqām* musics as these musics are mostly non-octavial.

[440] "Transnotated" and adapted from [Erlanger, 1949, v. 5, p. 178, 238 and 148]. Previously published as figures 189, 192 and 195 in [Beyhom, 2015, p. 233, 235 and 239].

ROOT TETRACHORD	STEM TETRACHORD: MAJOR			HIGAZ			RAST		
MAJOR	MAJOR / MAJOR			MAJOR / HIGAZ			MAJOR / RAST		
	4 4 2 4 4 4 2	Tib	A. OSHAIRAN	4 4 2 4 2 6 2	Tib	SHOK AFZA	4 4 2 4 4 3 3		
	4 2 4 4 4 2 4			4 2 4 2 6 2 4			4 2 4 4 3 3 4		
	2 4 4 4 2 4 4	Do	KURD	2 4 2 6 2 4 4			2 4 4 3 3 4 4		
	4 4 4 2 4 4 2			4 2 6 2 4 4 2			4 4 3 3 4 4 2		
	4 4 2 4 4 2 4			2 6 2 4 4 2 4	Re	HIGAZ	4 3 3 4 4 2 4	Do	SUZDLAR
	4 2 4 4 2 4 4	So	FARA FAZA	6 2 4 4 2 4 2			3 3 4 4 2 4 4		
	2 4 4 2 4 4 4			2 4 4 2 4 2 6			3 4 4 2 4 4 3		
MINOR	MINOR / MAJOR			MINOR / HIGAZ			MINOR / RAST		
	4 2 4 4 4 4 2			4 2 4 4 2 6 2	Do	NAHAWAND	4 2 4 4 4 3 3		
	2 4 4 4 4 2 4			2 4 4 2 6 2 4			2 4 4 4 3 3 4		
	4 4 4 4 2 4 2			4 4 2 6 2 4 2			4 4 4 3 3 4 2		
	4 4 4 2 4 2 4			4 2 6 2 4 2 4			4 4 3 3 4 2 4		
	4 4 2 4 2 4 4			2 6 2 4 2 4 4	Re	NAKRIZ	4 3 3 4 2 4 4		
	4 2 4 2 4 4 4			6 2 4 2 4 4 2			3 3 4 2 4 4 4		
	2 4 2 4 4 4 4			2 4 2 4 4 2 6			3 4 2 4 4 4 3		
HIGAZ	HIGAZ / MAJOR			HIGAZ / HIGAZ			HIGAZ / RAST		
	2 6 2 4 4 4 2			2 6 2 4 2 6 2	So	HIGAZ KAR	2 6 2 4 4 3 3		
	6 2 4 4 4 2 2			6 2 4 2 6 2 2			6 2 4 4 3 3 2		
	2 4 4 4 2 2 6			2 4 2 6 2 2 6			2 4 4 3 3 2 6		
	4 4 4 2 2 6 2			4 2 6 2 2 6 2	Re	NAWA ATHER	4 4 3 3 2 6 2		
	4 4 2 2 6 2 4			2 6 2 2 6 2 4	Me	HISAR	4 3 3 2 6 2 4		
	4 2 2 6 2 4 4			6 2 2 6 2 4 2			3 3 2 6 2 4 4	Re	SABA
	2 2 6 2 4 4 4			2 2 6 2 4 2 6			3 2 6 2 4 4 3		
RAST	RAST / MAJOR			RAST / HIGAZ			RAST / RAST		
	4 3 3 4 4 4 2	Do	MAHOR	4 3 3 4 2 6 2	Do	SUZNAK	4 3 3 4 4 3 3	Do	RAST
	3 3 4 4 4 2 4	Re	BAYATI	3 3 4 2 6 2 4	Re	B ASHORY	3 3 4 4 3 3 4	Re	HUSSEINI
	3 4 4 4 2 4 3			3 4 2 6 2 4 3	Me	HUZAM	3 4 4 3 3 4 3	Mb'	SIKA
	4 4 4 2 4 3 3			4 2 6 2 4 3 3			4 4 3 3 4 3 3	Fa	GIHARKA
	4 4 2 4 3 3 4			2 6 2 4 3 3 4			4 3 3 4 3 3 4	So	YEKAH
	4 2 4 3 3 4 4			6 2 4 3 3 4 2			3 3 4 3 3 4 4	La	H OSHAIRAN
	2 4 3 3 4 4 4			2 4 3 3 4 2 6			3 4 3 3 4 4 3	Tb'	IRAQ

TABLE 6: THE MOST POPULAR ARABIC MAQAMAT LOCATED IN THE HERMETIC MATRIX OF ARABIC MAQAMAT (THE NOTE TO THE LIFT OF EACH MAQAM IS THE TONIC

FHT 15 Matrices resulting from the combination of “Arabian” tetrachords expressed in multiples of the quarter-tone.[441]

hyper n° 12 ; val.: 2 2 4 4 4 4 4

sys.: 3 ; 5tes: 12 ; 4tes 12 ; D_QQ 9

(0; 12; 1; 2 2 4 4 4 4 4) ; 5te = 2; 4te = 2; D_QQ = 1; Umin = non; Min = oui; Max = non
00 sous-système n° 1 ; valeur: 2 2 4 4 4 4 4 ; 5te = non ; 4te = non ; D_QQ = non ; Umin = non ; min = oui ; Max = non ; M347 = non
00 sous-système n° 2 ; valeur: 2 4 4 4 4 4 2 ; 5te = oui ; 4te = oui ; D_QQ = oui ; Umin = non ; min = oui ; Max = non ; M347 = oui
00 sous-système n° 3 ; valeur: 4 4 4 4 4 2 2 ; 5te = non ; 4te = non ; D_QQ = non ; Umin = non ; min = oui ; Max = non ; M347 = non
00 sous-système n° 4 ; valeur: 4 4 4 4 2 2 4 ; 5te = non ; 4te = non ; D_QQ = non ; Umin = non ; min = oui ; Max = non ; M347 = non
00 sous-système n° 5 ; valeur: 4 4 4 2 2 4 4 ; 5te = oui ; 4te = non ; D_QQ = non ; Umin = non ; min = oui ; Max = non ; M347 = oui
00 sous-système n° 6 ; valeur: 4 4 2 2 4 4 4 ; 5te = non ; 4te = oui ; D_QQ = non ; Umin = non ; min = oui ; Max = non ; M347 = oui
00 sous-système n° 7 ; valeur: 4 2 2 4 4 4 4 ; 5te = non ; 4te = non ; D_QQ = non ; Umin = non ; min = oui ; Max = non ; M347 = non

(0; 12; 2; 2 4 2 4 4 4 4) ; 5te = 4; 4te = 4; D_QQ = 3; Umin = non; Min = non; Max = non
00 sous-système n° 1 ; valeur: 2 4 2 4 4 4 4 ; 5te = non ; 4te = non ; D_QQ = non ; Umin = non ; min = non ; Max = non ; M347 = non
11 sous-système n° 2 ; valeur: 4 2 4 4 4 4 2 ; 5te = oui ; 4te = oui ; D_QQ = oui ; Umin = non ; min = non ; Max = non ; M347 = non
00 sous-système n° 3 ; valeur: 2 4 4 4 4 2 4 ; 5te = oui ; 4te = oui ; D_QQ = oui ; Umin = non ; min = non ; Max = non ; M347 = non
00 sous-système n° 4 ; valeur: 4 4 4 4 2 4 2 ; 5te = non ; 4te = non ; D_QQ = non ; Umin = non ; min = non ; Max = non ; M347 = non
11 sous-système n° 5 ; valeur: 4 4 4 2 4 2 4 ; 5te = oui ; 4te = non ; D_QQ = non ; Umin = non ; min = non ; Max = non ; M347 = non
11 sous-système n° 6 ; valeur: 4 4 2 4 2 4 4 ; 5te = oui ; 4te = oui ; D_QQ = oui ; Umin = non ; min = non ; Max = non ; M347 = non
11 sous-système n° 7 ; valeur: 4 2 4 2 4 4 4 ; 5te = non ; 4te = oui ; D_QQ = non ; Umin = non ; min = non ; Max = non ; M347 = non

(0; 12; 3; 2 4 4 2 4 4 4) ; 5te = 6; 4te = 6; D_QQ = 5; Umin = non; Min = non; Max = non
11 sous-système n° 1 ; valeur: 2 4 4 2 4 4 4 ; 5te = non ; 4te = oui ; D_QQ = non ; Umin = non ; min = non ; Max = non ; M347 = non
11 sous-système n° 2 ; valeur: 4 4 2 4 4 4 2 ; 5te = oui ; 4te = oui ; D_QQ = oui ; Umin = non ; min = non ; Max = non ; M347 = non
11 sous-système n° 3 ; valeur: 4 2 4 4 4 2 4 ; 5te = oui ; 4te = oui ; D_QQ = oui ; Umin = non ; min = non ; Max = non ; M347 = non
11 sous-système n° 4 ; valeur: 2 4 4 4 2 4 4 ; 5te = oui ; 4te = oui ; D_QQ = oui ; Umin = non ; min = non ; Max = non ; M347 = non
11 sous-système n° 5 ; valeur: 4 4 4 2 4 4 2 ; 5te = oui ; 4te = non ; D_QQ = non ; Umin = non ; min = non ; Max = non ; M347 = non
11 sous-système n° 6 ; valeur: 4 4 2 4 4 2 4 ; 5te = oui ; 4te = oui ; D_QQ = oui ; Umin = non ; min = non ; Max = non ; M347 = non
11 sous-système n° 7 ; valeur: 4 2 4 4 2 4 4 ; 5te = oui ; 4te = oui ; D_QQ = oui ; Umin = non ; min = non ; Max = non ; M347 = non

FHT 16 Classification of the systems and sub-systems in Hyper-system no. 12 in the author’s Ph.D. thesis – [Beyhom, 2003d, p. 178].

441 [Ṣāliḥ, 1994, p. 91]. Previously published in [Beyhom, 2003a, p. 74].

Genre Awj-Ārā si^{db}	1er degré	1er int.	2^{e} degré	2^{e} int.	3^{e} degré	3^{e} int.	4^{e} degré
Erlanger (quarts)	*si*^{db}	→ 3	*do*	→ 6	*ré*$^{\#}$	→ 1	*mi*^{db}
Quarts (conceptuels)	*si*^{db}	→ 3	*do*	→ 5	*ré*^{dd} (?)	→ 2	*mi*^{db}
Conceptuel 17es	*si*$^{-}$	→ 2	*do*	→ 4	*ré*$^{+}$	→ 1	*mi*$^{-}$
Notation simplifiée 17es	*si*^{b}	→ 2	*do*	→ 4	*ré*$^{\#}$	→ 1	*mi*^{b}

Genre `Ajam si^{b}	1er degré	1er int.	2^{e} degré	2^{e} int.	3^{e} degré	3^{e} int.	4^{e} degré
Erlanger (quarts)	*si*^{b}	→ 4	*do*	→ 4	*ré*	→ 2	*mi*
Quarts (conceptuels)	*si*^{b}	→ 4	*do*	→ 4	*ré*	→ 2	*mi*
Conceptuel 17es	*la*$^{+}$	→ 3	*do*	→ 3	*ré*	→ 1	*mi*
Notation simplifiée 17es	*si*^{bb}	→ 3	*do*	→ 3	*ré*	→ 1	*mi*

Genre `Ajam do	1er degré	1er int.	2^{e} degré	2^{e} int.	3^{e} degré	3^{e} int.	4^{e} degré
Erlanger (quarts)	*do*	→ 4	*ré*	→ 4	*mi*	→ 2	*fa*
Quarts (conceptuels)	*do*	→ 4	*ré*	→ 4	*mi*	→ 2	*fa*
Conceptuel 17es	*do*	→ 3	*ré*	→ 3	*mi*	→ 1	*fa*
Notation simplifiée 17es	*do*	→ 3	*ré*	→ 3	*mi*	→ 1	*fa*

Genre `Ajam do$^{\#}$	1er degré	1er int.	2^{e} degré	2^{e} int.	3^{e} degré	3^{e} int.	4^{e} degré
Erlanger (quarts)	*do*$^{\#}$	→ 4	*ré*$^{\#}$	→ 4	*mi*$^{\#}$	→ 2	*fa*$^{\#}$
Quarts (conceptuels)	*do*$^{\#}$	→ 4	*ré*$^{\#}$	→ 4	*mi*$^{\#}$	→ 2	*fa*$^{\#}$
Conceptuel 17es	*do*$^{+}$	→ 3	*ré*$^{+}$	→ 3	*mi*$^{+}$	→ 1	*fa*$^{+}$
Notation simplifiée 17es	*ré*^{bb}	→ 3	*mi*^{bb}	→ 3	*fa*^{bb}	→ 1	*sol*^{bb}

Genre Ḥijāz ré	1er degré	1er int.	2^{e} degré	2^{e} int.	3^{e} degré	3^{e} int.	4^{e} degré
Erlanger (quarts)	*ré*	→ 2	*mi*^{b}	→ 6	*fa*$^{\#}$	→ 2	*sol*
Quarts (conceptuels)	*ré*	→ 3	*mi*^{db}	→ 5	*fa*^{dd}	→ 2	*sol*
Conceptuel 17es	*ré*	→ 2	*mi*$^{-}$	→ 4	*fa*$^{++}$	→ 1	*sol*
Notation simplifiée 17es	*ré*	→ 2	*mi*^{b}	→ 4	*fa*$^{\#\#}$	→ 1	*sol*

Genre Ḥijāz-Kār do	1er degré	1er int.	2^{e} degré	2^{e} int.	3^{e} degré	3^{e} int.	4^{e} degré
Erlanger (quarts)	*do*	→ 2	*ré*^{b}	→ 6	*mi*	→ 2	*fa*
Quarts (conceptuels)	*do*	→ 2	*ré*^{b}	→ 5	*mi*^{db}	→ 2	*fa*
Conceptuel 17es	*do*	→ 1	*ré*$^{-}$	→ 4	*mi*$^{-}$	→ 1	*fa*
Notation simplifiée 17es	*do*	→ 1	*ré*^{bb}	→ 4	*mi*^{b}	→ 1	*fa*

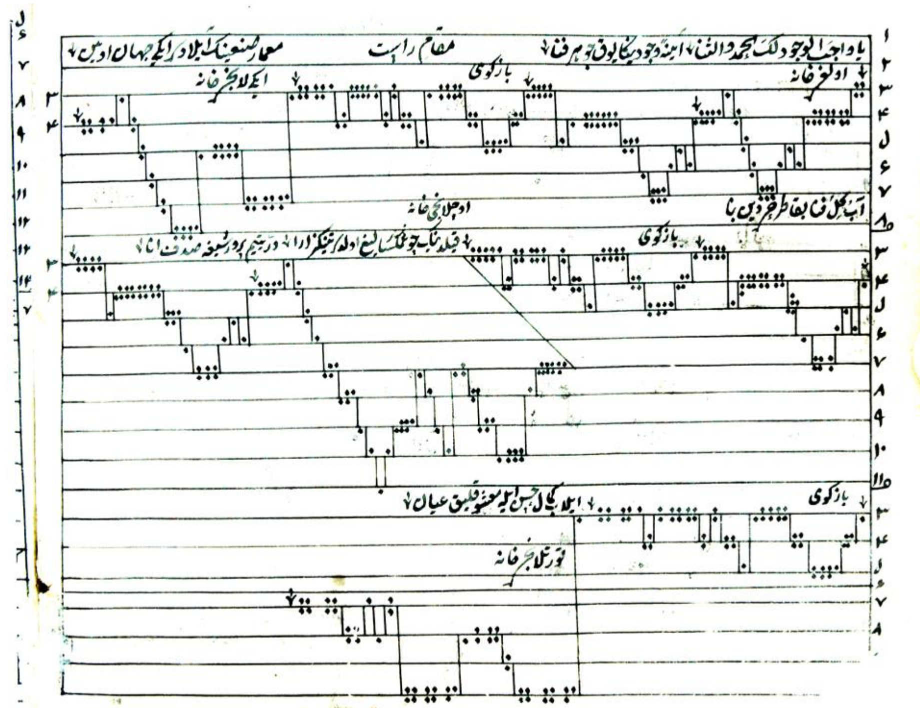
Genre Ḥijāz do$^{\#}$	1er degré	1er int.	2^{e} degré	2^{e} int.	3^{e} degré	3^{e} int.	4^{e} degré
Erlanger (quarts)	*do*$^{\#}$	→ 2	*ré*	→ 6	*fa*	→ 2	*sol*^{b}
Quarts (conceptuels)	*do*$^{\#}$	→ 3	*ré*^{dd}	→ 5	*fa*	→ 2	*sol*
Conceptuel 17es	*do*$^{+}$	→ 2	*ré*	→ 4	*fa*	→ 1	*fa*$^{+}$
Notation simplifiée 17es	*do*$^{\#}$	→ 2	*ré*	→ 4	*fa*	→ 1	*fa*$^{\#}$

"Enharmonique" do	1er degré	1er int.	2^{e} degré	2^{e} int.	3^{e} degré	3^{e} int.	4^{e} degré
Erlanger (quarts)	*do*	→ 1	*do*^{dd}	→ 8	*mi*^{dd}	→ 1	*fa*
Quarts (conceptuels)	*do*	-	-	-	-	-	*fa*
Conceptuel 17es	*do*	→ 1	*do*$^{+}$	→ 5	*mi*	→ 1	*fa*
Notation simplifiée 17es	*do*	→ 1	*do*$^{\#}$	→ 5	*mi*	→ 1	*fa*

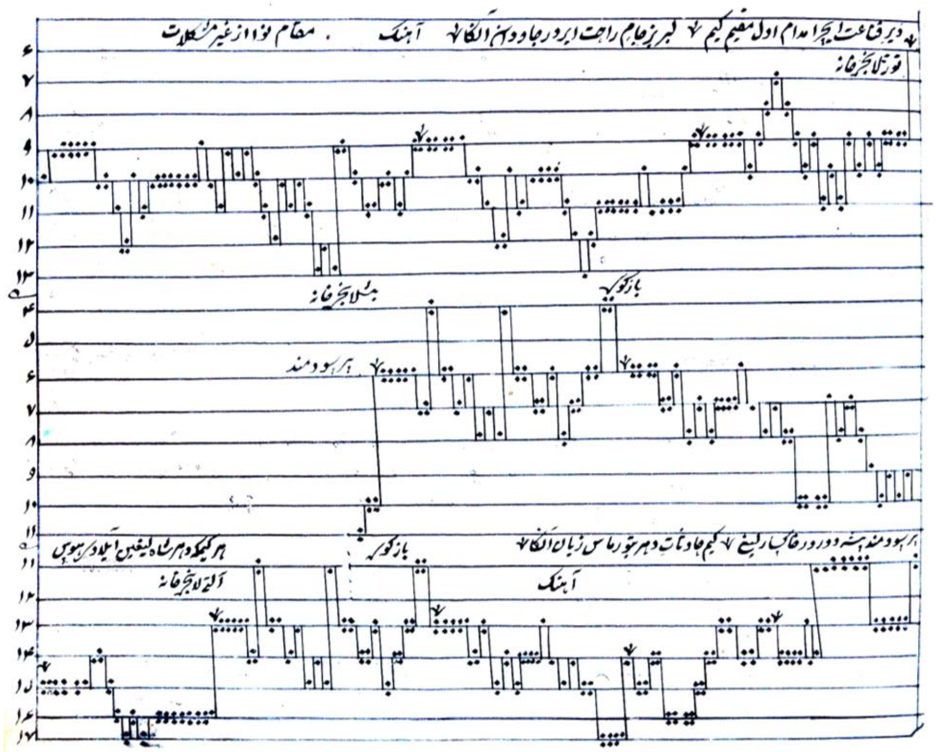
FHT 17 Intervallic equivalences and literal notation of tetrachords in Erlanger's formulation (1st row), in the author's proposition in quarter-tones (2nd row) and in 17^{ths} of the octave (3rd and 4th rows).[442]

[442] [Beyhom, 2010b, p. 127, Plate no. 10].

Khorezmian tablatures for the tanbur



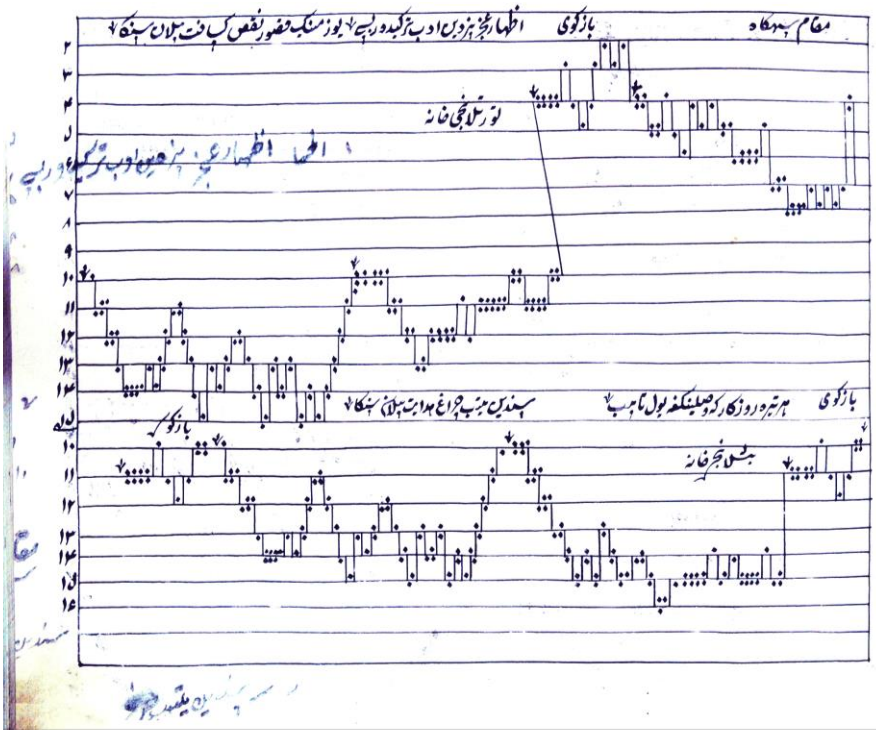
FHT 18 Khorezmian *tanbur* notation (copy of Jean During) p. 1: *maqām Rāst*.[443]



FHT 19 Khorezmian *tanbur* notation (copy of Jean During) p. 21: *maqām Nawā*.[444]

[443] Photograph by Jean During / Image treatment by Amine Beyhom.

[444] Photograph by Jean During / Image treatment by Amine Beyhom.



FHT 20 Khorezmian *tanbur* notation (copy of Jean During) p. 53: *maqām Segah*.[445]

Western and modified notations

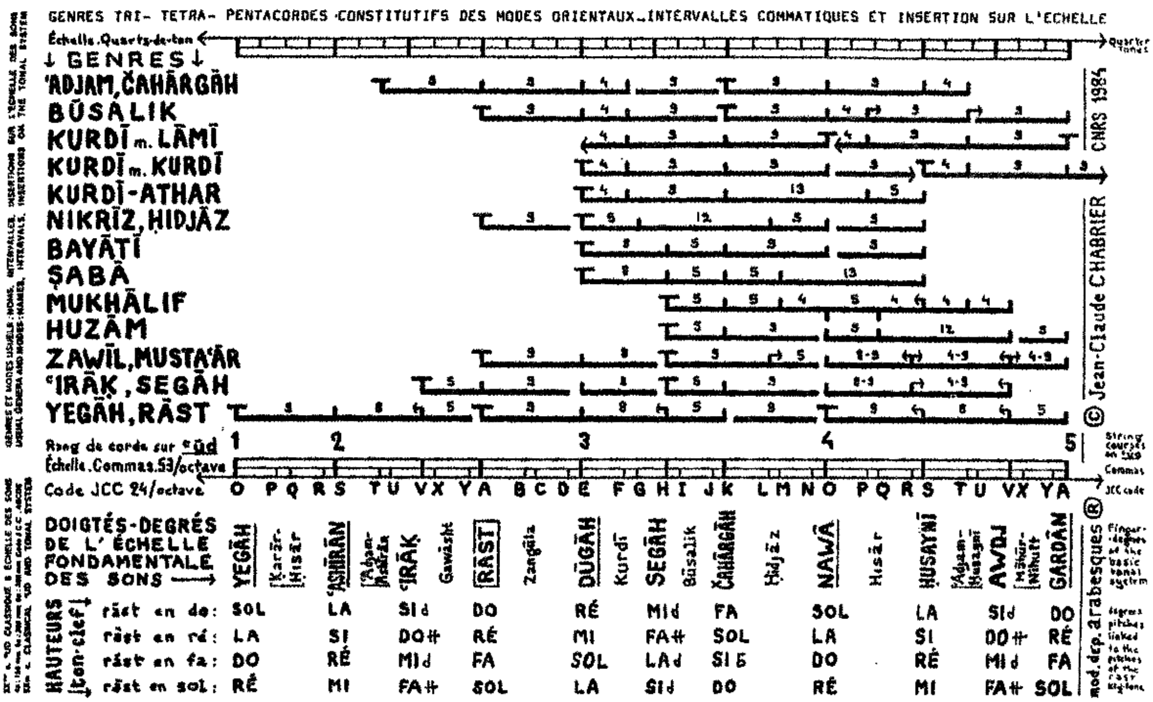
FHT 21 An exercise for the *ʿūd* by Kindī in the *Risāla fī-l-Luḥūn wa-n-Nagham.* Transnotated by Zakariyyā Yūsuf in 1965.[446]

[445] Photograph by Jean During / Image treatment by Amine Beyhom.

[446] [Kindī (al-) and 1965 ,الكندي, p. 31]: two right-hand fingers are used for the exercise, the thumb and the index.

FHT 22 One page from the score of *Dhekr* (Document No. 121-03, p. 005) from the archives of Erlanger in Ennejma Ezzahra (Sidi Bou-Said – Tunisia).[447]

[447] Downloaded 20/07/2018 from http://ennejma.tn/archives/fr/2018/07/18/121-03-partitions-dhekr/.



FHT 23 *geni* and "modes" according to Chabrier.[448]

FHT 24 *Muwashshaḥ* in *maqām Huzām*.[449]

[448] [Chabrier, 1995, p. 285].

[449] [Ḥilū (al-), 1980, p. 175].

FHT 25 Scale and legend for *maqām Bayāt* according to (al-) Bāshā.[450]

[450] [Bacha, s.d. (199x), p. 55]: the caption (above the score) is here reduced in size and reproduced strictly "as is". Further explanations from Bāshā (same page – the original text is also reproduced strictly as is): "**The violin and the quarter tone** – Quarter tones became an essential and a remarkable factor in the construction of Oriental-Arabic musical scales. Since hundred of years and until the present time scholars and musicologists are working on systematizing these quarter tones in order to become subdue and subjugate to both the composer and the interpreter. When we designate and establish the degrees and intervals of these quarter tones in order to conform with the needs of instrumental music composition, we do not mean to abolish what is traditionally and conventionally in use, but at the same time we cannot anymore be bound to the MAQAM with its one-tonal degree in the operation of music composition. The amplitude and profusion in MODAL TRANSFERS in the major and minor scales are far more abundant to the composer than that in the scales consisting of quarter tones. The practical and eloquent proof to this essay came out when J.S. Bach introduced through his 24 PRELUDES and FUGUES based on the WELL-TEMPERED scale, and consequently this eventuate that the term TEMPERED gave balance and equilibrium to the scale, which, at the same time caused a decisive turn in the history of music. Our essay in this book (THE VIOLIN AND THE ¾ TONES_ 21 ETUDES) seek to open a way to a highly disciplined playing of the quarter tones after mastering playing compositions of remarkable composers based on major and minor scales. This book is compiled to the violin to play scales with (WELL-TEMPERED) quarter tones. Since the violin is the basic and essential instrument in the Orchestra, the purpose of this book is to help in preparing and mobilizing Violin players with high techniques based on the world-wide tuning G - D - A - E (SOL - RE- LA - MI). Two similar books will follow, one for the Viola and another for the Cello".

FHT 26 Tuwfīq al-Bāshā: 1st page of the score of the *muwashshaḥ “Iṣqī-(a)l-ʿIṭāsh”*. (Courtesy of the author.)

FHT 27 1st page of the score of *A-ṣ-Ṣawt* by Sacha Bourguignon.[451]

[451] Courtesy of the author.

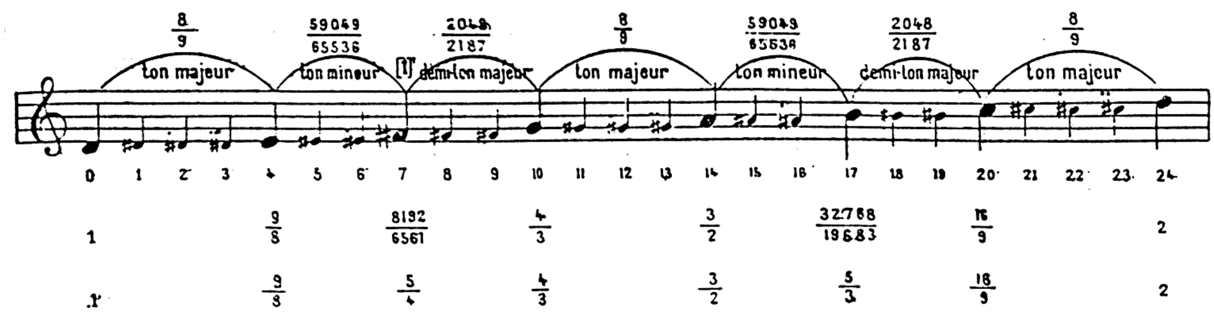
FHT 28 1st page of the score of *Marmar Zamānī* (for *qānūn*) by Toufic Succar.[452]

[452] Courtesy of the author.

FHT 29 1st page of the score of the *Scherzando* by Toufic Succar.[453]

[453] Courtesy of the author.

FHT 30 Notation (quarter-tone division of the octave) of the *maqām*(s) of the *sīkā* and *ʿirāk* "families" according to the CNSML[454]. Only the *ʿirāq* (second staff from bottom – to the left) tetrachord is in just fourth and "disjunctive tones" are all – except for the upper one – different from the "whole tone".[455]

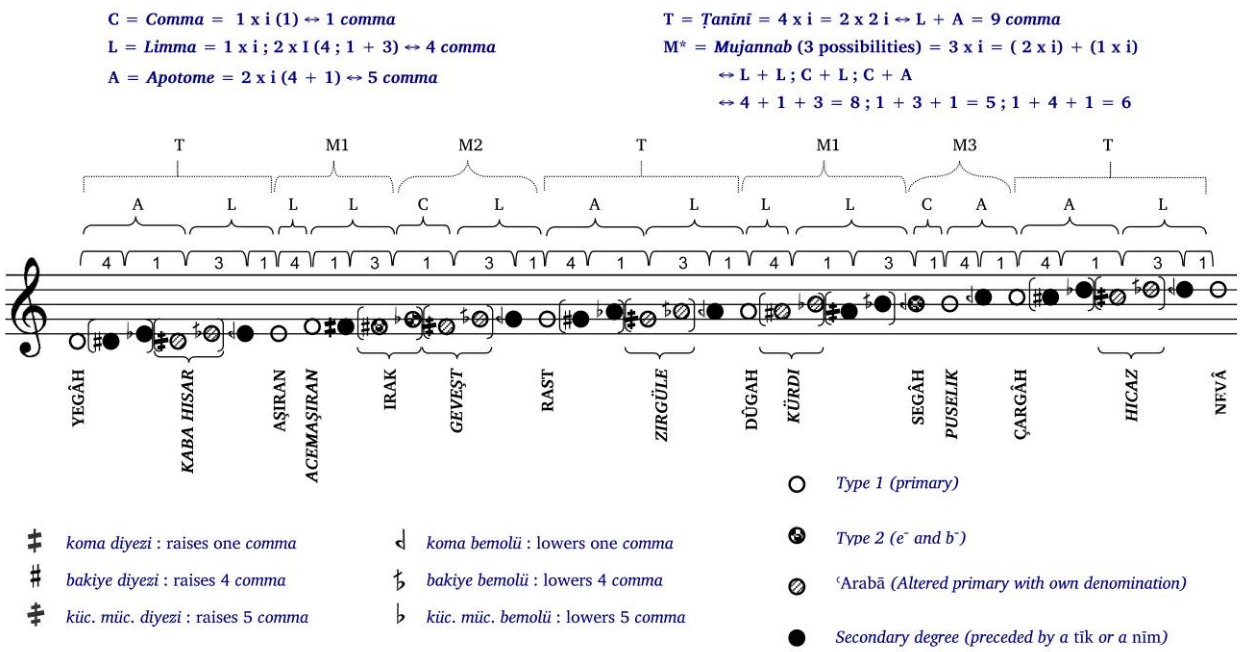


FHT 31 General scale of Turkish music according to Rauf Yekta Bey in [Yekta, 1922, p. 2987]. The scale is notated – according to Yekta – a fifth higher in order to fit it in a staff in treble clef (the initial *d* corresponds to a *g* in the Western scale).[456]

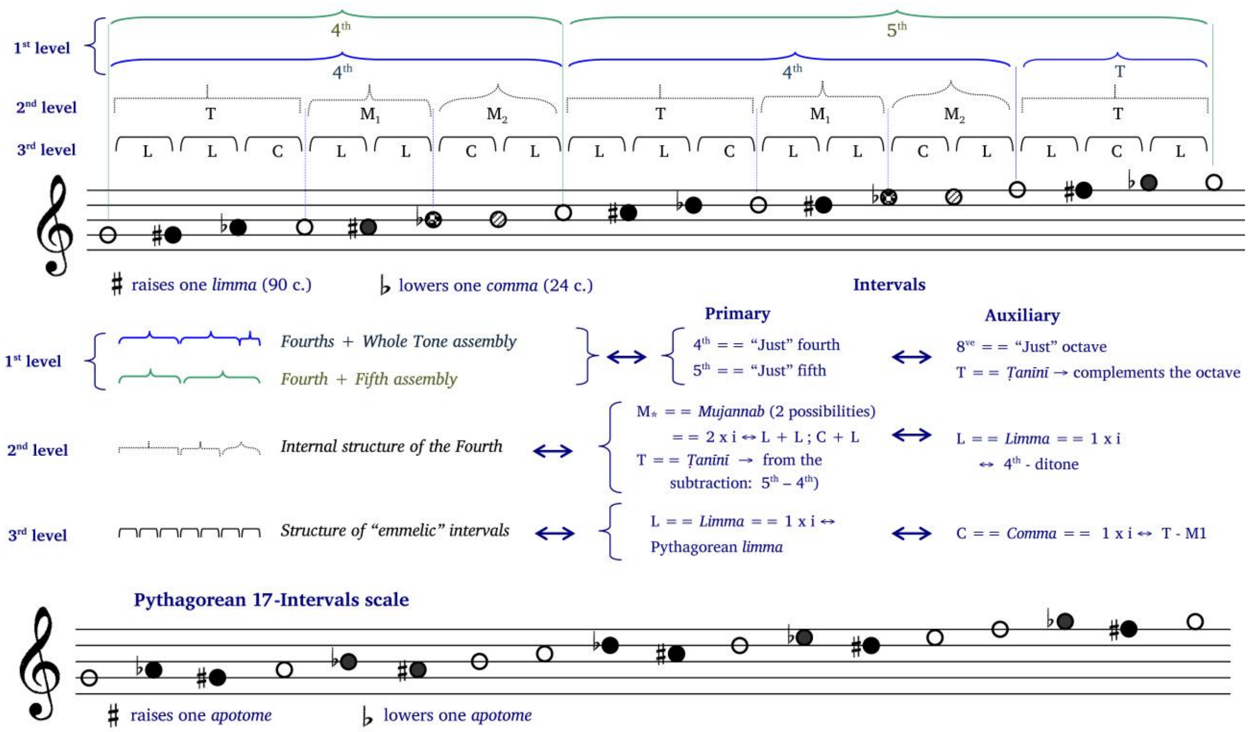
[454] The Lebanese national conservatoire.

[455] [Ghulmiyya, Kirbāj, and Faraḥ, 1996, v. 5, p. 22].

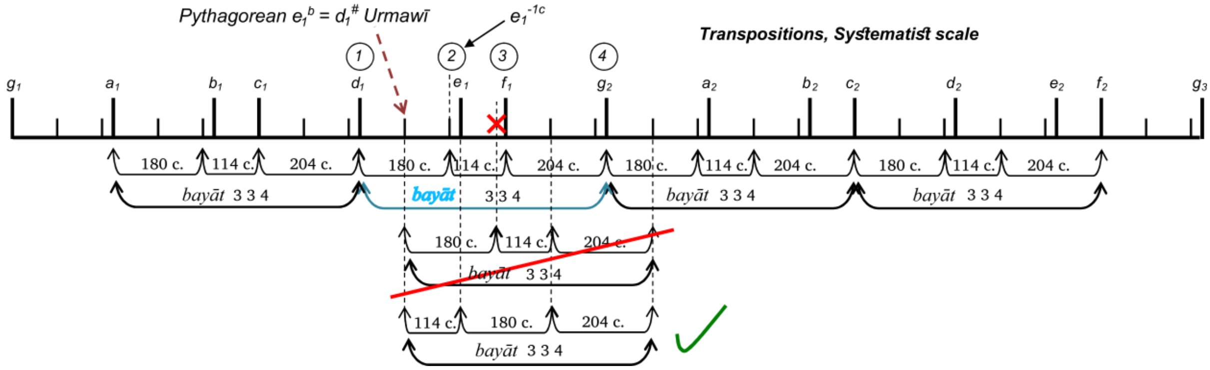
[456] "Ton majeur" = whole tone, "ton mineur" = *di-leimma*, "demi-ton majeur" = *apotome*. Note that the origin of the equivalence between *maqām*(ian) degree *RĀST* – in Arabian *maqām* music theory *c* – and the Western *g* goes back at least to Giuseppe Donizetti – as expounded in [Behar, 2013] (private communication). (See also [Ergur and Doğrusöz, 2015], notably [p. 151, fn. 5]: "E.g. identification of Rast makam with G Major or the recalibration of the makam scaling according to a basic tone by the theoreticians Ezgi-Arel, at the beginning of the 20th century, who accepted the Çargâh makam, which is structurally the most similar one to European major scale. (Signell, 1986: 24)".)



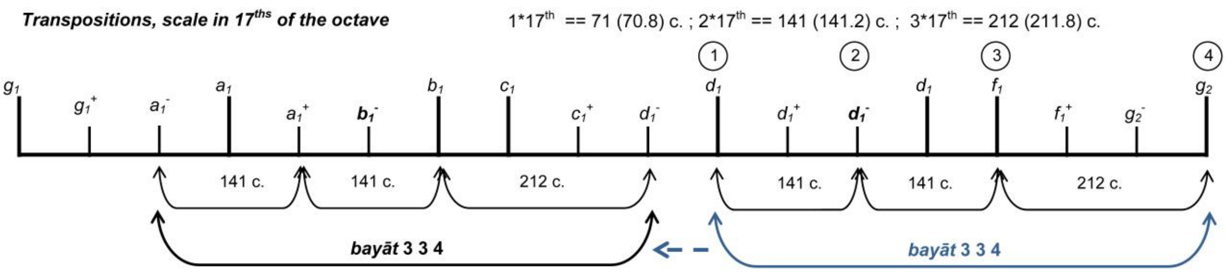
FHT 32 Yekta Bey's scale completely notated with "Modern" (Yekta-Ezgi-Arel) accidentals, conjunct intervals and structuring intervals.



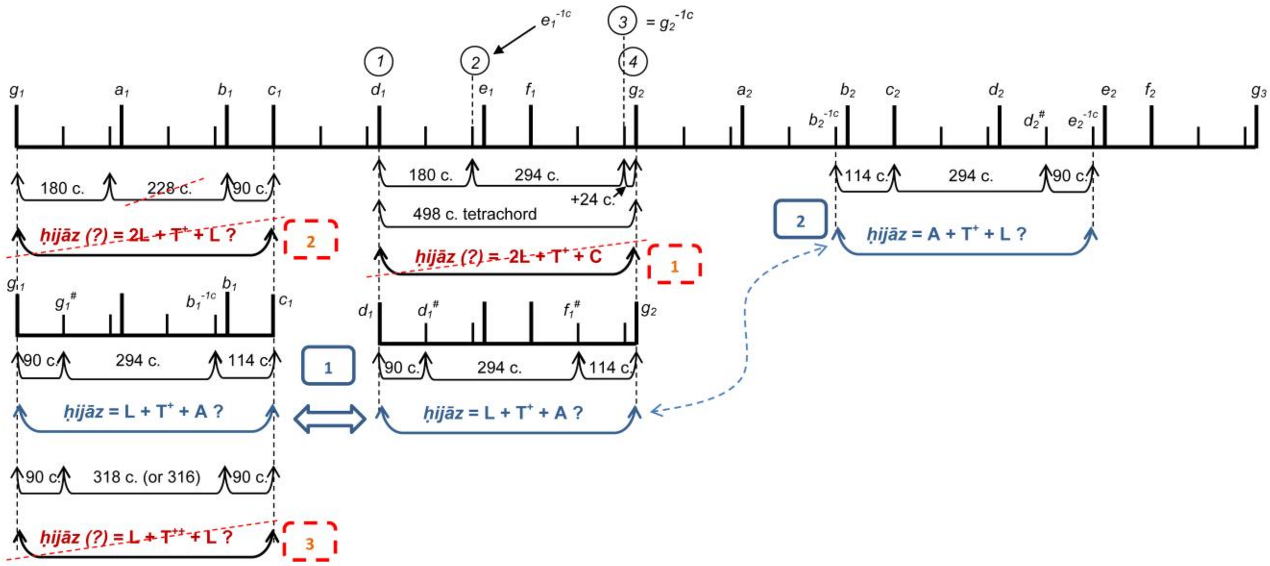
FHT 33 Conceptualization of the « Systematist » scale (Ṣafiyy-a-d-Dīn al-Urmawī) and comparison with the "Pythagorean" scale.



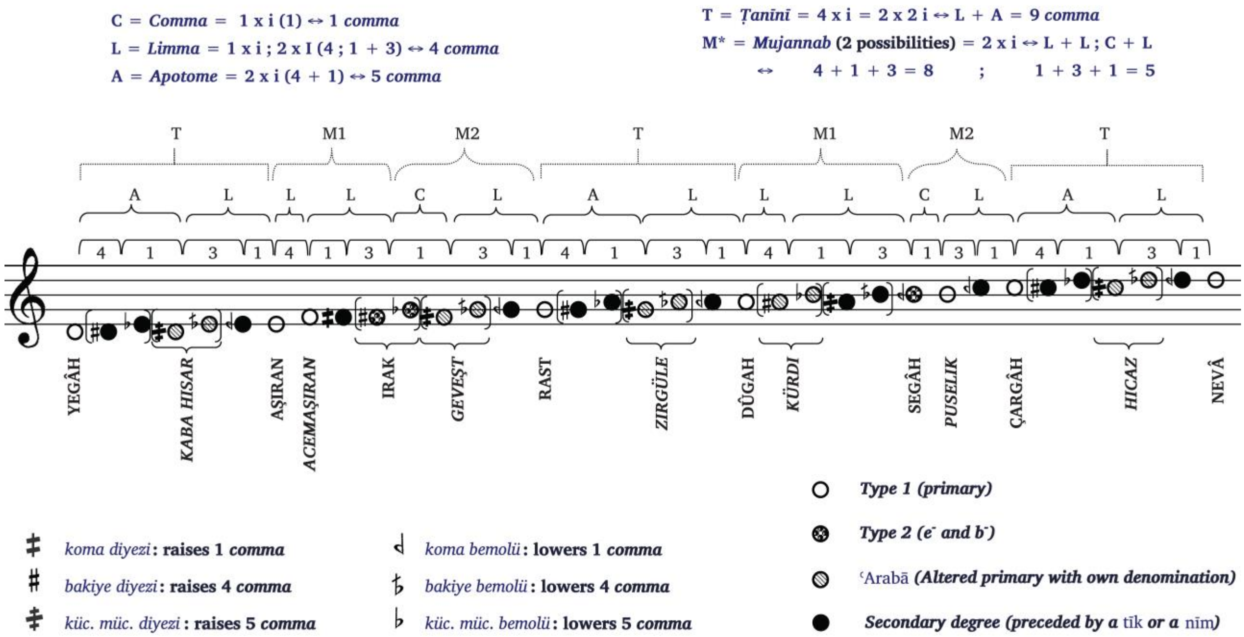
FHT 34 Theoretical transposition in the "Systematist scale" of a *bayāt* tetrachord [*d* ↑3 3 4], or M_1 M_2 T (*mujannab*$_1$ *mujannab*$_2$ whole-tone) on the degrees *g*, *a* and e^b: the transposition on $d^\#$ enforces the inversion of the *mujannab*(s) ("neutral seconds") as M_2 M_1 T.



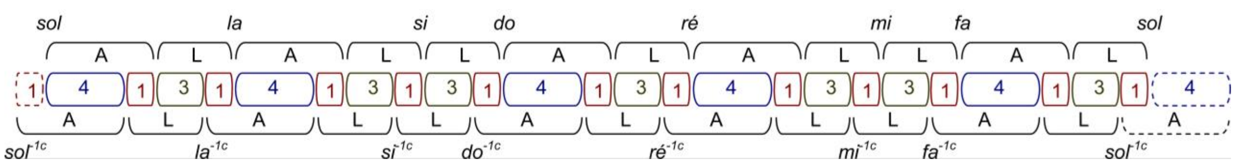
FHT 35 Example of a transposition of the same tetrachord as in FHT 34 on a 17th of the octave grid from *d* to a^-. All transpositions in this equal-temperament grid give similar intervals.



FHT 36 Transpositions of the *ḥijāz* tetrachord in Urmawī's scale: a "Great tone" in this scale is composed of 4 elementary intervals – 3 *leimmata* and 1 *comma*. This makes it impossible to use configuration 3 (red) as (1) a "Great tone" contains 5 elementary intervals in this configuration, and (2) this configuration cannot be transposed again on b^{-1c} and e^{-1c} – which are degrees of the main scale. Likewise, configuration 1 (red) contains a (too) small central interval (2L + 2C) while configuration 2 (red) contains one *comma* structural interval – which contravenes Urmawī's indications about interval compositions in the scale (no *comma* can be used alone in the scale). The only acceptable composition – central 3L + C with bordering *leimma* and *apotome* (in blue) – can be transposed without structural modifications except the inversion of the *mujannab*(s) as seen in FHT 34.



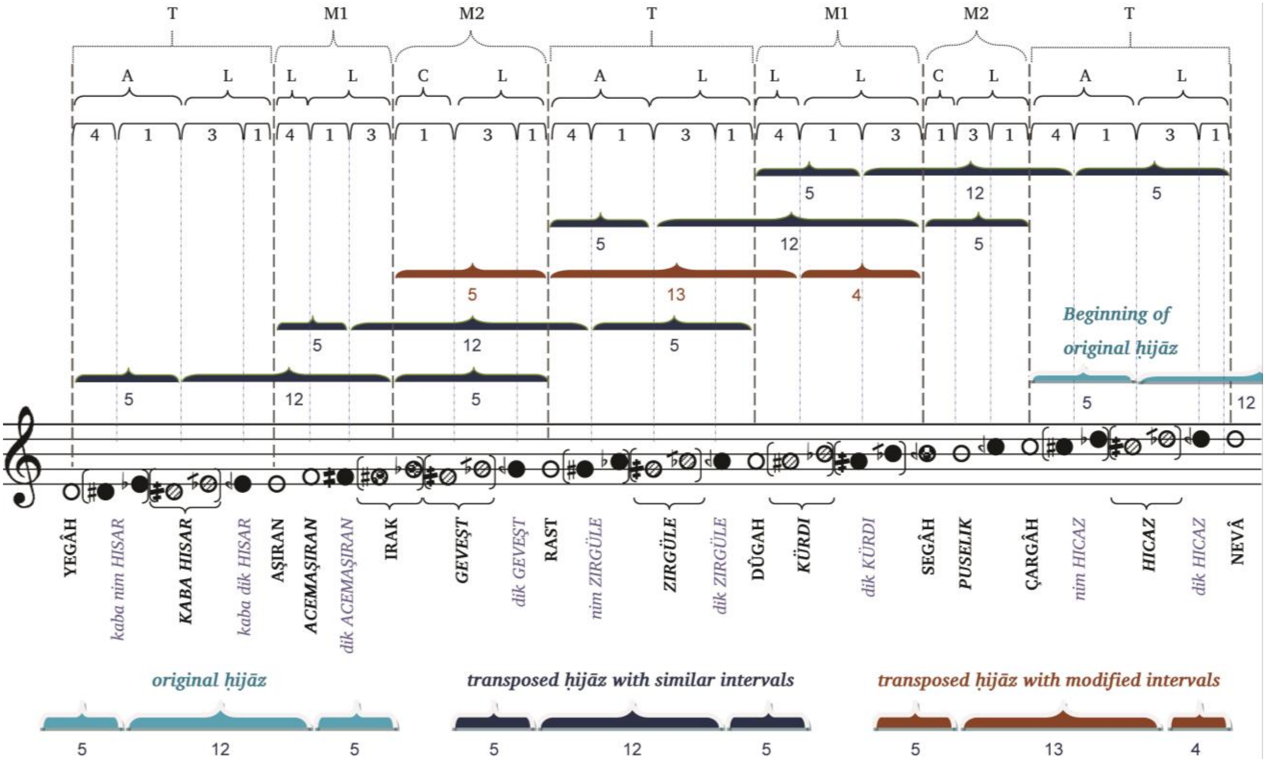
FHT 37 General analysis of the Yekta-Ezgi-Arel Turkish scale – and notation – according to the explanations of [Signell, 2004], structured in *Elementary* ("i", "*C*" and "*L*") and *Conceptual* ("*C*", "*L*", "*A*", "*T*" and "*M*") – different fillings for the notes are explained on the bottom-right.[457]



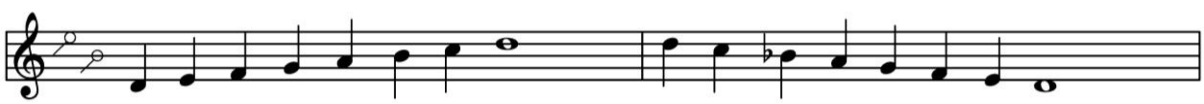
FHT 38 Conception (by Signell) of the general (Turkish) scale as deduced from the Yekta-Ezgi-Arel theory (literal notation in French). Two similar chains of 12 *apotomai* and *leimmata* are superposed with a one (Holderian) comma offset. The resulting scale is shown in the previous plate (FHT 37).

[457] Basic intervals are, according to [Signell, 2004, p. 23] :

- *koma* (*comma*, 23 c) – This is an auxiliary interval (not used as such in the scale between adjacent pitches) – see the Core Glossary of [Beyhom, 2018ap] for more explanations on types of intervals.
- *bakiye* (*leimma* or "small [lesser] half-tone", 90 c).
- *kücük mücennep* ("small *mujannab*" – *apotome*, or "big [greater] half-tone", 114 c).
- *büyuk mücennep* ("big *mujannab*" – "minor" tone, or "small tone", 180 c).
- *tanini* ("major" tone, or "big [greater] tone", 204 c).
- *artik ikili* ("augmented second", 271 c) – This can be 12, 13 or 14 Holderian commas according to the context, in the latter case equivalent to a "major tone" + an *apotome*, 114 + 204 = 318 c).



FHT 39 Transpositions of tetrachord *ḥijāz* in modern theories of the scale in Turkey.[458] Accidentals and graphical differences in the representation of the notes are explained in FHT 37.



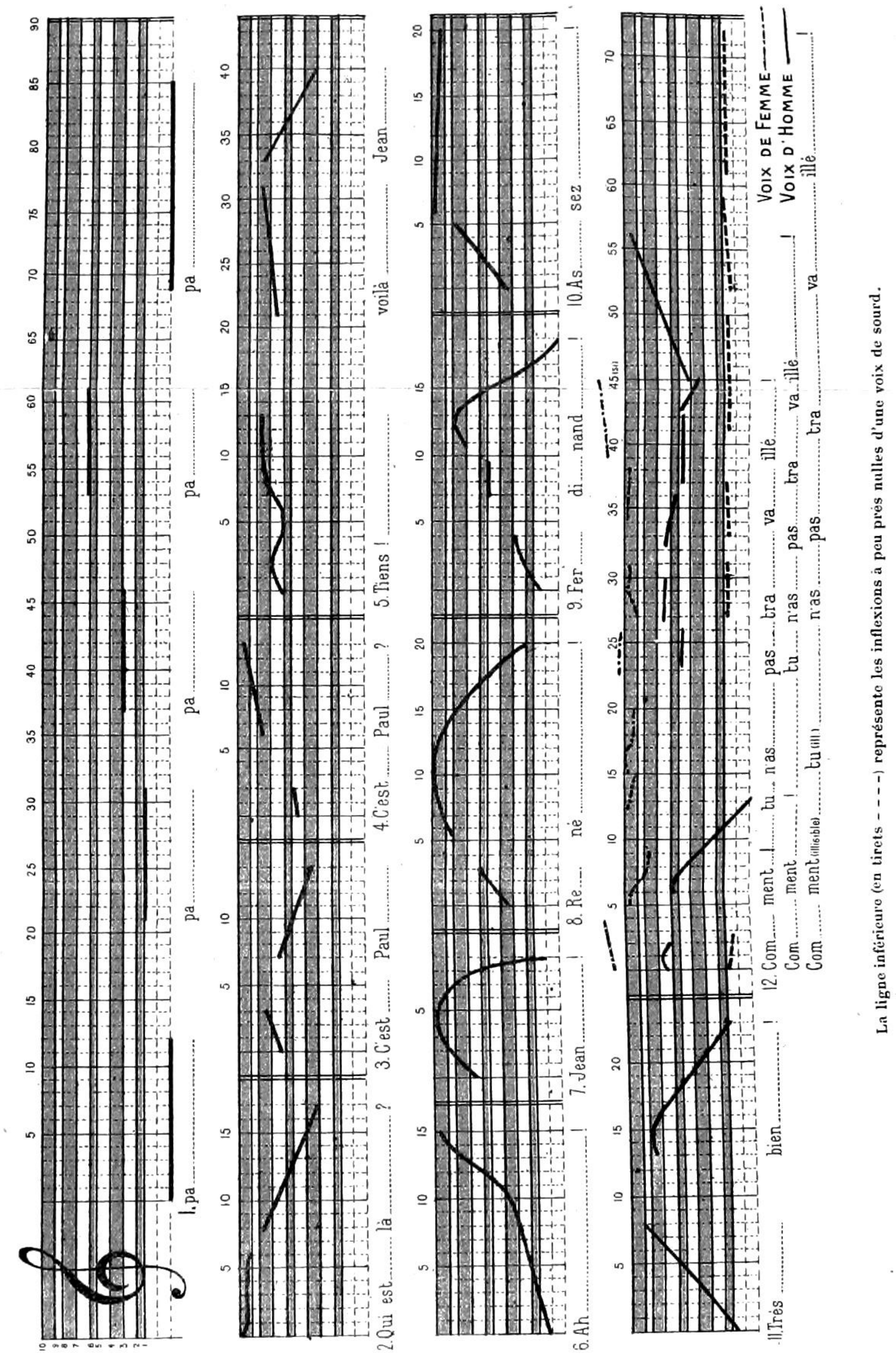
FHT 40 Scale of the First Byzantine mode {*πα* ↑10 8 12 12 10 8 12, *Πα* ↓12 12 6 12 12 8 10} in western notation with Byzantine accidentals.[459] The accidental used for the key signature lowers the pitch by a sixth of a (tempered) tone.

[458] [Signell, 2001, p. 31]: "Note that occasionally a 'transposition' will cause a slight alteration in the size of an interval. In Ex. 7.6 (in [Signell, 2001, p. 32]), the characteristic interval of an augmented second in the HİCAZ tetrachord is altered from 12 to 13 commas when it is transposed to F#. This is due to the necessity of accommodating the transposed tetrachord to the pitches available (i.e., willy-nilly, the closest pitch must be used)".

[459] As deduced from [Yāzijī, 2001] and [Commission musicale de (Musical Committee of) 1881, Aphtonidēs, and al., 1978] and others.

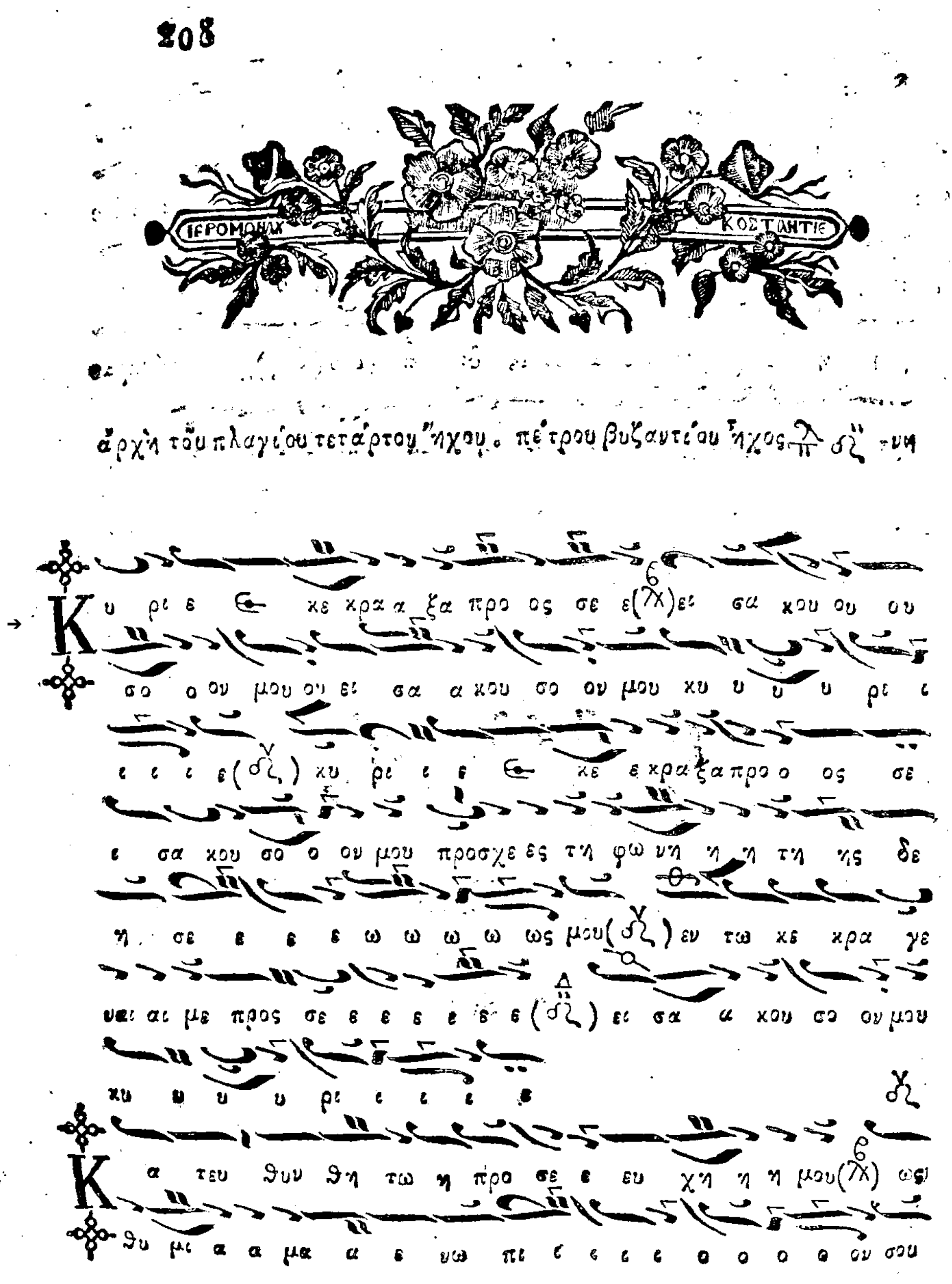
FHT 41 Richard Dumbrill's interpretation of Hurrian song H6 using MUS2 and comma-numbered accidentals (published in [Dumbrill, 2017, p. 117, Fig. 18] – Courtesy of the author).[460]

[460] (From the original caption): "Near-Eastern intonation implemented with the collaboration of Rosy Azar Beyhom and Amine Beyhom. The first bar of the introduction is the fourth bar of the conclusion. It is the musical version of well-known catch-lines often used in Mesopotamian texts. Numbers after accidentals indicate: #1 = 1 comma sharper = 22.64 cents; #2 = 2 commas sharper = 45.28 cents; #3 = 3 commas sharper = 67.92 cents; #5 = 5 commas sharper = 113.2 cents; b1 = 1 comma flat = - 22.64 cents; b2 = 2 commas flat = - 45.28 cents; b3 = 3 commas flat = - 67.92 cents; b4 = 4 commas flat = - 90.57 cents".

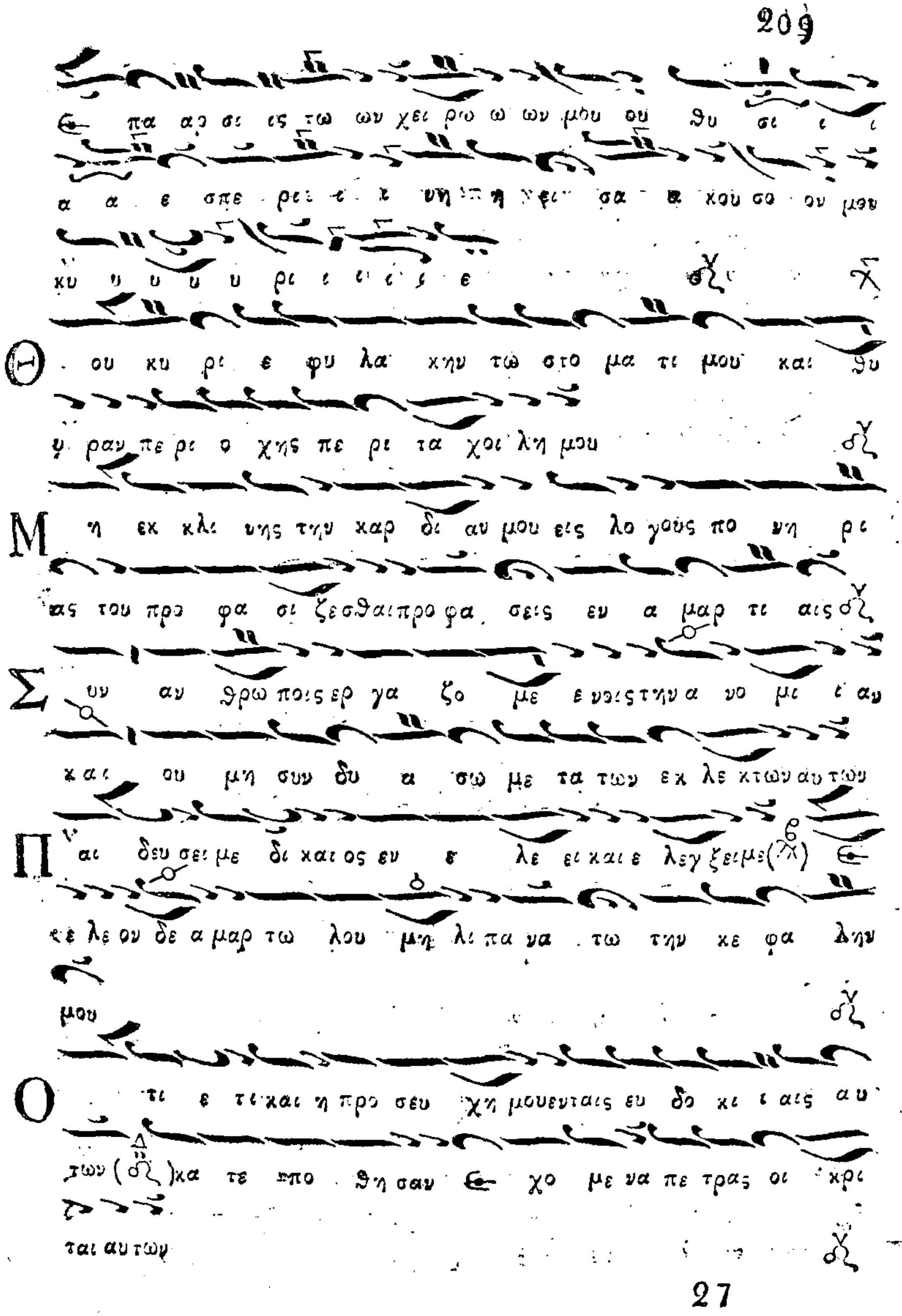


FHT 42 Notation of intonations in French language according to Marichelle (1900).[461]

[461] [Marichelle, 1897, p. 112-113 (Planche 11 inserted between ~)].



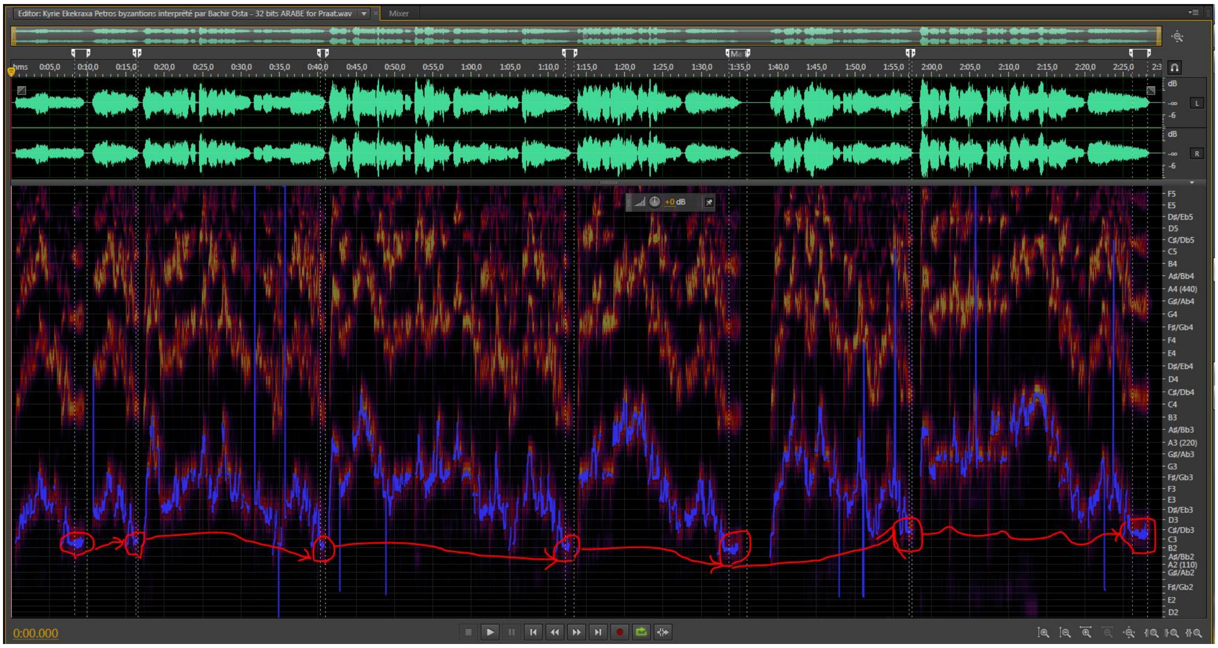
FHT 43 Page 1 of the Byzantine notation of *Kyrie Ekekraxa* by Petros Byzantios – from [Ephesios, 1820, p. 208].



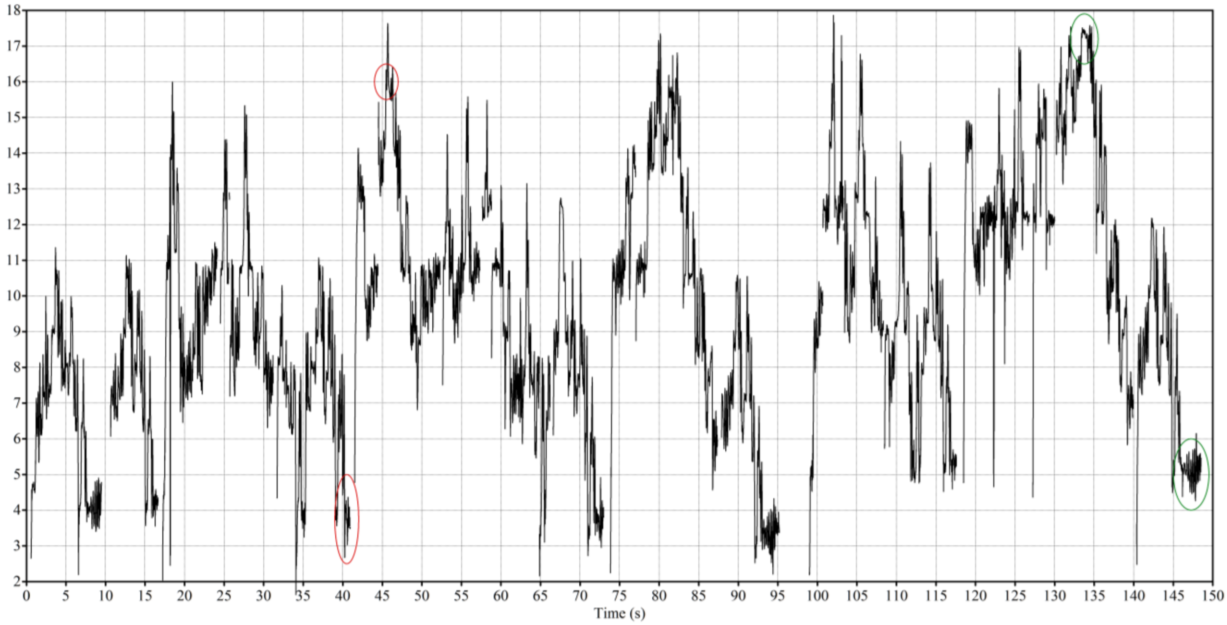
FHT 44 Page 2 of the Byzantine notation of *Kyrie Ekekraxa* by Petros Byzantios – from [Ephesios, 1820, p. 209].

FHT 45 Page 1 of the transnotation of *Kyrie Ekekraxa* (Petros Byzantios) by Joseph Yazbeck and Amine Beyhom.

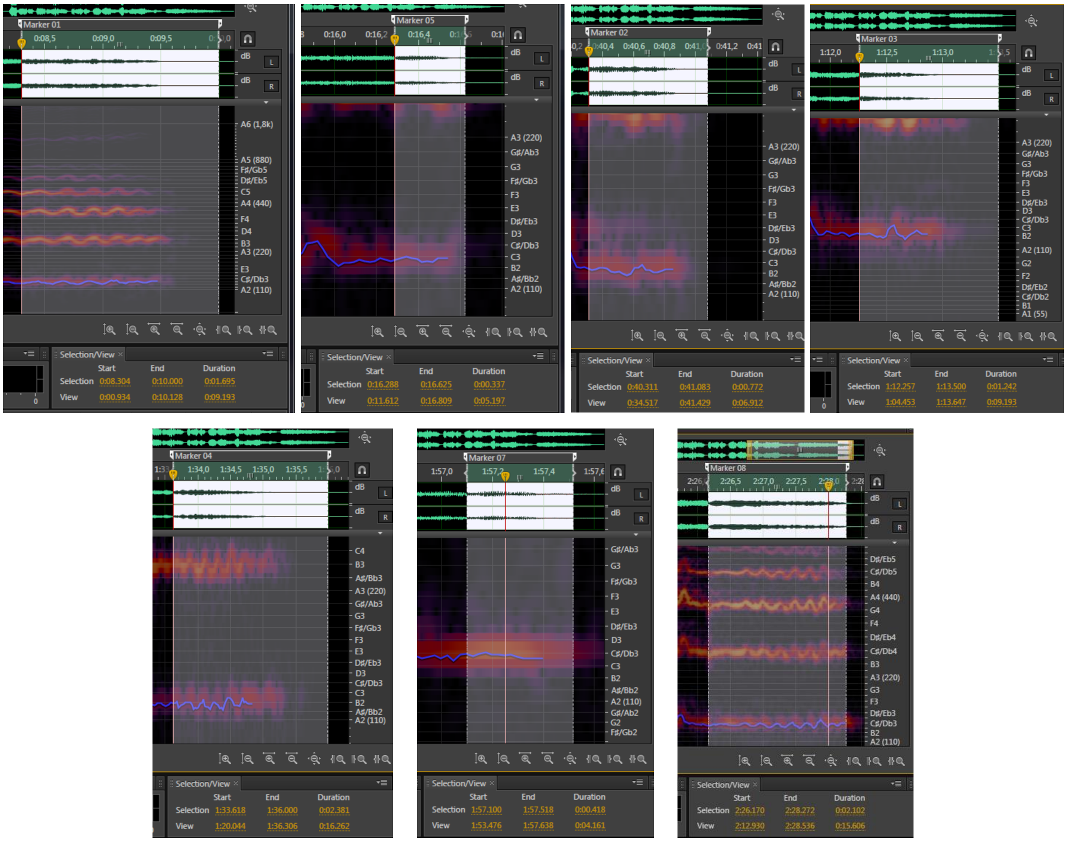
FHT 46 Page 2 of the transnotation of *Kyrie Ekekraxa* (Petros Byzantios) by Joseph Yazbeck and Amine Beyhom.



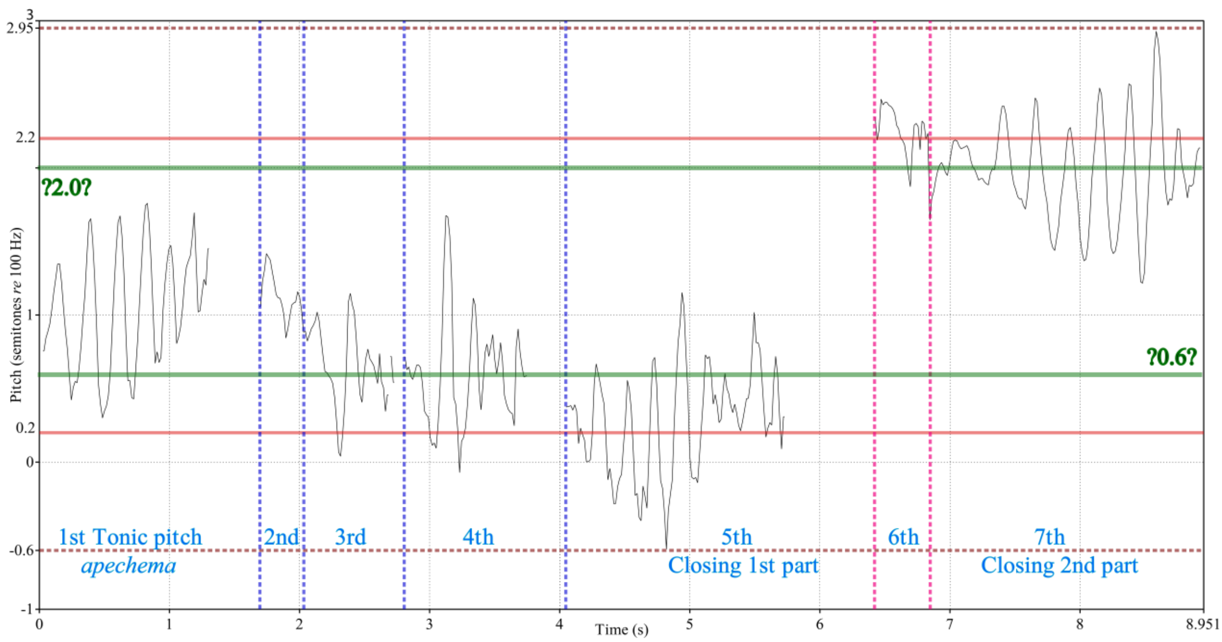
FHT 47 General view – and preliminary analysis – of the Arabic version of *Kyrie Ekekraxa* by Petros Byzantios in the interpretation of Bachir Osta, with approximated indicators for the change in the tonic pitches.



FHT 48 Global analysis of the Arabic version of *Kyrie Ekekraxa* by Petros Byzantios in the interpretation of Bachir Osta, with two neighboring tonics and octaves circled.



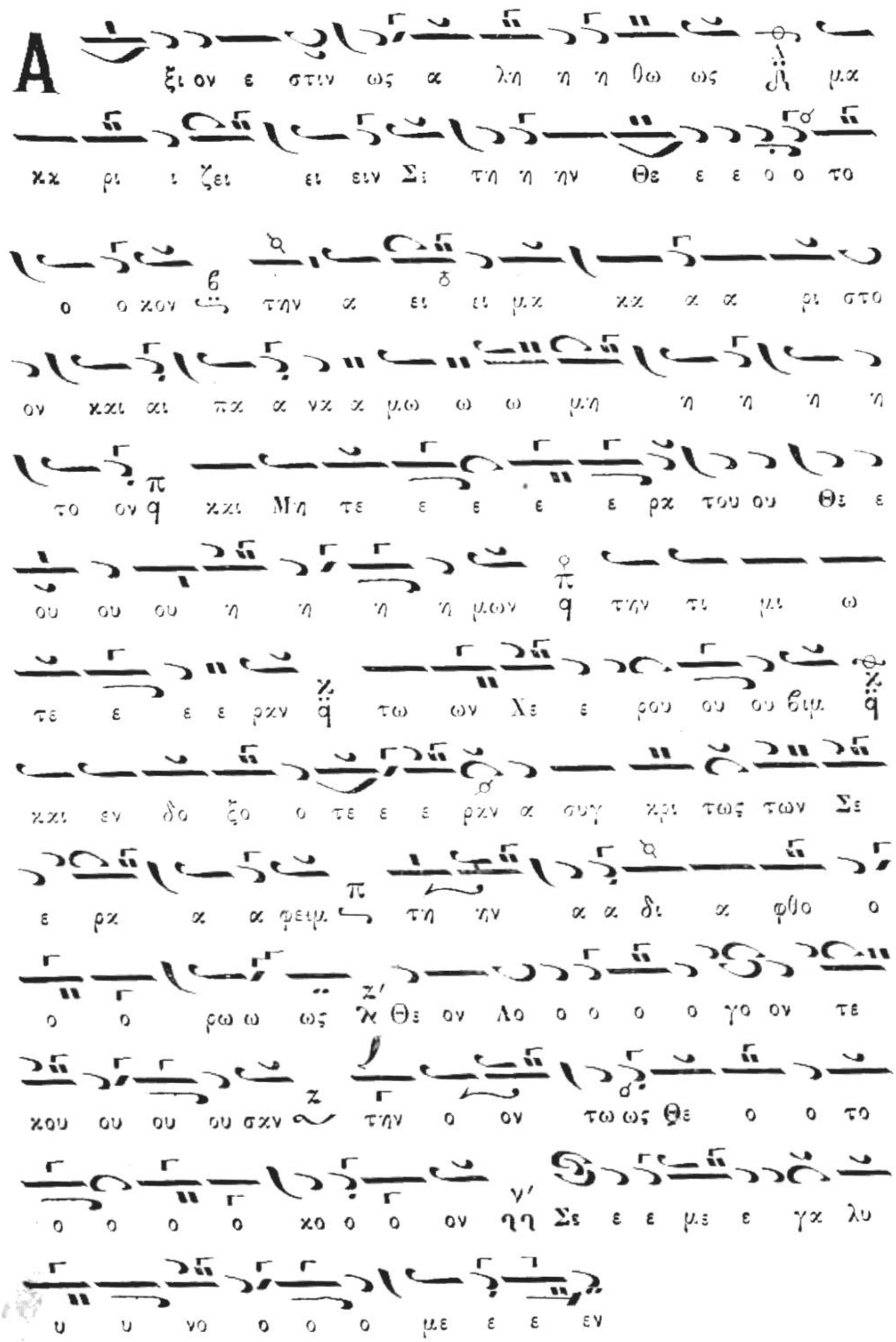
FHT 49 Seven tonic pitches from *Kyrie Ekekraxa* by Petros Byzantios and interpreted by Bachir Osta, marked for extraction and analysis.



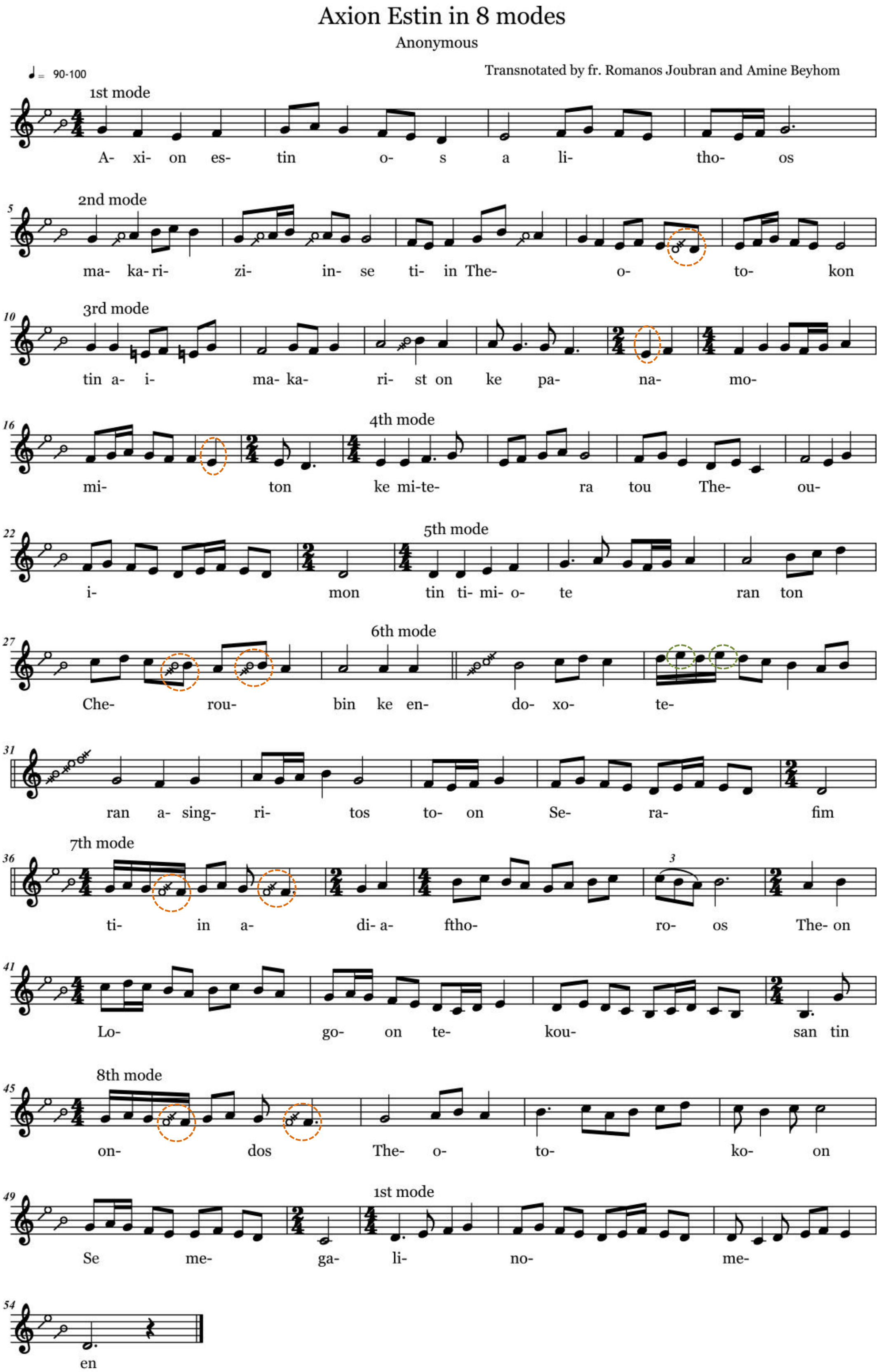
FHT 50 Seven tonic pitches from *Kyrie Ekekraxa* by Petros Byzantios and interpreted by Bachir Osta, extracted and analyzed with Praat.

Σειρὰ «Ἄξιόν ἐστιν» παρὰ διαφόρων.

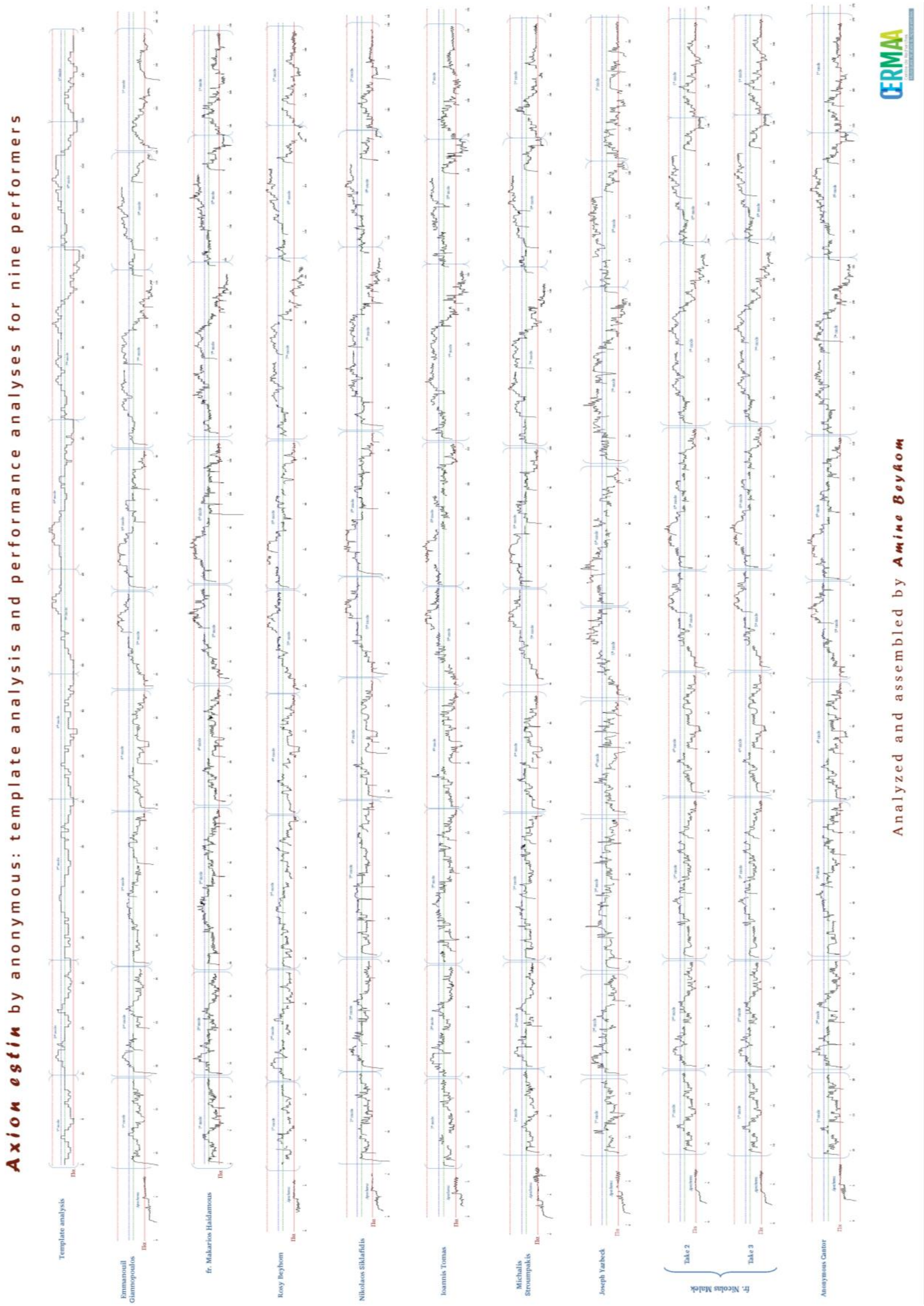
Τὸ παρὸν ὀκτάηχον οὗ ὁ μελοποιὸς ἄγνωστος. Ἦχος Πα.



FHT 51 Original Byzantine notation of *Axion Estin* by an Anonymous composer – from Κυριαζίδης, Αγαθάγγελος. *Αἱ Δύο Μέλισσαι*. Τόμος Β’. Κωνσταντινούπολη, 1906.



FHT 52 Transnotation of *Axion Estin* (Anonymous – see previous figure) by fr. Romanos Joubran and Amine Beyhom. Attractions are circled in orange, and the two "Natural" *βου* in green.



FHT 53 Synoptic table of the graphic analyses of *Axion Estin* (Anonymous) used as a poster by the author.

N°.	1st Octave (Lower)		2nd Octave (Upper)		N°. (+24)
(O)	*g*	*NAWĀ/ jawāb-(al-)YĀKĀ*	*RAMAL-TŪTĪ*	*g*	(O)
24	$g^{½b}$	*tīk-ḤIJĀZ*	*jawāb-tīk-ḤIJĀZ*	$g^{½b}$	24 (48)
23	$f^{\#}$ / g^{b}	*ḤIJĀZ/ṢABĀ*	*jawāb-ḤIJĀZ*	$f^{\#}/g^{b}$	23 (47)
22	$f^{½\#}$	*nīm-ḤIJĀZ/ʿARABĀʾ*	*jawāb-nīm-ḤIJĀZ*	$f^{½\#}$	22 (46)
21	*f*	*JAHĀRKĀ*	*MĀHŪRĀN*	*f*	21 (45)
20	$e^{½\#}/f^{½b}$	*tīk-BŪSALĪK*	*tīk-ḤUSAYNĪ-SHADD*	$e^{½\#}/f^{½b}$	20 (44)
19	*e*	*BŪSALĪK*	*ḤUSAYNĪ-SHADD*	*e*	19 (43)
18	$e^{½b}$	*SĪKĀ*	*BUZURK*	$e^{½b}$	18 (42)
17	$d^{\#}/e^{b}$	*KURD*	*ZAWĀL/SUNBULA*	$d^{\#}/e^{b}$	17 (41)
16	$d^{½\#}$	*nīm-KURD*	*nīm-ZAWĀL*	$d^{½\#}$	16 (40)
15	*d*	*DŪKĀ*	*MUḤAYYAR*	*d*	15 (39)
14	$d^{½b}$	*tīk-ZĪRKŪLĀ*	*tīk-SHĀH-NĀẒ*	$d^{½b}$	14 (38)
13	$c^{\#}/d^{b}$	*ZĪRKŪLĀ*	*SHĀH-NĀẒ*	$c^{\#}/d^{b}$	13 (37)
12	$c^{½\#}$	*nīm-ZĪRKŪLĀ*	*nīm-SHĀH-NĀẒ (KUNNĀZ)*	$c^{½\#}$	12 (36)
11	*c*	*RĀST*	*KARDĀN/MĀHŪR*	*c*	11 (35)
10	$b^{½\#}/c^{½b}$	*tīk-KAWASHT*	*tīk-NAHAFT*	$b^{½\#}/c^{½b}$	10 (34)
9	*b*	*KAWASHT*	*NAHAFT*	*b*	9 (33)
8	$b^{½b}$	*ʿIRĀQ*	*AWJ*	$b^{½b}$	8 (32)
7	$a^{\#}/b^{b}$	*qarār-(al-)ʿAJAM*	*ʿAJAM*	$a^{\#}/b^{b}$	7 (31)
6	$a^{½\#}$	*qarār-nīm-ʿAJAM*	*nīm-ʿAJAM*	$a^{½\#}$	6 (30)
5	*a*	*ʿUSHAYRĀN*	*ḤUSAYNĪ*	*a*	5 (29)
4	$a^{½b}$	*qarār-tīk-ḤIṢĀR*	*tīk-ḤIṢĀR*	$a^{½b}$	4 (28)
3	$g^{\#}/a^{b}$	*qarār-ḤIṢĀR*	*ḤIṢĀR/SHŪRĪ*	$g^{\#}/a^{b}$	3 (27)
2	$g^{½\#}$	*qarār-nīm-ḤIṢĀR*	*nīm-ḤIṢĀR*	$g^{½\#}$	2 (26)
1	*g*	*YĀKĀ*	*NAWĀ*	*g*	1 (25)

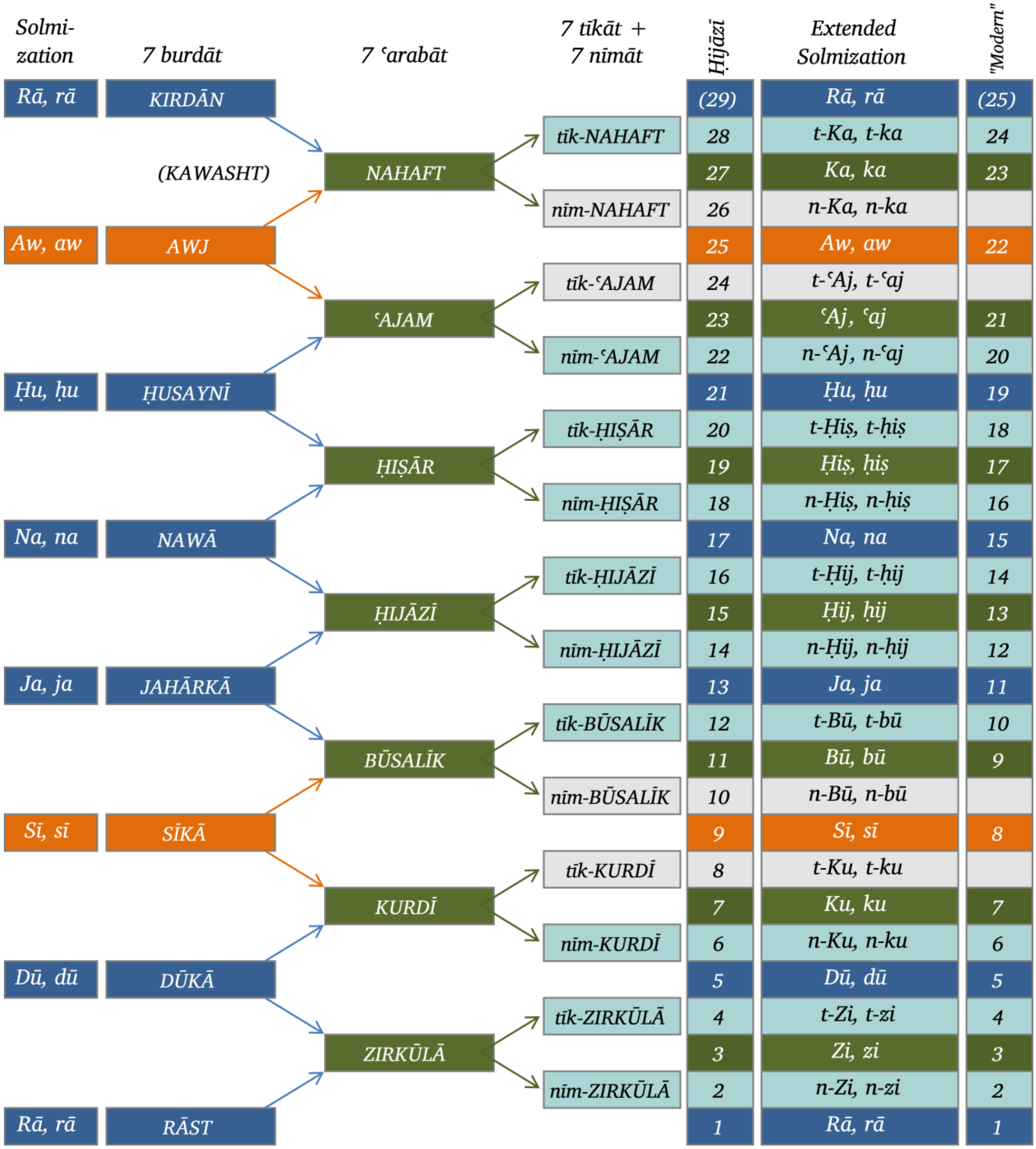
FHT 54 Transliterated denominations of the degrees of the “Arabian” scale according to [Ḥilū (al-), 1972, p. 69]. “(O)” indicates an octave change; background colors follow the conventions expounded in [Beyhom, 2005, p. 112, Fig. 3.29] and [Beyhom, 2012]. Note that *BŪSALĪK* is here equivalent to *e* “natural” (compare with Khulaʿī’s *BŪSALĪK* in the next figure) and that *SHŪRĪ* is assimilated to a^{b} and to *ḤIṢĀR*, while *ṢABĀ* is equivalent to *ḤIJĀZ*.

No.	Notation	Mashāqa	Khulaʿī	Ḥilū
(25)	g_2	NAWĀ	NAWĀ	NAWĀ
24	$g_2^{½b}$	t-ḤIJĀZ	t-ḤIJĀZ + ṢABĀ	t-ḤIJĀZ
23	$f_1^{\#}/g_2^{b}$	ḤIJĀZ	ḤIJĀZ	ḤIJĀZ + ṢABĀ
22	$f_1^{½\#}$	+ ʿARABĀʾ	n-ḤIJĀZ	+ ʿARABĀʾ
21	f_1	JAHĀRKĀ	JAHĀRKĀ	JAHĀRKĀ
20	$e_1^{½\#}/f_1^{½b}$	t-BŪSALĪK	BŪS. or ʿUSHSHĀQ	t-BŪSALĪK
19	e_1	BŪSALĪK	n-BŪSALĪK	BŪSALĪK
18	$e_1^{½b}$	SĪKĀ	SĪKĀ	SĪKĀ
17	$d_1^{\#}/e_1^{b}$	KURDĪ	KURDĪ	KURD
16	$d_1^{½\#}$	n-KURDĪ	n-KURDĪ + NAH.	n-KURD
15	d_1	DŪKĀ	DŪKĀ	DŪKĀ
14	$d_1^{½b}$	t-ZIRKULĀ	t-ZĪRKŪLA	t-ZIRKŪLĀ
13	$c_1^{\#}/d_1^{b}$	ZIRKULĀ	ZĪR. or ZINKULĀ	ZIRKŪLĀ
12	$c_1^{½\#}$	n-ZIRKULĀ	n-ZĪRKŪLA	n-ZIRKŪLĀ
11	c_1	RĀST	RĀST	RĀST
10	$b_1^{½\#}/c_1^{½b}$	t-KAWASHT	KAWASHT + NAHAFT	t-KAWASHT
9	b_1	KAWASHT	n-K. + RAHĀWĪ	KAWASHT
8	$b_1^{½b}$	ʿIRĀQ	ʿIRĀQ	ʿIRĀQ
7	$a_1^{\#}/b_2^{b}$	q-ʿAJAM	ʿAJAM-ʿU.	q-ʿAJAM
6	$a_1^{½\#}$	q-n-ʿAJAM	n-ʿAJAM-ʿU.	q-n-ʿAJAM
5	a_1	ʿUSHAYRĀN	ʿUSHAYRĀN	ʿUSHAYRĀN
4	$a_1^{½b}$	q-t-ḤIṢĀR	t-q-ḤIṢĀR + SHŪRĪ	q-t-ḤIṢĀR
3	$g_1^{\#}/a_1^{b}$	q-ḤIṢĀR	q-ḤIṢĀR	q-ḤIṢĀR
2	$g_1^{½\#}$	q-n-ḤIṢĀR	n-q-ḤIṢĀR	q-n-ḤIṢĀR
1	g_1	YĀKĀ	YĀKĀ	YĀKĀ
No.	Notation	Mashāqa	Khulaʿī	Ḥilū

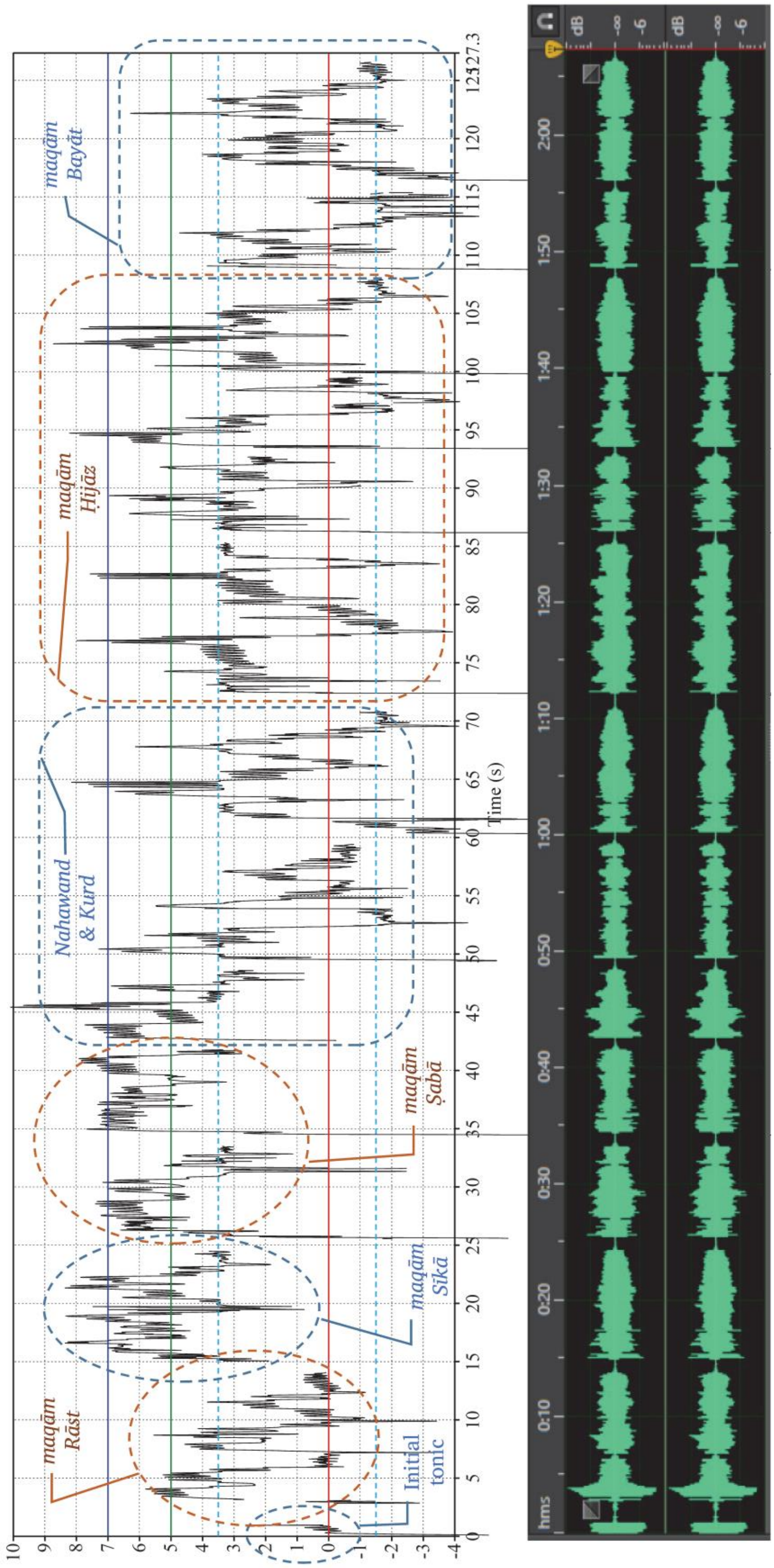
FHT 55 Compared denominations of the degrees of the lower octave of "Arabian" music according to Mashāqa, Khulaʿī and Ḥilū. *BŪS.* = *BŪSALIK*; *NAH.* = *NAHĀWAND*; *ʿU.* = *ʿUSHAYRĀN*; *ZĪR.* = *ZĪRKŪLA*; *q-* = *qarār* ("lower octave of"); *j-* = *jawāb* ("upper octave of"); *t-* = *tik* ("1 quarter-tone higher than"); *n-* = *nīm* ("1 quarter-tone lower than"); "+" = same as the other authors plus the following denomination. Detailed information is provided in footnotes to the original tables (in French) published in [Beyhom, 2014, p. 158–160].

No.	Notation	Mashāqa	Khulaʿī	Ḥilū
(49)	g_3	*RAMAL-TŪTĪ*	*RAMAL-TŪTĪ*	*RAMAL-TŪTĪ*
48	g_3^{hb}	*j-t-ḤIJĀZ*	*+ j-ṢABĀ*	*j-t-ḤIJĀZ*
47	$f_2^{\#}/g_3^{b}$	*j-ḤIJĀZ*	*j-ḤIJĀZ*	*j-ḤIJĀZ*
46	$f_2^{h\#}$	*+j-ʿARABĀʾ*	*j-n-ḤIJĀZ*	*j-n-ḤIJĀZ*
45	f_2	*MĀHŪRĀN*	*MĀHŪRĀN*	*MĀHŪRĀN*
44	$e_2^{h\#}/f_2^{hb}$	*t-ḤUS.-SHADD*	*j-BŪSALIK*	*t-ḤUS.-SHADD*
43	e_2	*ḤUS.-SHADD*	*j-n-BŪSALIK*	*ḤUS.-SHADD*
42	e_2^{hb}	*BUZURK*	*j-SĪKĀ*	*BUZURK*
41	$d_2^{\#}/e_2^{b}$	*SUNBULA*	*SUNBULA*	*+ZAWĀL*
40	$d_2^{h\#}$	*n-SUNBULA*	*n-SUNBULA*	*n-ZAWĀL*
39	d_2	*MUḤAYYAR*	*MUḤAYYAR*	*MUḤAYYAR*
38	d_2^{hb}	*t-SHĀH-NĀZ̤*	*t-SHĀH-NĀZ̤*	*t-SHĀH-NĀZ̤*
37	$c_2^{\#}/d_2^{b}$	*SHĀH-NĀZ̤*	*SHĀH-NĀZ̤*	*SHĀH-NĀZ̤*
36	$c_2^{h\#}$	*n-SHĀH-NĀZ̤*	*n-SHĀH-NĀZ̤*	*+KUNNĀZ*
35	c_2	*MĀHŪR*	*KARDĀN*	*+MĀHŪR*
34	$b_2^{h\#}/c_2^{hb}$	*t-NAHAFT*	*MĀHŪR+NAHAFT*	*t-NAHAFT*
33	b_2	*NAHAFT*	*n-MĀHŪR*	*NAHAFT*
32	b_2^{hb}	*AWJ*	*AWJ*	*AWJ*
31	$a_2^{\#}/b_3^{b}$	*ʿAJAM*	*ʿAJAM+NĪRIZ*	*ʿAJAM+NĪRIZ*
30	$a_2^{h\#}$	*n-ʿAJAM*	*n-ʿAJAM*	*n-ʿAJAM*
29	a_2	*ḤUSAYNĪ*	*ḤUSAYNĪ*	*ḤUSAYNĪ*
28	a_2^{hb}	*t-ḤIṢĀR*	*+SHŪRĪ*	*t-ḤIṢĀR*
27	$g_2^{\#}/a_2^{b}$	*ḤIṢĀR*	*ḤIṢĀR*	*ḤIṢĀR/SHŪRĪ*
26	$g_2^{h\#}$	*n-ḤIṢĀR*	*n-ḤIṢĀR*	*n-ḤIṢĀR*
25	g_2	*NAWĀ*	*NAWĀ*	*NAWĀ*
No.	Notation	Mashāqa	Khulaʿī	Ḥilū

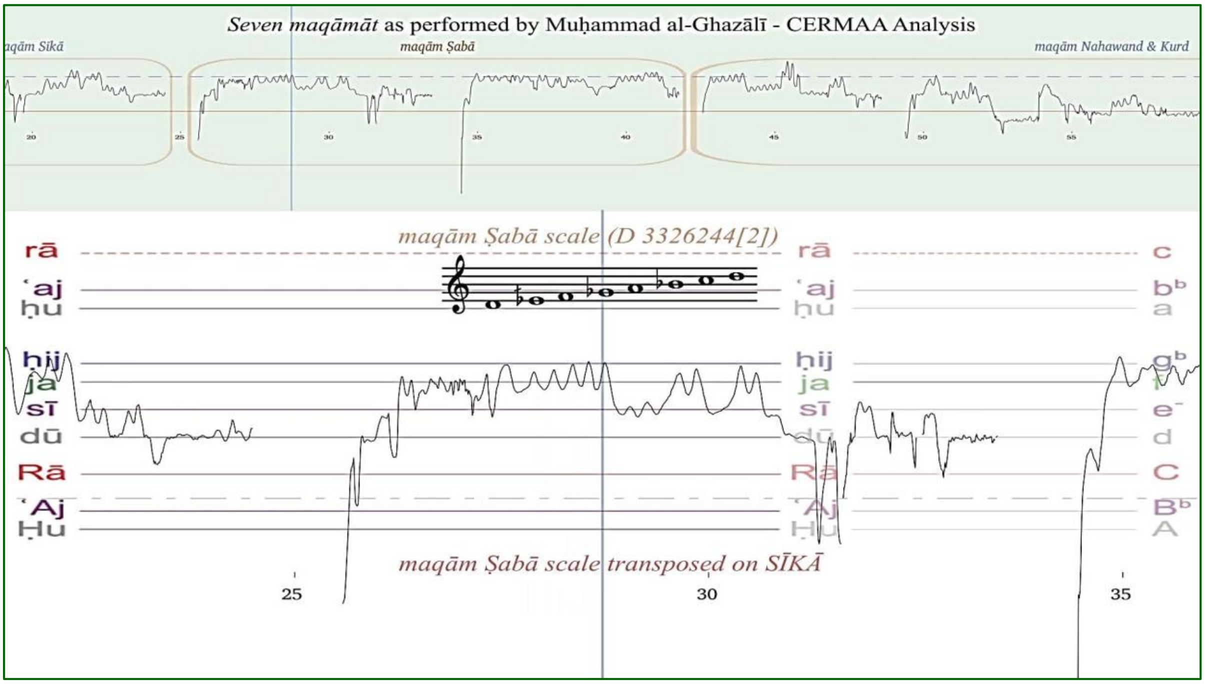
FHT 56 Compared denominations of the degrees of the upper octave of "Arabian" music according to Mashāqa, Khulaʿī and Ḥilū. *ḤUS.* = *ḤUSAYNĪ*; *q-* = *qarār* ("lower octave of"); *j-* = *jawāb* ("upper octave of"); *t-* = *tīk* ("1 quarter-tone higher than"); *n-* = *nīm* ("1 quarter-tone lower than"); "+" = same as the other authors plus the following denomination. Detailed information is provided in footnotes to the original tables (in French) published in [Beyhom, 2014, p. 158–160].

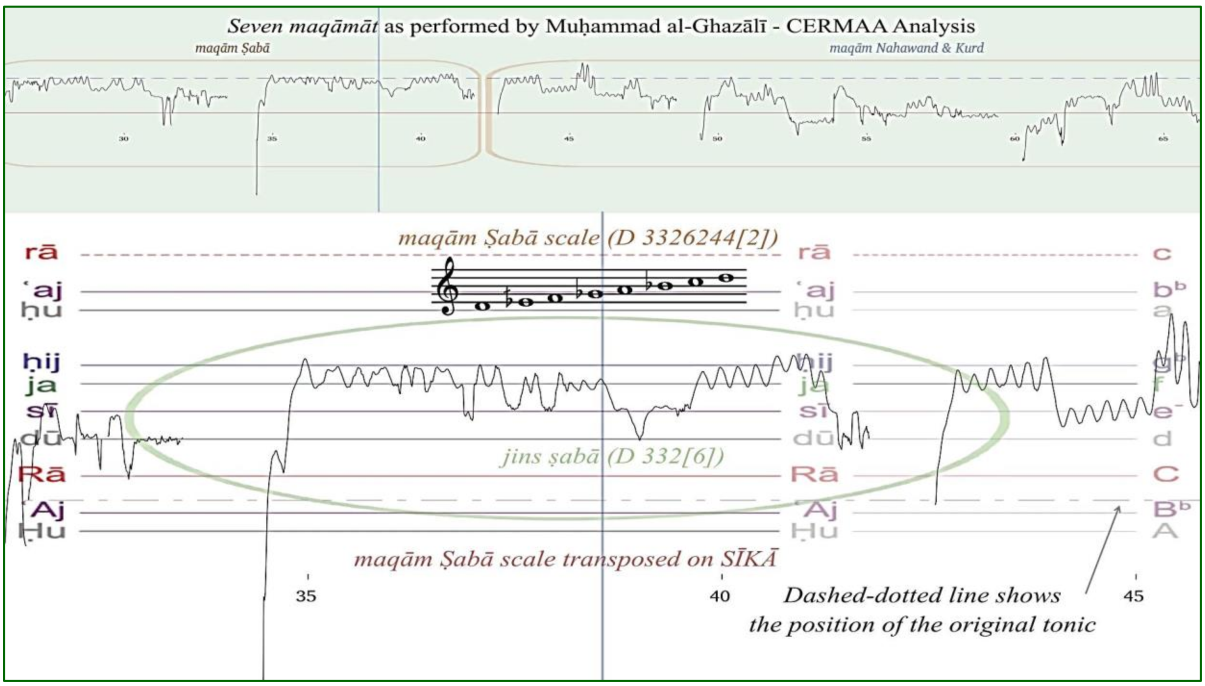


FHT 57 Extended solmization of the scale of *maqām* music as proposed by the author. Columns from left to right: (1) Original (7 notes per octave) solmization proposed in [Beyhom, 2012]; (2) Names of the main notes of the scale (the *burdāt* of *maqām RĀST*); (3) Names of the intermediate notes between the *burdāt* (*ʿarabāt*); (4) Names of the intermediate notes between the *ʿarabāt* (*tīk* = raised, *nīm* = lowered); (5) number of the note in the scale of al-Ḥijāzī; (6) Extended solmization as proposed by the author; (7) Corresponding numbers of the notes in the "Modern" scale (Western-inspired on the base of the division of the half-tone in two equal parts). Note that *RĀST* equates with *c* while however not indicating a fixed (but a relative) pitch. Degrees *tīk-KURDĪ*, *nīm-BŪSALĪK*, *tīk-ʿAJAM* and *nīm-NAHAFT* figure on a gray background to underline the fact that the "Modern" theory of the scale does not acknowledge them: consequently, the intervals between adjacent notes in column (7) – the last to the right – differ one from another by one quarter-tone (theoretical). Lastly: the solmization of note *NAHAFT* was modified as to avoid creating a duplicate with the (main) note *NAWĀ*: *KAWASHT* is the equivalent of *NAHAFT* in the lower octave (below the *RĀST*). See also the tables in FHT 54 for a complete review of the degrees of the two-octavial scale of *maqām* music.



FHT 58 An overview of the analysis of the *7 maqāmāt* piece by Muḥammad al-Ghazālī.





FHT 59 Two frames from the video-animated analysis of *7 maqāmāt* as performed by the *qāri*ʾ Muḥammad al-Ghazālī.

References

1. ABRAHAM, Otto and Erich Moritz (von) HORNBOSTEL: "Studien über das Tonsystem und die Musik der Japaner", *Sammelbände der Internationalen Musikgesellschaft 4 2* |1903-2-1| [url: http://www.jstor.org/stable/929003] p. 302–360.
2. ABRAHAM, Otto and Erich Moritz (von) HORNBOSTEL: "Phonographierte indische Melodien", *Sammelbände der Internationalen Musikgesellschaft 5 3* |1904-5-1| [url: http://www.jstor.org/stable/929162] p. 348–401.
3. ABRAHAM, Otto and Erich Moritz (von) HORNBOSTEL: "Über die Harmonisierbarkeit exotischer Melodien", *Sammelbände der Internationalen Musikgesellschaft 7 1* |1905-1-1| [url: http://www.jstor.org/stable/929150] p. 138–141.
4. ABRAHAM, Otto and Erich Moritz (von) HORNBOSTEL: "Vorschläge für die Transkription exotischer Melodien", *Sammelbände der Internationalen Musikgesellschaft 11 1* |1909-10-1| [url: http://www.jstor.org/stable/929275] p. 1–25.
5. ABRAHAM, Otto and Erich Moritz (von) HORNBOSTEL: "Suggested Methods for the Transcription of Exotic Music", *Ethnomusicology 38 3* |1994-10-1| [doi: 10.2307/852110. url: http://www.jstor.org/stable/852110] p. 425–456.
6. ALLAN, GE: "XVIII. The musical scale of the highland bagpipe", *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science 29 193* |1940| p. 154–161.
7. Anon. "DOTĀR" [url: http://www.iranicaonline.org/articles/dotar].
8. Anon. "First name Shirzad - NamepediA" [url: http://namepedia.org/en/firstname/Shirzad/].
9. Anon. "From the Editor (Vol. 8, issue 3)", *Ethnomusicology 8 3* |1964| [url: http://www.jstor.org/stable/850123] p. iv.
10. Anon. "How Can I Keep From Singing? A Seeger Family Tribute (The American Folklife Center, Library of Congress)" [url: http://www.loc.gov/folklife/Seegersymposium/].
11. Anon. "iAnalyse 3 & 4 | Pierre Couprie" [url: http://logiciels.pierrecouprie.fr/?page_id=672].
12. Anon. "Notation musicale et visualisation du son - SEEM" [url: http://seem.paris-sorbonne.fr/Notation-musicale-et-visualisation].
13. Anon. "Pierre Couprie | Logiciels" [url: http://logiciels.pierrecouprie.fr/].
14. Anon. "pierrecouprie (Pierre Couprie)", *GitHub* [url: https://github.com/pierrecouprie].
15. Anon. "Seeger Family Concert", Video, *Library of Congress, Washington, D.C. 20540 USA* [url: https://www.loc.gov/item/ihas.200196407/].
16. Anon. "sheikh", *The Free Dictionary* [url: https://www.thefreedictionary.com/sheikh].
17. Anon. "Sheikh | Arabic title", *Encyclopedia Britannica* [url: https://www.britannica.com/topic/sheikh].
18. Anon. "Sonic Visualiser" [url: https://www.sonicvisualiser.org/].
19. ANONYME: *A-sh-Shajara Dhāt al-Akmām al-Ḥāwiya li-Uṣūl al-Anghām [The tree with calyxes which contains the origins of the melodies]*, editors Ghaṭṭās ʿAbd-al-Malik Khashaba (غطاس عبد الملك خشبة) and Isis Fatḥ-al-Lāh (د. أيزيس فتح الله), Al-Hayʾa al-Miṣriyya al-ʿĀmma li-l-Kitāb (الهيئة المصرية العامة للكتاب) |Le Caire, 1983-xiv^e siècle|.
20. ANONYMOUS: Kyrie Ekekraxa *in Arabic*, Windows PCM (.wav), Comp. Petros (Byzantios), CDA-009 |Mansourieh - Liban, 2011a-5-25|.
21. ANONYMOUS: Kyrie Ekekraxa *in Greek*, Windows PCM (.wav), Comp. Petros (Byzantios) and Mitrī Murr (al-), CDA-008 |Mansourieh - Liban, 2011b-5-25|.
22. ANTAR, Thérèse (soeur Berthe): *Héritage de la musique orientale*, Dār Al-Ibdāʿ |Beyrouth, 1999|.
23. APEL, Willi: *The notation of polyphonic music, 900-1600*, Cambridge, Mass., Mediaeval Academy of America |1961| [url: http://archive.org/details/notationofpolyph00apel].
24. AROM, Simha: "Essai d'une notation des monodies a des fins d'analyse", *Revue de Musicologie 55 2* |1969-1-1| [doi: 10.2307/927823. url: http://www.jstor.org/stable/927823] p. 172–216.
25. AROM, Simha: "Une méthode pour la transcription de polyphonies et polyrythmies de tradition orale", *Revue de Musicologie 59 2* |1973-1-1| [doi: 10.2307/928853. url: http://www.jstor.org/stable/928853] p. 165–190.
26. AROM, Simha: "The Use of Play-Back Techniques in the Study of Oral Polyphonies", *Ethnomusicology 20 3* |1976| [doi: 10.2307/851046. url: http://www.jstor.org/stable/851046] p. 483–519.
27. AROM, Simha: "Nouvelles perspectives dans la description des musiques de tradition orale", *Revue de Musicologie 68 1/2* |1982-1-1| [doi: 10.2307/928289. url: http://www.jstor.org/stable/928289] p. 198–212.
28. ATKINSON, Charles M.: *The Critical Nexus: Tone-System, Mode, and Notation in Early Medieval Music, AMS studies in music*, Oxford University Press |Oxford; New York, 2008-12-19|.
29. AZAR BEYHOM, Rosy: "La modalité écrite: un exemple avec Mīkhāʾīl Mashāqa au XIX^e siècle", *Near Eastern Musicology Online 1 1* |2012-11| [url: http://nemo-online.org/wp-content/uploads/2016/12/INTERNET-05.-Article-NEMO-n%C2%B01-1-Rozy-Azar-Beyhom-Reissue-201612S.pdf] p. 55–66.
30. BACHA, Toufic El: *Le violon et les quarts des tons, Vol. 2*, ed. Original, *CNSM (Liban)* 24, Conservatoire National de Musique (Liban) |Beyrouth - Liban, s.d. (199x)|.
31. BAKER, Theodore: *Über die Musik der nordamerikanischen Wilden*, Ph.D., Universität Leipzig, Druck von Breitkopf & Härtel |Leipzig, 1882| [url: http://archive.org/details/berdiemusikdern01bakegoog].
32. BEHAR, Cem @ to Amine Beyhom: "do = sol" |2013-10-5|.
33. BEHAR, Cem @ to Amine Beyhom: "Shadd-Araban" |2014-9-26|.
34. BENT, Ian D., David W. HUGHES, Robert C. PROVINE, et al.: "Notation", editor Stanley Sadie, *New Grove: Dictionary of Music & Musicians 18/* |Oxford, 2001| p. 73–189.
35. BERGER, Donald Paul: "The Shakuhachi and the Kinko Ryū Notation", *Asian Music 1 2* |1969-10-1| [doi: 10.2307/833910. url: http://www.jstor.org/stable/833910] p. 32–72.
36. BEYHOM, Amine: *1. Systématique modale – Volume I*, Thèse de doctorat, Université Paris Sorbonne |2003a-9-1| [url: http://foredofico.org/CERMAA/publications/publications-on-the-site/publications-amine-beyhom].
37. BEYHOM, Amine: *Systématique modale – Volume I-II-III*, Thèse de doctorat, Université Paris Sorbonne |Paris, 2003b-9-1| [url: http://foredofico.org/CERMAA/publications/publications-on-the-site/publications-amine-beyhom].
38. BEYHOM, Amine: *2. Systématique modale – Volume II*, Thèse de doctorat, Université Paris Sorbonne |2003c-9-2| [url: http://

foredofico.org/CERMAA/publications/publications-on-the-site/publications-amine-beyhom].
39. Beyhom, Amine : *3. Systématique modale – Volume III*, Thèse de doctorat, Université Paris Sorbonne |2003d-9-3| [url: http://foredofico.org/CERMAA/publications/publications-on-the-site/publications-amine-beyhom].
40. Beyhom, Amine : "Systématique modale : génération et classement d'échelles modales", *Musurgia XI 4* |2004-12| [url: http://foredofico.org/CERMAA/wp-content/uploads/2017/11/Beyhom-2004-Systématique-modale-intro-appendices-Musurgia-XI_4-2004_OCR.pdf] p. 55–68.
41. Beyhom, Amine : "Approche systématique de la musique arabe : genres et degrés système", *De la théorie à l'Art de l'improvisation : analyse de performances et modélisation musicale*, ed. Mondher Ayari, Delatour |Paris, 2005-12| [url: http://foredofico.org/CERMAA/wp-content/uploads/2017/11/Beyhom_2005_Genres_et_echelle_systeme_Delatour.pdf] p. 65–114.
42. Beyhom, Amine : "Dossier : Mesures d'intervalles – méthodologie et pratique", *Revue des Traditions Musicales des Mondes Arabe et Méditerranéen 1 1* |2007-6| [url: http://foredofico.org/CERMAA/wp-content/uploads/2017/11/Beyhom_2007_Mesures_d_intervalles_RTMMAM_n11.pdf] p. 181–235.
43. Beyhom, Amine : "A new hypothesis on the elaboration of heptatonic scales and their origins", *ICONEA 2008*, Lulu on behalf of ICONEA PUBLICATIONS, LONDON-UK |London, 2010a| [url: http://foredofico.org/CERMAA/wp-content/uploads/2017/11/ICONEA-2008-2010-Hypothesis-Beyhom-complete.pdf] p. 151–209.
44. Beyhom, Amine : *Une approche systématique et diachronique de la modalité maqamienne*, Mémoire d'habilitation à diriger les recherches (HDR), Université Paris Sorbonne |Paris (France), 2010b-3-9|.
45. Beyhom, Amine : *Théories de l'échelle et pratiques mélodiques chez les Arabes – Volume 1 : L'échelle générale et les genres – Tome 1 : Théories gréco-arabes de Kindī (IXe siècle) à Ṭūsī (XIIIe siècle) 1/4* (vols.), Librairie orientaliste Paul Geuthner |Paris, 2010c-11|.
46. Beyhom, Amine : "*Kashf al-Asrār ʿan Karkarat al-Aḥbār fī Taʾwīl al-Adwār* كشف الأسرار عن كركرة الأحبار في تأويل الأدوار", *Near Eastern Musicology Online 1 1* |2012-11| [url: http://nemo-online.org/wp-content/uploads/2016/12/INTERNET-06.-Article-NEMO-n%C2%B01-1-Amine-Beyhom-Reissue-201612S.pdf] p. 67–88.
47. Beyhom, Amine : "*Dossier* : Influence des théories européanisées du XIXe siècle sur la notation et la pratique des modes de la musique arabe et d'autres musiques, à travers la mise en exergue du mythe du genre *ḥijāz* semi-tonal", *Near Eastern Musicology Online 2 3* |2014-11| [url: http://nemo-online.org/wp-content/uploads/2016/12/INTERNET-06.-Article-NEMO-n%C2%B01-1-Amine-Beyhom-Reissue-201612S.pdf] p. 87–177.
48. Beyhom, Amine : *Théories et pratiques de l'échelle dans le chant byzantin arabe : Une approche comparative et analytique proposant une solution inédite pour le système théorique de Chrysanthos le Madyte*, Par l'auteur |Broummana (Liban), 2015-9|.
49. Beyhom, Amine : "*Dossier*: Hellenism as an Analytical tool for Occicentrism (in musicology) (V2)", *Near Eastern Musicology Online 3 5* |2016a-11| [url: http://nemo-online.org/wp-content/uploads/2017/02/(V2-INTERNET)%205-04.%20Article%20NEMO%20n%C2%B05%20Amine%20Beyhom%20170219S.pdf] p. 53–275.
50. Beyhom, Amine : "*Dossier*: Hellenism as an Analytical tool for Occicentrism (in musicology)", *Near Eastern Musicology Online 3 5* |2016b-11| [url: http://nemo-online.org/articles] p. 53–273.
51. Beyhom, Amine : "A Hypothesis for the Elaboration of Heptatonic Scales", *Near Eastern Musicology Online 4 6* |2017-11| [url: http://nemo-online.org/] p. 5–89.
52. Beyhom, Amine : *HURRIAN SONG 6 (H6) by CERMAA (DUMBRILL BEYHOM AZAR-BEYHOM JOKHADAR)*, 1920x1080, CERMAA |Broummana, 2018a-2-15| [url: https://www.youtube.com/watch?v=U8Yr6mKc550].
53. Beyhom, Amine : Kyrie Ekekraxa *by Petros Byzantios performed by fr. Makarios Haidamous in Arabic*, 1920x1080, *Kyrie Ekekraxa by Petros Byzantios*, CERMAA |Broummana - Lebanon, 2018b-2-16| [url: https://www.youtube.com/edit?o=U&video_id=j8w9I9CfF0c].
54. Beyhom, Amine : Kyrie Ekekraxa *by Petros Byzantios performed by an Anonymous Cantor in Greek*, 1920x1080, *Kyrie Ekekraxa by Petros Byzantios*, CERMAA |Broummana - Lebanon, 2018c-2-19| [url: https://www.youtube.com/edit?o=U&video_id=ush88CvgQYk].
55. Beyhom, Amine : Kyrie Ekekraxa *by Petros Byzantios performed by fr. Makarios Haidamous in Greek*, 1920x1080, *Kyrie Ekekraxa by Petros Byzantios*, CERMAA |Broummana - Lebanon, 2018d-2-19| [url: https://www.youtube.com/edit?o=U&video_id=8SSETdJWC8o].
56. Beyhom, Amine : Kyrie Ekekraxa *by Petros Byzantios performed by an Anonymous Cantor in Arabic*, 1920x1080, *Kyrie Ekekraxa by Petros Byzantios*, CERMAA |Broummana - Lebanon, 2018e-2-19| [url: https://www.youtube.com/edit?o=U&video_id=Uek_AD_aRQg].
57. Beyhom, Amine : Kyrie Ekekraxa *by Petros Byzantios performed by fr. Nicolas Malek in Arabic*, 1920x1080, *Kyrie Ekekraxa by Petros Byzantios*, CERMAA |Broummana - Lebanon, 2018f-2-22| [url: https://www.youtube.com/edit?o=U&video_id=wI-hyN30y-qc].
58. Beyhom, Amine : Kyrie Ekekraxa *by Petros Byzantios performed by fr. Nicolas Malek in Greek*, 1920x1080, *Kyrie Ekekraxa by Petros Byzantios*, CERMAA |Broummana - Lebanon, 2018g-2-22| [url: https://www.youtube.com/edit?o=U&video_id=w6YWloCd2Do].
59. Beyhom, Amine : Kyrie Ekekraxa *by Petros Byzantios performed by Joseph Yazbeck in Arabic (abrid.)*, 1920x1080, *Kyrie Ekekraxa by Petros Byzantios*, CERMAA |Broummana - Lebanon, 2018h-2-26| [url: https://www.youtube.com/edit?o=U&video_id=QvKcoi7LdVI].
60. Beyhom, Amine : Kyrie Ekekraxa *by Petros Byzantios performed by Joseph Yazbeck in Greek (abrid.)*, 1920x1080, *Kyrie Ekekraxa by Petros Byzantios*, CERMAA |Broummana - Lebanon, 2018i-2-26| [url: https://www.youtube.com/edit?o=U&video_id=uvElBc7-3-4].
61. Beyhom, Amine : Kyrie Ekekraxa *by Petros Byzantios performed by Bachir Osta in Arabic*, 1920x1080, *Kyrie Ekekraxa by Petros Byzantios*, CERMAA |Broummana - Lebanon, 2018j-9-6| [url: https://www.youtube.com/edit?o=U&video_id=QvKcoi7LdVI].
62. Beyhom, Amine : Kyrie Ekekraxa *by Petros Byzantios performed by Bachir Osta in Arabic (Half-Tempo)*, 1920x1080, *Kyrie Ekekraxa by Petros Byzantios*, CERMAA |Broummana - Lebanon, 2018k-9-6| [url: https://www.youtube.com/edit?o=U&video_id=QvKcoi7LdVI].
63. Beyhom, Amine : Kyrie Ekekraxa *by Petros Byzantios performed by Bachir Osta in Greek*, 1920x1080, *Kyrie Ekekraxa by Petros Byzantios*, CERMAA |Broummana - Lebanon, 2018l-9-6| [url: https://youtu.be/WQVdSqLh1v4].
64. Beyhom, Amine : Kyrie Ekekraxa *by Petros Byzantios performed by Bachir Osta in Greek (Half-Tempo)*, 1920x1080, *Kyrie Ekekraxa by*

Petros Byzantios, CERMAA |Broummana - Lebanon, 2018m-9-6| [url: https://youtu.be/Jcg_xSC5NXA].

65. BEYHOM, Amine : Kyrie Ekekraxa *by Petros Byzantios performed by an Anonymous Cantor in Arabic (V2)*, 1920x1080, *Kyrie Ekekraxa by Petros Byzantios*, CERMAA |Broummana - Lebanon, 2018n-9-6| [url: https://youtu.be/uGL8PtgNH1Y].
66. BEYHOM, Amine : Kyrie Ekekraxa *by Petros Byzantios performed by an Anonymous Cantor in Arabic (V2 - Half-Tempo)*, 1920x1080, *Kyrie Ekekraxa by Petros Byzantios*, CERMAA |Broummana - Lebanon, 2018o-9-6| [url: https://youtu.be/2-zsuOXtFsU].
67. BEYHOM, Amine : Kyrie Ekekraxa *by Petros Byzantios performed by an Anonymous Cantor in Greek (V2)*, 1920x1080, *Kyrie Ekekraxa by Petros Byzantios*, CERMAA |Broummana - Lebanon, 2018p-9-6| [url: https://youtu.be/f-QHaMJ5138].
68. BEYHOM, Amine : Kyrie Ekekraxa *by Petros Byzantios performed by an Anonymous Cantor in Greek (V2 - Half-Tempo)*, 1920x1080, *Kyrie Ekekraxa by Petros Byzantios*, CERMAA |Broummana - Lebanon, 2018q-9-6| [url: https://youtu.be/cVvwFtQE8Dc].
69. BEYHOM, Amine : Kyrie Ekekraxa *by Petros Byzantios performed by Emmanouil Giannopoulos*, 1920x1080, *Kyrie Ekekraxa by Petros Byzantios*, CERMAA |(Volos) Broummana - (Greece) Lebanon, 2018r-9-6| [url: https://youtu.be/7_DawlHFeOk].
70. BEYHOM, Amine : Kyrie Ekekraxa *by Petros Byzantios performed by Ioannis Tomas*, 1920x1080, *Kyrie Ekekraxa by Petros Byzantios*, CERMAA |(Volos) Broummana - (Greece) Lebanon, 2018s-9-6| [url: https://youtu.be/ettIzTmrlpw].
71. BEYHOM, Amine : Kyrie Ekekraxa *by Petros Byzantios performed by Michalis Stroumpakis*, 1920x1080, *Kyrie Ekekraxa by Petros Byzantios*, CERMAA |(Volos) Broummana - (Greece) Lebanon, 2018t-9-6| [url: https://youtu.be/Ije3EdE9bws].
72. BEYHOM, Amine : Kyrie Ekekraxa *by Petros Byzantios performed by Nikolaos Siklafidis*, 1920x1080, *Kyrie Ekekraxa by Petros Byzantios*, CERMAA |(Volos) Broummana - (Greece) Lebanon, 2018u-9-6| [url: https://youtu.be/AvNz2oUYSHY].
73. BEYHOM, Amine : Axion Estin *by Anonymous performed by fr. Makarios Haidamous*, 1920x1080, *Axion Estin by Anonymous*, CERMAA |Broummana - Lebanon, 2018v-9-6| [url: https://youtu.be/aWnwPvG0Ri8].
74. BEYHOM, Amine : Axion Estin *by Anonymous performed by an Anonymous Cantor*, 1920x1080, *Axion Estin by Anonymous*, CERMAA |Broummana - Lebanon, 2018w-9-6| [url: https://youtu.be/DWsRxCih8hM].
75. BEYHOM, Amine : Axion Estin *by Anonymous performed by fr. Nicolas Malek*, 1920x1080, *Axion Estin by Anonymous*, CERMAA |Broummana - Lebanon, 2018x-9-6| [url: https://youtu.be/UNYUlFNwHuM].
76. BEYHOM, Amine : Axion Estin *by Anonymous performed by fr. Nicolas Malek (Alternate Take no. 2)*, 1920x1080, *Axion Estin by Anonymous*, CERMAA |Broummana - Lebanon, 2018y-9-6| [url: https://youtu.be/JYZAjDYjj60].
77. BEYHOM, Amine : Axion Estin *by Anonymous performed by Joseph Yazbeck*, 1920x1080, *Axion Estin by Anonymous*, CERMAA |Broummana - Lebanon, 2018z-9-6| [url: https://youtu.be/_Cpyf9hqUEc].
78. BEYHOM, Amine : Axion Estin *by Anonymous performed by Emmanouil Giannopoulos*, 1920x1080, *Axion Estin by Anonymous*, CERMAA |(Volos) Broummana - (Greece) Lebanon, 2018aa-9-6| [url: https://youtu.be/4VpOchjbEZA].
79. BEYHOM, Amine : Axion Estin *by Anonymous performed by Nikolaos Siklafidis*, 1920x1080, *Axion Estin by Anonymous*, CERMAA |(Volos) Broummana - (Greece) Lebanon, 2018ab-9-6| [url: https://youtu.be/gyxoviJs1aU].
80. BEYHOM, Amine : Axion Estin *by Anonymous performed by Ioannis Tomas*, 1920x1080, *Axion Estin by Anonymous*, CERMAA |(Volos) Broummana - (Greece) Lebanon, 2018ac-9-6| [url: https://youtu.be/QICHWCaOfQA].
81. BEYHOM, Amine : Axion Estin *by Anonymous performed by Michalis Stroumpakis*, 1920x1080, *Axion Estin by Anonymous*, CERMAA |(Volos) Broummana - (Greece) Lebanon, 2018ad-9-6| [url: https://youtu.be/qM34JswCUZo].
82. BEYHOM, Amine : Axion Estin *by Anonymous performed by Rosy Beyhom*, 1920x1080, *Axion Estin by Anonymous*, CERMAA |Broummana - Lebanon, 2018ae-9-6| [url: https://youtu.be/lDhi2g6dPkY].
83. BEYHOM, Amine : Axion Estin *by Anonymous. Template Analysis of audio output by programs MUS2 (V2.1 - midi score) & CUBASE (V. 8.5 - HALION SONIC SE2 VST) - Left to Right*, 1920x1080, *Axion Estin by Anonymous*, CERMAA |Broummana - Lebanon, 2018af-9-6| [url: https://youtu.be/YuRD6G4PTuE].
84. BEYHOM, Amine : Axion Estin *by Anonymous. Template Analysis of audio output by programs MUS2 (V2.1 - midi score) & CUBASE (V. 8.5 - HALION SONIC SE2 VST) - Left to Right (Half-Tempo)*, 1920x1080, *Axion Estin by Anonymous*, CERMAA |Broummana - Lebanon, 2018ag-9-6| [url: https://youtu.be/MiRuhUt_tMQ].
85. BEYHOM, Amine : Axion Estin *by Anonymous. Template Analysis of audio output by programs MUS2 (V2.1 - midi score) & CUBASE (V. 8.5 - HALION SONIC SE2 VST) - Right to Left*, 1920x1080, *Axion Estin by Anonymous*, CERMAA |Broummana - Lebanon, 2018ah-9-6| [url: https://youtu.be/j3lyDA-IFPE].
86. BEYHOM, Amine : Axion Estin *by Anonymous. Template Analysis of audio output by programs MUS2 (V2.1 - midi score) & CUBASE (V. 8.5 - HALION SONIC SE2 VST) - Right to Left (Half-Tempo)*, 1920x1080, *Axion Estin by Anonymous*, CERMAA |Broummana - Lebanon, 2018ai-9-6| [url: https://youtu.be/tDXJkXGO8fo].
87. BEYHOM, Amine : *7* Maqāmāt *performed by Muḥammad al-Ghazālī*, 1920x1080, *Arabian* Maqāmāt, CERMAA |Broummana - Lebanon, 2018aj-9-6| [url: https://youtu.be/Uc22jh65r0M].
88. BEYHOM, Amine : *7* Maqāmāt *performed by Muḥammad al-Ghazālī (Half-Tempo)*, 1920x1080, *Arabian* Maqāmāt, CERMAA |Broummana - Lebanon, 2018ak-9-6| [url: https://youtu.be/6TvK2keRZe4].
89. BEYHOM, Amine : Ahlan bi-Ghazālin *performed by sheikh ʿAlī Maḥmūd*, 1920x1080, *Arabian* Maqāmāt, CERMAA |Broummana - Lebanon, 2018al-9-6| [url: https://youtu.be/s_Nsm4mzFns].
90. BEYHOM, Amine : Ahlan bi-Ghazālin *performed by sheikh ʿAlī Maḥmūd (Half-Tempo)*, 1920x1080, *Arabian* Maqāmāt, CERMAA |Broummana - Lebanon, 2018am-9-6| [url: https://youtu.be/3pbprgsRuRA].
91. BEYHOM, Amine : *"Ar bern plouz" chanté par Manu Kerjean à Bonen (22) éd. Dastum :* Manu Kerjean Chanteur du Centre-Bretagne *DAS153 (piste 15)*, 1920x1080, *Brittany*, CERMAA |Broummana - Lebanon, 2018an-10-10| [url: https://youtu.be/IlERM9mEw9g].
92. BEYHOM, Amine : *"Ar bern plouz" chanté par Manu Kerjean à Bonen (22) éd. Dastum :* Manu Kerjean Chanteur du Centre-Bretagne *DAS153 (piste 15) - Tempo = 1:3*, 1920x1080, *Brittany*, CERMAA |Broummana - Lebanon, 2018ao-10-10| [url: https://youtu.be/JYZAjDYjj60].

93. BORREL, Eugène : "La musique turque", *Revue de Musicologie 3 4* |1922| [url: http://www.jstor.org/stable/925743] p. 149–161.
94. BORREL, Eugène : "La musique turque (Suite)", *Revue de Musicologie 4 5* |1923a| [doi: 10.2307/925512. url: http://www.jstor.org/stable/925512] p. 26–32.
95. BORREL, Eugène : "La musique turque (Suite et fin). Les Oussouls", *Revue de Musicologie 4 6* |1923b| [url: http://www.jstor.org/stable/925898] p. 60–70.
96. BORREL, Eugène : "Raouf Yekta Béy. (1871-1935)", *Revue de Musicologie 16 53* |1935-2-1| [url: http://www.jstor.org/stable/925950] p. 64.
97. BRĂILOIU, Constantin : "Sur une mélodie russe", ed. P. Souvtchinsky, *Musique Russe* II, Presses Universitaires de France |1953| p. 329–391.
98. BUSONI, Ferruccio : *Sketch Of A New Esthetic Of Music*, translator Theodore Baker, New York : G. Schirmer |1911| [url: http://archive.org/details/sketchofanewesth000125mbp].
99. CARPENTER, Nan Cooke : "The Study of Music at the University of Paris in the Middle Ages", *Journal of Research in Music Education 2 2* |1954-10| [doi: 10.2307/3343693. url: http://journals.sagepub.com/doi/10.2307/3343693] p. 119–133.
100. CAZDEN, Norman : "Staff Notation as a Non-Musical Communications Code", *Journal of Music Theory 5 1* |1961-4-1| [doi: 10.2307/842874. url: http://www.jstor.org/stable/842874] p. 113–128.
101. CHABRIER, Jean-Claude Ch. : *Analyses de musiques traditionnelles. identification de systèmes acoustiques, scalaires, modaux et instrumentaux. représentation morpho-mélodique, structuro-modale et du langage instrumental Vol. 1 (A-B)*, Doctorat d'état, Université de Paris-Sorbonne |Paris - France, 1995|.
102. CHRYSANTHOS (DE MADYTOS) : *Εισαγωγή εις το Θεωρητικόν και Πρακτικό της Εκκλησιαστικής Μουσικής [Eisagogē eis to theōrētikon kai praktikon tēs ekklesiastikēs mousikēs – Introduction to the Theory and Practice of Ecclesiastical Music]*, Koultoura |En Parisiois (Paris), 1821|.
103. CHRYSANTHOS (DE MADYTOS) : *Great theory of music*, translator Kaitē Rōmanou, The Axion Estin Foundation |2010|.
104. CHRYSANTHOS (DE MADYTOS) and Panagiōtēs G. PELOPIDĒS : *Θεωρητικόν Μέγα της Μουσικής [Theōrētikon mega tēs mousikēs – Great theoretical book of music]*, En Tergeste : ek tes typographias Michael Vais (Michele Weis) |Trieste - Italie, 1832|.
105. CHRYSANTHOS (DE MADYTOS) and Kaitē RŌMANOU : *Great theory of music by Chrysanthos of Madytos*, Thesis, Indiana University |1973|.
106. COLLECTIF : *كتاب مؤتمر الموسيقى العربية Kitāb mu'tamar al-mūsīqā al-ʿarabiyya [Livre du Congrès de Musique arabe]*, Al-Maṭbaʿa al-Amīriyya (وزارة المعارف العمومية) |Le Caire 1933 ,القاهرة|.
107. COLLECTIF, ouvrage : *Recueil des Travaux du Congrès de Musique Arabe qui s'est tenu au Caire en 1932 (Hég. 1350) sous le Haut Patronage de S. M. FOUAD 1er, ROI D'ÉGYPTE*, Imprimerie Nationale d'Egypte |Le Caire - Egypte, 1934|.
108. COMMISSION MUSICALE DE (MUSICAL COMMITTEE OF) 1881, APHTONIDĒS and AL. : *Στοιχειώδης διδασκαλία της εκκλησιαστικής μουσικής εκπονηθείσα επί τη βάσει του ψαλτηρίου υπό της μουσική επιτροπής του Οικουμενικού* Πατριαρχείου *εν έτει 1883 [Elementary teachings of ecclesiastical music elaborated on the basis of the psaltery by the musical committee of the Ecumenical Patriarchate in the year 1883]*, ed. 2 (?), Coultoura |Athènes, 1978-1888|.
109. CONOMOS, Dimitri E. : "Petros Peloponnesios", *Grove Music Online* |2007-2012| [url: http://www.oxfordmusiconline.com/].
110. COOK, Nicholas : *Music: a very short introduction*, Oxford University Press |Oxford, 2000|.
111. COOK, Nicholas and Daniel LEECH-WILKINSON : "A musicologist's guide to Sonic Visualiser" [url: http://www.charm.rhul.ac.uk/analysing/p9_1.html].
112. COUPRIE, Pierre, Dominique FOBER, Jean BRESSON and Yann GESLIN : "Les nouveaux espaces de la notation musicale", *Journées d'informatique musicale* [url: https://www.academia.edu/20847919/Les_nouveaux_espaces_de_la_notation_musicale].
113. CRAWFORD, Richard : *The American Musicological Society, 1934-1984: An Anniversary Essay*, The AMS |1984|.
114. DAY, C. R. (Charles Russell) : *The music and musical instruments of southern India and the Deccan*, London & New York Novello, Ewer & co. [etc.] |1891| [url: http://archive.org/details/musicmusicalinst00dayc].
115. DENNY, F. M. : "Tad̲j̲wīd", *Encyclopaedia of Islam, Second Edition* |2012-4-24| [url: http://referenceworks.brillonline.com/entries/encyclopaedia-of-islam-2/tadjwid-COM_1145?s.num=0&s.rows=20&s.mode=DEFAULT&s.f.s2_parent=encyclopaedia-of-islam-2&s.start=0&s.q=tadjwid].
116. DESCHÊNES, Bruno : "A preliminary approach to the analysis of *honkyoku*, the solo repertoire of the Japanese *shakuhachi*", *Near Eastern Musicology Online 4 6* |2017-11| [url: http://nemo-online.org/Articles] p. 123–143.
117. DHĀKIR (BEY), Muḥammad : *الروضة البهية في أوزان الألحان الموسيقية [*A-r-Rawda al-Bahiyya fī Awzān al-Alḥān al-Mūsīqiyya*]*, *Dār al-Kutub al-Miṣriyya* |Le Caire ,القاهرة, 1890a|.
118. DHĀKIR (BEY), Muḥammad : *حياة الانسان في ترديد الالحان* Ḥayāt al-Insān fī Tardīd al-Alḥān, *Al-Kutubkhāna al-Khidyawiyya fī Miṣr* [La librairie khédiévale en Égypte] |Le Caire ,القاهرة, 1890b|.
119. DHĀKIR (BEY), Muḥammad : *تحفة الموعود بتعليم العود* Tiḥfat al-Mawʿūd fī Taʿlīm al-ʿŪd, 1st ed., Maṭbaʿat al-Liwā' |Shāriʿ a-d-Dawāwīn Miṣr (rue Dawāwīn – Égypte!), 1903|.
120. DUMBRILL, Richard : "The Truth about Babylonian music", *Near Eastern Musicology Online 4 6* |2017-11| [url: http://nemo-online.org/Articles] p. 91–121.
121. DURING, Jean : *La musique iranienne: tradition et évolution*, Recherche sur les Civilisations |Paris, France, 1984|.
122. ELLIS, Alexander John : "On the musical scales of various nations", *Journal of the Society of Arts 33* |1885| p. [485]-527.
123. ELLIS, Alexander John and A. J. HIPKINS : "Tonometrical Observations on Some Existing Non-Harmonic Musical Scales", *Proceedings of the Royal Society of London 37 232–234* |1884| p. 368–385.
124. EPHESIOS, Petros : *Neon Anastasimatarion* |1820|.
125. ERGUR, Ali and Nilgün DOĞRUSÖZ : "Resistance and Adoption towards Written Music at the Crossroads of Modernity: Gradual Passage to Notation in Turkish Makam Music", *International Review of the Aesthetics and Sociology of Music 46 1* |2015| [url: http://www.jstor.org/stable/24327332] p. 145–174.
126. ERLANGER, Rodolphe (d') : *La musique arabe, 6 tomes – I. [Al-Fārābī] (1930) ; II. [Al-Fārābī et Ibn Sīnā] (1935) ; III. [Commentaires sur Le Livre des Cycles de Safiyy-a-d-Dīn al-Urmawī] (1938) ; IV. [Anon. – a-sh-Shirwānī – et al-Lādhiqī] (1939) ; V. [Échelles et modes] (1949) ; VI. [Rythmes et formes] (1959)* 6 (vols.), Librairie orientaliste Paul Geuthner |Paris, 1930-1959|.
127. ERLANGER, Rodolphe (d') : *La musique arabe (5) – Essai de codification des règles usuelles de la musique arabe moderne. Échelle générale des sons, système modal 5/6* (vols.), Librairie Orientaliste Paul Geuthner |Paris, France, 1949|.

128. ERLANGER, Rodolphe (d'), Lasaad KRIAA and الأسعد قريعة : *Translation in Arabic of* La musique arabe (5) – Essai de codification des règles usuelles de la musique arabe moderne. Échelle générale des sons, système modal *5/6* (vols.), Sotimedia |Paris, France, 2018-1949|.

129. FELDMAN, Walter : *Music of the Ottoman Court: makam, composition and the early Ottoman instrumental repertoire*, *Intercultural Music studies*, VWB-Verlag für Wissenschaft und Bildung |Berlin, 1996|.

130. FILLMORE, John Comfort : "THE HARMONIC STRUCTURE OF INDIAN MUSIC", *American Anthropologist 1 2* |1899-4| [doi: 10.1525/aa.1899.1.2.02a00060. url: http://doi.wiley.com/10.1525/aa.1899.1.2.02a00060] p. 297–318.

131. FRASER, C. Gerald : "Charles Seeger, Musicologist, 92", *The New York Times*, sec. Archives |1979-2-8| [url: https://www.nytimes.com/1979/02/08/archives/charles-seeger-musicologist-92-father-of-folk-singer-was-first-to.html].

132. GEOFFROY, E. : "Shaykh", *Encyclopaedia of Islam, Second Edition* |2012-4-24| [url: http://referenceworks.brillonline.com/entries/encyclopaedia-of-islam-2/shaykh-SIM_6890?s.num=0&s.f.s2_parent=s.f.book.encyclopaedia-of-islam-2&s.q=shaykh].

133. GERSON-KIWI, Edith : "Towards an Exact Transcription of Tone-Relations", *Acta Musicologica 25 1/3* |1953-1-1| [doi: 10.2307/931677. url: http://www.jstor.org/stable/931677] p. 80–87.

134. GHULMIYYA, Walīd, Tawfīq KIRBĀJ and Anṭūn FARAḤ : *Naẓariyyāt al-Mūsīqā A-sh-Sharqī ʿArabiyya 5/*, CNSMB – Conservatoire National Supérieur de Musique de Beyrouth |Beyrouth, 1996|.

135. GIOVANNELLI, Alessandro : "Goodman's Aesthetics", *The Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta, ed. Fall 2017, Metaphysics Research Lab, Stanford University |2017| [url: https://plato.stanford.edu/archives/fall2017/entries/goodman-aesthetics/].

136. GOODMAN, Nelson : *Languages of Art*, Bobbs-Merrill |1968|.

137. HAIDAMOUS, Makarios : Kyrie Ekekraxa *in Arabic*, Windows PCM (.wav), Comp. Petros (Byzantios), CDA-007 |Deir al-Mukhallis (Couvent Saint-Sauveur - Joun) - Liban, 2010a-2011|.

138. HAIDAMOUS, Makarios : Kyrie Ekekraxa *in Greek*, Windows PCM (.wav), Comp. Petros (Byzantios) and Mitrī Murr (al-), CDA-006 |Deir al-Mukhallis (Couvent Saint-Sauveur - Joun) - Liban, 2010b-2011|.

139. HASSAN, Schéhérazade Qassim : "Un récent colloque sur le Congrès du Caire de 1932", *Cahiers de musiques traditionnelles 3* |1990| [doi: 10.2307/40240086. url: http://www.jstor.org/stable/10.2307/40240086?origin=crossref] p. 268.

140. HAYNES, Bruce and Peter COOKE : "Pitch", *Grove Music Online* |2001| [url: http://www.oxfordmusiconline.com/subscriber/article/grove/music/40883?q=pitch&search=quick&pos=1&_start=1#firsthit].

141. ḤIJĀZĪ (AL-MAKKĪ AL-), a-sh-Shaykh Shihāb-a-d-Dīn Muḥammad ibn Ismāʿīl ibn ʿUmar (الشيخ شهاب الدين محمد بن اسماعيل بن عمر المكي الحجازي) : *سفينة الملك ونفيسة الفلك - المعروفة بسفينة الشيخ شهاب [Safīnat al-Mulk wa-Nafīsat al-Fulk (F) 2274.8769.379 PUL]* |Égypte, 1864|.

142. ḤILŪ (AL-), Salīm سليم الحلو: *الموسيقى النظرية Al-Mūsīqā a-n-Naẓariyya [La musique théorique]*, 2nd ed., منشورات دار مكتبة الحياة Dār Maktabat al-Ḥayāt |بيروت - لبنان Beyrouth - Liban, 1972|.

143. ḤILŪ (AL-), Salīm سليم الحلو : *الموشحات الأندلسية، نشأتها و تطورها* Al-Muwashshaḥāt al-Andalūsiyya : Nashʾatuhā wa-Taṭawwuruhā *[Les muwashshaḥāt andalous : leur origine et leur développement]*, 2nd ed., منشورات دار مكتبة الحياة Dār Maktabat al-Ḥayāt |بيروت - لبنان Beyrouth, 1980|.

144. HINDEMITH, Paul : *The craft of musical composition*, Associated music publishers, inc. |1945|.

145. HIPKINS, A. J. : "Dorian and Phrygian", *Sammelbände der Internationalen Musikgesellschaft 4 3* |1903-5-1| [url: http://www.jstor.org/stable/929209] p. 371–381.

146. HIRST, Daniel : "The analysis by synthesis of speech melody: from data to models", *Journal of Speech Sciences 1 1* |2012-1-25| [url: http://www.journalofspeechsciences.org/index.php/journalofspeechsciences/article/viewArticle/21] p. 55–83.

147. HOLDER, William and Gottfried KELLER : *A treatise of the natural grounds, and principles of harmony*, Printed by W. Pearson, ... for J. Wilcox ... and T. Osborne |London, 1731|.

148. HOOD, M. : "Musical significance", *Ethnomusicology 7 3* |1963| p. 187–192.

149. HOOD, M. : "Reminiscent of Charles Seeger", *Yearbook of the International Folk Music Council 11* |1979| p. 76–82.

150. HOOD, Mantle : *The ethnomusicologist*, Kent, Ohio : Kent State University Press |1982| [url: http://archive.org/details/ethnomusicologis00hood].

151. HORNBOSTEL, E. M. v : "Musikalische Tonsysteme", *Akustik*, *Handbuch der Physik*, Springer, Berlin, Heidelberg |1927| [doi: 10.1007/978-3-642-47352-4_9. url: https://link.springer.com/chapter/10.1007/978-3-642-47352-4_9] p. 425–449.

152. HORNBOSTEL, Erich M. von : "On Comparative Acoustic and Music Psychological Studies", *Translingual Discourse in Ethnomusicology 2 0* |2017-8-23| [url: https://www.tde-journal.org/index.php/tde/article/view/1870] p. 1–18.

153. HORNBOSTEL, Erich Moritz (von) : "Phonographierte tunesische Melodien", *Sammelbände der Internationalen Musikgesellschaft 8 1* |1906-1-1| [url: http://www.jstor.org/stable/929108] p. 1–43.

154. HOUTSMA, A. J. M. and J. SMURZYNSKI : "Pitch identification and discrimination for complex tones with many harmonics", *The Journal of the Acoustical Society of America 87 1* |1990-1| [doi: 10.1121/1.399297. url: http://asa.scitation.org/doi/10.1121/1.399297] p. 304–310.

155. IFRAH, Georges : *Histoire universelle des chiffres: l'intelligence des hommes racontée par les nombres et le calcul*, R. Laffont |Paris, 1994|.

156. IVEY, Bill : "Ethnomusicology and the Twenty-First Century Music Scene (Seeger Lecture presented at the Society for Ethnomusicology Annual Meeting, 2007)", *Ethnomusicology 53 1* |2009| [url: http://www.jstor.org/stable/25653045] p. 18–31.

157. JABAQJĪ, ʿAbd-a-r-Raḥmān عبد الرحمن جبقجي: *تحليل الأنغام في علم المقام Taḥlīl al-Anghām fī ʿIlm al-Maqām*, دار التراث الموسيقي Dār a-t-Turāth al-Mūsīqī |حلب - سوريا Alep - Syrie, sd.|.

158. JÄGER, Ralf Martin : "Concepts of Western and Ottoman Music History", *Writing the history of "Ottoman Music"*, ed. Martin Greve, ed. 1. Aufl, *Istanbuler Texte und Studien* 33, Ergon-Verl |Würzburg, 2015| p. 33–50.

159. JARGY, Simon and Alexis CHOTTIN : "La Musique Arabe", editor Roland-Manuel, *Histoire de la musique Tome I - Des Origines à Jean-Sébastien Bach*, *Encyclopédie de la Pléiade 1/2* (vols.), Gallimard |Paris, 2001| p. 526–571.

160. JUYNBOLL, Th W. : "Adhān", *Encyclopaedia of Islam, Second Edition* |2012-4-24| [url: http://referenceworks.brillonline.com/entries/encyclopaedia-of-islam-2/adhan-SIM_0302?s.num=0&s.f.s2_parent=s.f.book.encyclopaedia-of-islam-2&s.q=adhan].

161. KARADENIZ, M. Ekrem : *Türk musikîsinin nazariye ve esasları [Theory and Principles of Turkish Music]*, Kültür |Ankara, 1965|.

162. KARADENIZ, M. Ekrem : *Türk musikîsinin nazariye ve esasları*, Türkiye İş Bankası Kültür Yayınları |1983|.

163. KAUFMANN, Walter : *Musical notations of the Orient; notational systems of Continental, East, South and Central Asia*, Bloomington, Indiana University Press |1967| [url: http://archive.org/details/musicalnotations00kauf].

164. KHULAʿĪ (AL-), Muḥammad Kāmil محمد كامل الخلعي : *كتاب الموسيقي الشرقي Kitāb al-Mūsīqī a-sh-Sharqiyy [The book of oriental music / Le livre de la musique orientale]* |1904|.

165. KHULAʿĪ (AL-), Muḥammad Kāmil محمد كامل الخلعي : *كتاب الموسيقي الشرقي Kitāb al-Mūsīqī a-sh-Sharqiyy [The book of oriental music / Le livre de la musique orientale]*, ed. X, *Maktabat a-d-Dār al-ʿArabiyya li-l-Kitāb*مكتبة الدار العربية للكتاب |Beirut, 1993|.

166. KIESEWETTER, Raphael Georg : *Die Musik der Araber nach Originalquellen dargestellt, mit einem Vorworte von Jos. von Hammer-Purgstall: Mit VI. Abbildungen im Text und XXIV. Seiten Noten-Beilagen, welche die Tonformeln der alten Autoren, dann einige jetzt gangbare Volksweisen und Gesänge enthalten*, Breitkopf und Härtel |1842|.

167. KINDĪ (AL-), Yaʿqūb ibn Isḥāq Abū Yūsuf (0801?-0867?) and الكندي : *Risāla fi-l-Luḥūn wa-n-Nagham (Mukhtaṣar al-Mūsīqā fī Taʾlīf a-n-Nagham wa Ṣinʿat al-ʿūd) [from Manisa (Turquie), MS. 1705, f^{os} 110v^{o}-123r^{o}] رسالة الكندي في اللحون و النغم*, Maṭbaʿat Shafiq |Baghdād, 1965|.

168. KORZYBSKI, Alfred : “A non-Aristotelian system and its necessity for rigour in mathematics and physics” (Paper presented before the American Mathematical Society, December, 28 1933) |1931|.

169. KRISHNASWAMY, A. : “Melodic atoms for transcribing carnatic music”, *Proceedings of the International Conference on Music Information Retrieval, Barcelona, Spain* |2004|.

170. KRISHNASWAMY, Arvindh : “Pitch measurements versus perception of south indian classical music”, *Proc. of the Stockholm Music Acoustics Conference (SMAC)* |2003| p. 627–630.

171. KRISHNASWAMY, Arvindh : “Multi-dimensional musical atoms in South-Indian classical music”, *Proc. of the International Conference of Music Perception & Cognition* |2004|.

172. KUNST, Jaap : “Memorial to Curt Sachs (June 29, 1881 - Feb. 5, 1959)”, *Ethnomusicology 3 2* |1959-5-1| [url: http://www.jstor.org/stable/924288] p. 71–74.

173. LEE, Riley Kelly : “Fu Ho U vs. Do Re Mi: The Technology of Notation Systems and Implications of Change in the Shakuhachi Tradition of Japan”, *Asian Music 19 2* |1988-4-1| [doi: 10.2307/833867. url: http://www.jstor.org/stable/833867] p. 71–81.

174. LEPENDORF, Jeffrey : “Contemporary Notation for the Shakuhachi: A Primer for Composers”, *Perspectives of New Music 27 2* |1989-7-1| [doi: 10.2307/833414. url: http://www.jstor.org/stable/833414] p. 232–251.

175. LEVY, Kenneth and Christian TROELSGÅRD : “Byzantine Chant”, editors Stanley Sadie and John Tyrrell, *The New Grove Dictionary of Music and Musicians - Vol. 4 - Barovski to Canobbio 4/29* (vols.), Oxford University Press |Oxford, 2001| p. 734–755.

176. LIST, George : “The Musical Significance of Transcription (Comments on Hood, ‘Musical Significance’)”, *Ethnomusicology 7 3* |1963| [doi: 10.2307/924577. url: http://www.jstor.org/stable/924577] p. 193–197.

177. LIST, George : “Transcription III”, *Ethnomusicology 8 3* |1964| [doi: 10.2307/850127. url: http://www.jstor.org/stable/850127] p. 252–265.

178. LIST, George : “The Reliability of Transcription”, *Ethnomusicology 18 3* |1974| [doi: 10.2307/850519. url: http://www.jstor.org/stable/850519] p. 353–377.

179. LUNN, Henry C. : “The History of Musical Notation”, *The Musical Times and Singing Class Circular 12 278* |1866-4-1| [doi: 10.2307/3354152. url: http://www.jstor.org/stable/3354152] p. 261–263.

180. MAHDĪ (AL-), Muḥammad Ṣāliḥ الدكتور صالح المهدي : *مقامات الموسيقى العربية [Maqāmāt al-Mūsīqā al-ʿArabiyya]*, *Maʿ al-Fann wa-l-Fannānīn* 3, المعهد الرشيدي للموسيقى التونسية Al-Maʿhad a-r-Rashīdī li-l-Mūsīqā a-t-Tūnisiyya |نج السداي - تونس Tunis, 1982|.

181. MALEK, Nicolas : Kyrie Ekekraxa *in Arabic*, Windows PCM (.wav), Comp. Petros (Byzantios) and Mitrī Murr (al-), CDA-005 |Mansourieh - Liban, 2011a-5-25|.

182. MALEK, Nicolas : Kyrie Ekekraxa *in Greek*, Windows PCM (.wav), Comp. Petros (Byzantios) and Mitrī Murr (al-), CDA-004 |Mansourieh - Liban, 2011b-5-25|.

183. MARICHELLE, H. : *La Parole d’après le tracé du phonographe;*, Paris, Delagrave |1897| [url: http://archive.org/details/laparoledaprsl00mari].

184. MASHĀQA, Mīkhāʾīl : “Ms. A-r-Risālā a-sh-Shihābiyya fi-ṣ-Ṣināʿa al-Mūsīqīyya – رسالة في (الرسالة الشهابية في) الصناعة الموسيقية BO 220 34 f^{os}” |Beyrouth, 1887-xix^{e} siècle| [Bibliothèque Orientale – Beyrouth. url: http://cdm.csbsju.edu/u?/HMMLCollect,7092].

185. MASHĀQA, Mīkhāʾīl : “A-r-Risālā a-sh-Shihābiyya fi-ṣ-Ṣināʿa al-Mūsīqīyya”, editor Louis Ronzevalle, *Al-Mashriq (Beyrouth) 2* |1899| p. 146, 218, 296, 408, 561, 629, 726, 883, 928, 1018, 1073.

186. MASHĀQA, Mīkhāʾīl : *Un traité de musique arabe moderne – Version française (avec reproduction de l’original arabe) de* A-r-Risāla a-sh-Shihābiyyah fi-ṣ-Ṣināʿa al-Mūsīqiyya *[The Shihabi treatise of the musical art]*, editor Louis Ronzevalle, translator Louis Ronzevalle, Imprimerie Catholique |Beyrouth, 1913|.

187. MASHĀQA, Mīkhāʾīl and Eli SMITH : “A Treatise on Arab Music, Chiefly from a Work by Michail Meschakah of Damascus”, *Journal of the Oriental American Society 1 3* |1849-1847 selon JSTOR| p. 171 + 173-217.

188. MATYAKUBOV, Otanazar and Harold S. POWERS : “19th Century Khorezmian Tanbur Notation: Fixing Music in an Oral Tradition”, *Yearbook for Traditional Music 22* |1990-1-1| [doi: 10.2307/767929. url: http://www.jstor.org/stable/767929] p. 29–35.

189. MEER, Wim van der : “Praat manual (for musicologists)”, *Wim van der Meer’s music pages* |2015-1-30| [url: https://wimvandermeer.wordpress.com/praat-manual-for-musicologists/].

190. MEER, Wim van der : “PRAAT Manual for musicologists” |2018a-1-19| [url: https://www.academia.edu/10404719/PRAAT_Manual_for_musicologists].

191. MEER, Wim van der : “What you hear isn’t what you see...”, *Thoughts for Ideas* |2018b-2-22| [url: http://thoughts4ideas.eu/what-you-hear-isnt-what-you-see/].

192. MEER, Wim van der : “PRAAT TUTORIAL FOR MUSICOLOGISTS” [url: http://www.musicology.nl/wm/research/praat_musicologists.htm].

193. MEER, Wim van der and ERICKSON, R. : “Resonating Cultural Musicology: sources, streams and issues”, *Cultural Musicology: premises, practices, prospects*, Musicology at Amsterdam University, Bake Society |2014| [url: http://dare.uva.nl/personal/pure/en/publications/resonating-cultural-musicology-sources-streams-and-issues(5845cfae-095d-40fe-8ce0-2618f64b0fd2).html].

194. MEER, Wim van der and Suvarnalata RAO : “What You Hear Isn’t What You See: The representation and cognition of fast movements in Hindustani music”, *Proceedings of the International Symposium Frontiers of Research on Speech and Music* |2006|

[url: http://www.academia.edu/340912/What_You_Hear_Isnt_What_You_See_The_representation_and_cognition_of_fast_movements_in_Hindustani_music] p. 12–20.

195. MIRAMON-BONHOURE, Jeanne and Amine BEYHOM : “Praat : Petit manuel pratique pour débutants – 1ère partie : Analyses de systèmes intervalliques et d’échelles V 1.0.3”, Université Paris Sorbonne |2010-9|.

196. MIYAKAWA, Felicia M. : “Turntablature: Notation, Legitimization, and the Art of the Hip-hop DJ”, *American Music 25 1* |2007-4-1| [doi: 10.2307/40071644. url: http://www.jstor.org/stable/40071644] p. 81–105.

197. MOLINO, Jean : “EXPÉRIENCE ET SAVOIR”, *Musurgia 2 4* |1995| p. 112–118.

198. MOLINO, Jean : “La Sociologie de la Musique de Max Weber Après un Siècle”, *Revue de Synthèse 129 2* |2008-6| [doi: 10.1007/s11873-008-0039-2. url: http://link.springer.com/10.1007/s11873-008-0039-2] p. 215–239.

199. MOUSSALI, Bernard : *Congrès de musique arabe du Caire: The Cairo congress of Arab music* |2015|.

200. NETTL, Bruno : *The study of ethnomusicology: twenty-nine issues and concepts*, Univ. of Illinois Press |Urbana, Ill., 1983|.

201. NEUBAUER, Eckhard : “al- Ṣaydāwī: Encyclopaedia of Islam, Second Edition : Brill Online”, *[Print Version: Volume IX, page 101, column 1]* |1997| [url: http://www.brillonline.nl/subscriber/uid=2022/entry?result_number=1&entry=islam_SIM-6680&search_text=Saydawi&refine_editions=islam_islam#hit].

202. ODEIMI, Bechir : “*Makhṭūṭ ʿArabiyy fī Tadwīn al-Mūsīqā*”, Al-Ḥayāt al-Mūsīqiyya *5* |1994-1| [url: [Damas]] p. 27–61.

203. OLLEY, Jacob : “Modal diversity in early Ottoman music : the case of *makâm Sabâ*”, *Near Eastern Musicology Online 1 1* |2012-11| [url: http://nemo-online.org/articles] p. 39–54.

204. OSTA, Bachir : Kyrie Ekekraxa *in Arabic*, Windows PCM (.wav), Comp. Petros (Byzantios), CDB-054 |Patriarcat des Grecs-Catholiques - Liban, 2013a-3-15|.

205. OSTA, Bachir : Kyrie Ekekraxa *in Greek*, Windows PCM (.wav), Comp. Petros (Byzantios), CDB-053 |Patriarcat des Grecs-Catholiques - Liban, 2013b-3-15|.

206. PARISOT, Jean (1862-) : *Musique orientale : Conférence prononcée dans la salle de la Société Saint-Jean, le 28 février 1898*, Schola Cantorum |Paris, 1898|.

207. PASLER, Jann : “Musical Hybridity in Flux: Representing Race, Colonial Policy, and Modernity in French North Africa, 1860s-1930s”, *Afrika Zamani: revue annuelle d’histoire africaine = annual journal of African history 20–21* |2012| p. 21–68.

208. PICARD, François : “Oralité et notations, de Chine en Europe”, *Cahiers de musiques traditionnelles 12* |1999-1-1| [doi: 10.2307/40240342. url: http://www.jstor.org/stable/40240342] p. 35–53.

209. PICARD, François : “Un protocole de visualisation du son” |2011-Summer| [url: http:// http://seem.paris-sorbonne.fr/IMG/pdf/un_protocole_de_visualisation_du_son.pdf] p. 2.

210. PIGGOTT, Francis Taylor and T. L. (Thomas Lea) SOUTHGATE : *The music and musical instruments of Japan*, London : B.T. Batsford |1893| [url: http://archive.org/details/musicmusicalinst00pigg2].

211. PLOMP, Reinier : *Aspects of tone sensation: A psychophysical study*, Academic Press |1976|.

212. PLOMP, Reinier : *The intelligent ear: on the nature of sound perception*, Lawrence Erlbaum Associates |Mahwah, N.J, 2002|.

213. POLAND, William : “Theories of Music and Musical Behavior”, *Journal of Music Theory 7 2* |1963-12-1| [doi: 10.2307/843107. url: http://www.jstor.org/stable/843107] p. 150–173.

214. RAO, Suvarnalata and Wim van der MEER : “Visual representation of Indian music” p. 11.

215. REID, James : “Transcription in a New Mode”, *Ethnomusicology 21 3* |1977| [doi: 10.2307/850727. url: http://www.jstor.org/stable/850727] p. 415–433.

216. ROUSSEAU, Jean-Jacques : *Collection complete des œuvres de J.J. Rousseau XVI/XXXIII* (vols.), [Paul Moultou et duPeyrou] |Genève, 1782| [url: http://archive.org/details/collectioncompl70rousgoog].

217. ROUSSEAU, Jean-Jacques and John T SCOTT : *Essay on the Origin of Languages and Writings Related to Music (The Collected Writings of Rousseau)*, Dartmouth College |1998|.

218. RUWET, Nicolas : “Méthodes d’analyse en musicologie”, *Revue belge de Musicologie/Belgisch Tijdschrift voor Muziekwetenschap* |1966| p. 65–90.

219. RUWET, Nicolas and Mark EVERIST : “Methods of Analysis in Musicology”, *Music Analysis 6 1/2* |1987-3| [doi: 10.2307/854214. url: http://www.jstor.org/stable/854214?origin=crossref] p. 3.

220. SABAT, Marc and Wolfgang von SCHWEINITZ : “The Extended Helmholtz Ellis-J-I Pitch Notation.pdf” |2004| [url: http://www.marcsabat.com/pdfs/legend.pdf].

221. SACHS, Curt : *The wellsprings of music*, Martinus Nijhoff |The Hague, 1962|.

222. SACHS, Ignacy : *The discovery of the Third world*, translator Michael Fineberg, MIT Press |Cambridge, Mass, 1976|.

223. {ṢAFADĪ (A-Ṣ-)}, Khalīl ibn Aybak Ṣalāḥ-a-d-Dīn : خليل بن أيبك الصفدي *رسالة في علم الموسيقا Risāla fī ʿIlm al-Mūsīqā*, editors ʿAbdul-Majīd Dyāb, Ghaṭṭās ʿAbd-al-Malik Khashaba, الأستاذ غطاس عبد الملك خشبة, and الدكتور عبد المجيد دياب, *تراثنا Turāthuna*, الهيئة المصرية العامة للكتاب Al-Hayʾa al-Miṣriyya al-ʿĀmma li-l-Kitāb |Le Caire, 1991-1297?-1363) xive siècle|.

224. ṢĀLIḤ, Fatḥī : “*Naḥwa Mafhūm Shāmil Muwaḥḥad li-l-Maqāmāt a-sh-Sharqiyya – Taṣawwur Mustaqbaliyy li-Taṭawwur al-Mūsīqa a-sh-Sharqiyya*”, *Al-Ḥadātha (Dār al-Ḥadātha li-ṭ-Ṭibaʿa wa-n-Nashr - Beirut) 3–4* |1994-Fall| p. 83–92.

225. ṢAYDĀWĪ (A-Ṣ-), شمس الدين الصيداوي الدمشقي Shams-a-d-Dīn (a-d-Dimashqī) : “BNF Ms. or-2480 *Kitāb al-Inʿām fī Maʿrifat al-Anghām wa Sharḥihā = Kitāb fī Maʿrifat al-Anghām wa Sharḥihā* (كتاب في معرفة الأنغام وشرحها)” |XVe siècle|.

226. ṢAYDĀWĪ (A-Ṣ-), شمس الدين الصيداوي الدمشقي Shams-a-d-Dīn (a-d-Dimashqī) and Thérèse B. ANTAR : *Livre de la connaissance des tons et leur explication* = Kitāb al-Inʿām fī Maʿrifat al-Anghām wa Sharḥihā *(كتاب في معرفة الأنغام وشرحها)*, Th. 3e cycle Hist. mus. et musicol. Paris 4 (Sorbonne), Université de Paris Sorbonne |1979|.

227. ṢAYDĀWĪ (A-Ṣ-), شمس الدين الصيداوي الدمشقي Shams-a-d-Dīn (a-d-Dimashqī) and Thérèse (soeur Berthe) ANTAR : *Kitāb al-Inʿām fī Maʿrifat al-Anghām wa Sharḥihā = Kitāb fī Maʿrifat al-Anghām wa Sharḥihā (كتاب في معرفة الأنغام وشرحها) [traduction et commentaire par Thérèse B. Antar du manuscrit BNF Ms. or-2480] (Exploitation de la couleur en musique : Livre de la connaissance des tons et leur explication)*, Chemaly and Chemaly |Beyrouth, 2001-XVe siècle|.

228. ṢAYDĀWĪ (A-Ṣ-), شمس الدين الصيداوي الدمشقي Shams-a-d-Dīn (a-d-Dimashqī) and Anas GHRAB : *Livre de la générosité dans la connaissance des modes = Kitāb al-Inʿām fī Maʿrifat al-Anghām wa Sharḥihā (كتاب الإنعام في معرفة الأنغام وشرحها)*, Master II (French DEA), Université LUMIÈRE-LYON2 |2002|.

229. SCHULTER, Margo : "Systematist Buzurg and its Relatives: Notes on a Zalzalian Modal Genre", *Near Eastern Musicology Online 2 2* |2013-11| [url: http://nemo-online.org/articles] p. 25–49.

230. SEEGER, Charles : "Prescriptive and Descriptive Music-Writing", *The Musical Quarterly 44 2* |1958-4-1| [url: http://www.jstor.org/stable/740450] p. 184–195.

231. SHILOAH, Amnon and Annie BERTHIER : "A propos d'un 'petit livre arabe de musique'", *Revue de Musicologie 71 1/2* |1985-1-1| [doi: 10.2307/928598. url: http://www.jstor.org/stable/928598] p. 164–177.

232. SHIRLAW, Matthew : *The theory of harmony; an inquiry into the natural principles of harmony, with an examination of the chief systems of harmony from Rameau to the present day*, DeKalb, Ill., B. Coar |1955| [url: http://archive.org/details/theoryofharmonyi1955shir].

233. SIGNELL, Karl L. : *Makam: modal practice in Turkish art music, D (Monographs) 4*, Asian Music Publications |1977|.

234. SIGNELL, Karl L. : *Makam: modal practice in Turkish art music*, Da Capo Press |1986-1|.

235. SIGNELL, Karl L. : "Contemporary Turkish Makam Practice", *Garland Encyclopedia of World Music Volume 6: The Middle East*, Routledge |United Kingdom, 2001-8-1| [url: http://glnd.alexanderstreet.com/View/329978#page47] p. 47–58.

236. SIGNELL, Karl L. : *Makam : modal practice in Turkish art music*, Usul |Nokomis (FL), 2004|.

237. SIGNELL, Karl L. : *Makam : modal practice in Turkish art music*, Usul Editions |Sarasota, FL, 2008|.

238. SKOULIOS, Markos : "Modern theory and notation of Byzantine chanting tradition : a Near-Eastern musicological perspective", *Near Eastern Musicology Online 1 1* |2012-11| [url: http://nemo-online.org/articles] p. 19–38.

239. SOKAL, Alan : "What is science and why should we care", *Vortrag, gehalten am 27* |2008| [url: http://ai2-s2-pdfs.s3.amazonaws.com/6b8c/57e888f5e61e892d3093de6c1dd29ab2dae0.pdf] p. 2008.

240. SOMFAI, László : *Béla Bartók: Composition, Concepts, and Autograph Sources*, University of California Press |1996-5-7|.

241. STAINER, John : "On the Principles of Musical Notation", *Proceedings of the Musical Association 1* |1874-1-1| [url: http://www.jstor.org/stable/765409] p. 88–111.

242. STOCK, Jonathan : "The Application of Schenkerian Analysis to Ethnomusicology: Problems and Possibilities", *Music Analysis 12 2* |1993-7-1| [doi: 10.2307/854273. url: http://www.jstor.org/stable/854273] p. 215–240.

243. TURA, Yalçın : *Türk mûsıkîsinin mes'eleleri*, Pan Yayincilik |Istanbul, 1988|.

244. URMAWĪ (D. 1294), Ṣafiyy-a-d-Dīn ʿAbd-al-Muʾmin ibn Yūsuf ibn (ab-ī-l-Ma)Fākhir (al-) صفي الدين الارموي : "Kitāb al-Adwār – ljs235", [D. 1293, XIIIe siècle] |2001| [url: http://sceti.library.upenn.edu/ljscollection/index.cfm, http://dewey.library.upenn.edu/sceti/ljs/PageLevel/index.cfm?ManID=ljs235].

245. URMAWĪ (D. 1294), Ṣafiyy-a-d-Dīn ʿAbd-al-Muʾmin ibn Yūsuf ibn (ab-ī-l-Ma)Fākhir (al-) صفي الدين الارموي and ʿAlī ibn Muḥammad [JURJĀNĪ (AL-)] : *La musique arabe (3) – I.* A-sh-Sharafiyya *ou Épître à Sharaf a-d-Dīn. II. (Commentaire anonyme du)* Kitāb al-Adwār *ou Livre des Cycles musicaux*, translator Rodolphe (d') Erlanger, ed. orig., *La Musique Arabe 3/6* (vols.), Librairie Orientaliste Paul Geuthner |Paris, 1938|.

246. VIGREUX, Philippe and Scheherazade Qassim HASSAN : *Musique arabe : le congrès du Caire de 1932*, CEDEJ |Le Caire – Égypte, 1992|.

247. VILLOTEAU, Guillaume André : *De l'état actuel de l'art musical en Égypte, ou relation historique et descriptive des recherches et observations faites sur la musique en ce pays*, 2nd ed., *Description de l'Égypte, ou Recueil des observations et des recherches qui ont été faites en Égypte pendant l'expédition de l'armée française* État Moderne *14/*, Impr. de Charles Louis Fleury Panckoucke |France, 1826|.

248. WALKER, George : "Ethnomusicologist George List", *Profiles - Indiana Public Media* |2007-7-29| [url: http://indianapublicmedia.org/profiles/george-list/].

249. WIKIPEDIA CONTRIBUTORS : "Rauf Yekta Bey", *Wikipedia, the free encyclopedia* |2014-9-8| [url: http://en.wikipedia.org/w/index.php?title=Rauf_Yekta_Bey&oldid=594546466].

250. WIKIPEDIA CONTRIBUTORS : "Labanotation", *Wikipedia* |2017a-3-16| [url: https://en.wikipedia.org/w/index.php?title=Labanotation&oldid=770629628].

251. WIKIPEDIA CONTRIBUTORS : "Znamenny chant", *Wikipedia* |2017b-10-12| [url: https://en.wikipedia.org/w/index.php?title=Znamenny_chant&oldid=805053732].

252. WIKIPEDIA CONTRIBUTORS : "Jianpu", *Wikipédia* |2017c-10-22| [url: https://fr.wikipedia.org/w/index.php?title=Jianpu&oldid=141783665].

253. WIKIPEDIA CONTRIBUTORS : "Jaap Kunst", *Wikipedia* |2017d-11-23| [url: https://en.wikipedia.org/w/index.php?title=Jaap_Kunst&oldid=811678960].

254. WIKIPEDIA CONTRIBUTORS : "Numbered musical notation", *Wikipedia* |2017e-12-18| [url: https://en.wikipedia.org/w/index.php?title=Numbered_musical_notation&oldid=815949389].

255. WIKIPEDIA CONTRIBUTORS : "Khwarezm", *Wikipedia* |2018a-1-3| [url: https://en.wikipedia.org/w/index.php?title=Khwarezm&oldid=818396111].

256. WIKIPEDIA CONTRIBUTORS : "Musical notation", *Wikipedia* |2018b-1-4| [url: https://en.wikipedia.org/w/index.php?title=Musical_notation&oldid=818640041].

257. WIKIPEDIA CONTRIBUTORS : "Qāriʾ", *Wikipedia* |2018c-5-23| [url: https://en.wikipedia.org/w/index.php?title=Q%C4%81ri%CA%BE&oldid=842657681].

258. WIKIPEDIA CONTRIBUTORS : "Tajwid", *Wikipedia* |2018d-6-22| [url: https://en.wikipedia.org/w/index.php?title=Tajwid&oldid=846999415].

259. WIKIPEDIA CONTRIBUTORS : "Adhan", *Wikipedia* |2018e-6-27| [url: https://en.wikipedia.org/w/index.php?title=Adhan&oldid=847743430].

260. WIKIPEDIA CONTRIBUTORS : "Byzantine music", *Wikipedia* |2018f-7-11| [url: https://en.wikipedia.org/w/index.php?title=Byzantine_music&oldid=849795769].

261. WILL, Udo : "The magic wand of ethnomusicology.", *Cahiers de musiques traditionelles 12* |1999a| p. 9–34.

262. WILL, Udo : "La baguette magique de l'ethnomusicologue: Repenser la notation et l'analyse de la musique", *Cahiers de musiques traditionnelles 12* |1999b-1-1| [doi: 10.2307/40240341. url: http://www.jstor.org/stable/40240341] p. 9–33.

263. YARMAN, Ozan : "Search for a Theoretical Model Conforming to Turkish Maqam Music Practice: A Selection of Fixed-Pitch Settings. From 34-Equal Temperament to the 79-tone Tuning", *Problems and Solutions for Practice and Theory in Turkish Music*, Kültür A. Ş. |Istanbul, 2008a|.

264. YARMAN, Ozan : *79-Tone Tuning & Theory for Turkish Maqam Music - as a solution to the non-conformance between current model and practice*, Istanbul Technical University - Institute of Social Sciences |Istanbul - Turkie, 2008b-6|.

265. YAZBECK, Joseph : “الأنماط في الموسيقى البيزنطيّة Form in Byzantine Music”, SEM (School of Ecllesiastic Music) |Mtaileb - Lebanon, 2012a-8-1| [url: http://www.semlebanon.org/sem/home.do].

266. YAZBECK, Joseph : Kyrie Ekekraxa *in Arabic*, Windows PCM (.wav), Comp. Petros (Byzantios) and Mitrī Murr (al-), CDA-011 |Mansourieh - Liban, 2012b-9-5|.

267. YAZBECK, Joseph : Kyrie Ekekraxa *in Greek*, Windows PCM (.wav), Comp. Petros (Byzantios) and Mitrī Murr (al-), CDA-010 |Mansourieh - Liban, 2012c-9-5|.

268. YĀZIJĪ, Yūhannā الأسقف د. يوحنا يازجي : *مبادىء الموسيقى البيزنطية* *Mabādiʾ al-Mūsīqā al-Bīzanṭiyya*, 2nd ed., منشورات معهد القديس يوحنا الدمشقي اللاهوتي - جامعة البلمند Manshūrāt Maʿhad al-Qiddīs Yūḥanna a-d-Dimashqī al-Lāhūtī – Jāmiʿat al-Balamand |لبنان Liban, 2001|.

269. YEKTA, Rauf : “La musique turque”, editor Albert Lavignac, *Encyclopédie de la musique et dictionnaire du conservatoire – Première partie : Histoire de la musique 1.5/2.6* (vols.), Delagrave |Paris, 1922| [url: http://gallica.bnf.fr/ark:/12148/bpt6k1237270] p. 2945–3064.

270. YEKTA, Rauf : *Türk musikisi nazariyatı: ilmin en son usullerine göre Türk musikisinin müstenid olduğu nazari kaideleri tesbit ve bu kaidelerin milli musikimizin ameliyatına ne suretle tatbik edeceğini izah eder nazari ve ameli bir eserdir*, Mahmud Bey Matbaası |1924|.

271. YEKTA, Rauf : *Türk musikisi*, Pan Yayıncılık |1986|.

272. ZOUARI, Mohamed Zied : *Évolution du langage musical de l’istikhbâr en Tunisie au XXe siècle : une approche analytique musico-empirique*, Sorbonne - Paris 4 |Paris, 2014| [url: http://www.theses.fr/2014PA040028].

273. ʿĀMIRĪ (AL-), Thāmir ʿAbd-al-Ḥasan : *المغنون الريفيّون وأطوار الأبونّيّة العراقيّة* *Al-Mughannūn a-r-Rīfiyyūn wa Aṭwār al-Abūdhiyya al-ʿIrāqiyya*, دار الشؤون الثقافية العامة Dār a-sh-Shuʾūn a-th-Thaqāfiyya al-ʿĀma |Baghdad?, 1987|.

274. ʿAMR, Shīrzād : *Al-Buzuq. Tārīkh wa Manhaj wa Fann*, Dār ʿAlāʾu-d-Dīn |Damascus, 2000|.

275. الأرموي, صفي الدين عبد المؤمن : *كتاب الأدوار في الموسيقى*, ed. غطاس عبد الملك خشبة, الهيئة المصرية العامة للكتاب،مركز تحقيق التراث |القاهرة, 1986|.

276. العباس, حبيب ظاهر and Ḥabīb Ẓāhir ʿABBĀS (AL-) : *نظريات الموسيقى العربية* *Naẓariyyāt al-Mūsīqā al-ʿArabiyya*, وزارة الثقافة والإعلام، دائرة الفنون الموسيقية، معهد الدراسات النغمية العراقى (Wizārat a-th-Thaqāfa wa-l Iʿlām, Dāʾirat al-Funūn al-Mūsīqiyya, Maʿhad a-d-Dirāsāt a-n-Naghmiyya al-ʿIrāqiyy) |(Baghdad – Irak) 1986 ,بغداد - العراق|.