

SEARCH FOR THE OPTIMAL TONE-SYSTEM FOR AN AUTHENTIC TURKISH SOUNDSCAPE: WEIGHING SEVERAL MORE THEORETICAL MODELS ON MAKAM MUSIC AGAINST PITCH-HISTOGRAMS

Ozan Yarman¹

ABSTRACT

This study is the continuation of an older musicological work I had co-authored with Bozkurt et al. [2009, JNMR:38/1 pp.45-70], where I now analyze the match between several more alternative theoretical models and the histogram peaks of collated pitch measurements from audio recordings in 9 makam categories by prominent Turkish musicians. Previously, these histogram peaks were pitted against 53-tone Equal Temperament (53-tET), Yekta-Arel-Ezgi-Uzdilek (the 24-tone Pythagorean tuning in force), Yarman-24a (its notable substitute), Karadeniz-41 (a subset of 106-tET) and Yavuzoğlu-48 (in 48-tET). This time, new results indicate an outstanding marksmanship in the contrivance of 79 MOS 159-tET (my 79-tone Qanun tuning) above all others. A “*Just Noticeable Difference*” (JND) of solely 7-8 cents (¢) unweighted maximum divergence from the histogram peaks – in comparison to the as much as “half a comma” corresponding divergences of the contending 60-tET, 65-tET and 72-tET from the same peaks – enables 79 MOS 159-tET to outclass its competition. When size is an issue however, the “*bulk vs. peak-matching performance*” of the mentioned three immediate rivals to the 79-tone Qanun tuning are over the top and analogous to each other. All the same, the minimalist Yarman-24 a-b-c-d variants (as direct replacements for Arel-Ezgi-Uzdilek) do, despite being about thrice as sparse, deviate from the measured peak values by only “one comma” at most while performing reasonably. The key question therefore is: “Why triple the number of conventional tones just to gain half a comma finer granularity for makams that would still remain coarse?”. Likewise, one may ask: “Why double the number of tones whilst technically not managing to overcome the need for commatic alterations?”. The findings are discussed in terms of which fixed-pitch approach is more optimal for traditional and modern practice in Turkish Classical/Art/Folk music.

Keywords:

Tuning, temperament, music theory, makam, maqam, pitch measurement, histogram peak, computational musicology

THE PRESENT-DAY MAKAM THEORY SCENERY

In a preceding musicological paper that I had co-authored with Bozkurt et al. [2009], a groundbreaking analysis was performed in which we juxtaposed 5 contending tone-systems against peaks of collated histograms generated from pitch measurements of renowned masters of Turkish

¹ Prof. Dr., Istanbul University State Conservatory Musicology Dept.: ozanyarman@ozanyarman.com (originally submitted: 28/4/2020; revised & re-submitted: 15/8/2020.)

Classical/Art music. The theoretical models of concern were 53-tone Equal Temperament (tET²) as used by the *Mus2okur* software [DataSoft: See APPENDIX B for its encapsulation and adaptation of Arel-Ezgi-Uzdilek pitch ratios]; Yarman-24a as a barebones substitution for the official tone-system [Yarman 2010, 64-99]; the official Arel-Ezgi-Uzdilek (which is simply a restyling of Rauf Yekta's precursor 24-tone Pythagorean tuning [Yarman 2007a]); the derelict Karadeniz-41 that is just a subset of 106-tET [Karadeniz 1965 & Yarman 2007a]; and the contemporary Yavuzoğlu-48 [Yavuzoğlu 2008] (that just appropriates – the way I had disclosed back then – Edward J. Hines' 48-tET grid for makams [cf. Hines 1989 & Yarman and Karaosmanoğlu 2009]) – with the first two tunings coming out on top, and the last two acquiring the worst overall rank (i.e., they overshoot or undershoot performed pitches by no less than “a whole comma” in general due to either poor choices or technical hardships in the suitable determination of given makam scales).

I recently computed and corrected very minor calculation errors in the mentioned study, to the extent that they do not affect the end results in any significant way. Be that as it may, I will use the updated information when referencing this work hereunder.

Checking the match between said histograms grouped under 9 makam categories and several more alternative tunings flooding the market nowadays will reveal whether or not the proposed theoretical solutions actually have true merit in the authentic representation of makams. This is especially important since there is still an ongoing (albeit somewhat abated) crisis with regards to which tone-system is the correct one for traditional music-making in Turkey (and possibly elsewhere, too).

Before I elaborate on what these are, let me first enumerate the digital files that come along with this manuscript:

- **MehmetYektay-65tET-Kanun_Mandallama_Birlesik_Dosya.pdf* (Mehmet Yektay's framework for affixing mandals on Turkish Qanuns based on dividing the octave into 65 equal parts. He also gives some elemental makam scales in degrees of this equal temperament);
- **MehmetYektay-TheoryPractice-65tET-Makamlar.xls* (My effort to decipher and octave-normalize some of Mehmet Yektay's elemental makam scales that relate to the scope of this manuscript);
- **Gunalcin-Weiss.xls* (Calculations for the *rast-çargâh* tetrachordal span of Günalçin's “Model 2” versus Weiss's rational “Q9” Qanun);
- **Chronicles_Yarman24.xls* (A comparative outline of how the Yarman-24 idea evolved);
- **YA24-to-Mus2.xls* (Schematics of what cent values AEU accidentals get in the *b-c-d* variants of the Yarman-24/31 cast for their incorporation into the Mus2 score editor released by DataSoft);
- **Yarman24d_equalizationOFmeantonefifth.xls* (Sketch of a mathematical optimization with respect to the Yarman-24/31 cast);
- **Yarman24E.pdf* (A monograph in Turkish detailing my Yarman-24/42e venture following in the footsteps of the previous Yarman-24 variants);
- **Yarman36_ahenkler-PB-beats.xls* (Derivation of Yarman-36 from a specially given reference frequency and recommended transpositions);

² Some theorists may also use the abbreviations -ET (standing for “Equal Temperament” or “Eşit Taksimât” the way I had Turkicized it), -EDO (standing for “Equal Divisions of the Octave” or “Eşite Dilimlenmiş Oktav” the way I had Turkicized it), and -ED2 (standing for “Equal Divisions of 2/1”), with the last one submitted as a terminological <overkill> in driving the point home, if only for the sake of satisfying a methodical concern towards punctiliousness.

**79-tones_mandal-ADO.xls* (String lengths-based mandal locations to effectuate the 79-tone Qanun tuning);

**WeighingAgainstHistograms-oldbatch2009.xls* (Original and amended data from the preceding musicological study [Bozkurt and Yarman et al. 2009], where theorized makam scales had been compared against pitch measurements);

**WeighingAgainstHistograms-newbatch2020.xls* (Data corresponding to the cornerstone tables and figures of APPENDIX C in this contribution, where even more theorized makam scales are now compared against the same pitch measurements).

The theoretical models I hereby aim to investigate are:

- 1) *79 MOS 159-tET formal* (with scales “formally defined” in my Expanded Ph.D. Thesis at long last [Yarman 2016, 428-62]),
- 2) *79 MOS 159-tET matching* (with closest and most meaningful matches to the peaks instead for the sake of fairness),
- 3) *Yarman-24a* (with occasional modifications to the original makam scales the way I had suggested in Bozkurt and Yarman et al. [2009]),
- 4) *Yarman-24b* (that copies the updated makam scales of the above),
- 5) *Yarman-24/31c* (that I lately endorse the most among these Yarman-24 variants [Yarman 2014a]),
- 6) *Yarman-24/31d* (which is an algebraically calibrated version of the above having the same scales [Yarman 2014b]),
- 7) *Yarman-24/42e* (that was contrived in an effort to systematize maestro Fikret Karakaya’s vague perdes [Yarman 2014b]),
- 8) *Yarman-36a formal* (with scales formally defined in terms of our suggested compendium of genera in [Yarman & Karaosmanoğlu 2014]),
- 9) *Yarman-36a matching* (with closest and most meaningful matches to the peaks instead for the sake of fairness),
- 10) *Yektay-65 formal* (which Mehmet Yektay [2012] formally defined as the “true sixer-mandal system” in place of 72-tET on Qanuns),
- 11) *Yektay-65 matching* (that is the same 65-tET grid as above – with, however, closest and most meaningful matches to the peaks instead),
- 12) *Durgun-60* (that is Sait Durgun’s ET proposal in place of 72-tET on Qanuns – with closest and most meaningful matches to the peaks),
- 13) *72-tET* (which is the informal resolution on commonplace Qanuns – with closest and most meaningful matches to the peaks),
- 14) *41-tET* (the way I had first brought to attention in [Yarman 2008] – with closest and most meaningful matches to the peaks),
- 15) *34-tET* (the way I had first brought to attention in [Yarman 2008] – with closest and most meaningful matches to the peaks),
- 16) *29-tET* (the way I used to consider in line with our apocryphal interpretations of Marchetto di Padua [Marchetto webpages] – with closest and most meaningful matches to the peaks).

These are explained in greater detail in APPENDIX B.

The makam categories for this new analysis are once again RAST (16 collated samples), NĪHAVEND (12 collated samples), KŪRDĪLĪHĪCAZKAR (17 collated samples), UŞŞAK (11 collated samples), HŪSEYNĪ (15 collated samples), HĪCAZ (17 collated samples) SABA (11 collated samples), SEGAH (16 collated samples) and HŪZZAM (13 collated samples), constituting a total of 128 audio files, with highly characteristic microtonal inflexions by such celebrated masters as Tanburi Cemil and Yorgo Bacanos [Bozkurt and Yarman et al. 2009].

The obtained results – i.e., both the unweighted and complexity-weighted (and this will be elaborated below) averages across the board – indicate, unsurprisingly enough, the exceptional fidelity of my 79-tone Qanun tuning (i.e., “79-tone *Moment of Symmetry out of 159-tone Equal Temperament*”, or 79 MOS 159-tET in brief, to be explained under APPENDIX B) above all the rest when it comes to pointillistically representing makams with a sufficiently high degree of mathematical precision: I call this “PANORAMA A”. Though, not quite so much with an additional “efficiency scaling” (and this will also be elaborated below) as compared to particularly the percentages for 72-tET – as well as for 65-tET and 60-tET to a lesser extent; constituting what I call “PANORAMA B”... Yet, these minutely larger offsets under PANAROMA B in the case of 79 MOS 159-tET are somewhat understandable from the perspective of slightly decreased temperamental regularity and performability.

The obvious downside to such a crowded population of 78 equal + 1 non-equal pitches in 79 MOS 159-tET is hence the challenge in theoretical formalism and difficulty in scale formulation, aside from the taxation of the musician with respect to on-the-fly *mandal* management. Nevertheless, the proposed 79-tone Qanun tuning readily compensates for intonational deficiencies because one has a maximum of (as I long since maintained) only 7-8 cents (ϕ) unweighted divergence from any histogram peak – as compared to the as much as “half a comma” deviation of the best contending 60-tET, 65-tET and 72-tET from the same peaks. The consistent happenstance of lowest differences in cents in PANORAMA A for the “peak-matching version of 79 MOS 159-tET” corroborates just this fact; but one may immediately object: “At what cost?”

While the 79-tone Qanun tuning’s size can be rather unmanageable as such, the “*bulk versus peak-matching performance*” (with this also to be elaborated on further below) of 72-tET, 65-tET and 60-tET – even with their relatively low voluminousness – are still comparable to 79 MOS 159-tET. Even so, their over the top percentages in said measure as shown under PANORAMA B speak more in their favor and against 79 MOS 159-tET. This measure also constitutes a neat way of portraying the tipping point in the balance between a tuning’s useful pitch population and its unwieldiness among a group of tunings – as exemplified by the archetypal 72-tET being at or very near said tipping point! Be that as it may, the somewhat better manageability of these three rival resolutions deprives them of overall pitch accuracy when pitted against the 79-tone Qanun tuning; so much so that the slight benefits gained do not really seem to be worth the downsizing in this author’s opinion.

In contradistinction, any Yarman-24 a-b-c-d variant (as a direct replacement for the notorious “Arel-Ezgi-Uzdilek” – or AEU for short – through reliance on the exact same palette of accidentals) does, in spite of being about thrice as sparse, deviate from the measured peak values only by “a comma” at most while performing fairly reasonably. To put things in perspective, the array of efficiency-scaled AND complexity-weighted grand averages of the mean of maximum differences OR of the average of differences from histogram peaks (i.e., the so-called “*bulk vs. peak-matching performance*” panorama, or PANORAMA B) is much more satisfactory than for AEU or even its 53-tET encapsulation under *Mus2okur*. The critical question therefore is this: “Why triple the size of the tuning only to gain half a comma finer detail which would still remain vulgar?”. Or one may ask in a similar fashion: “Why double the number of conventional tones while not succeeding to overcome the need for commatic alterations in the construction of relatively simple and straightforward makam scales?”

At any rate, while 72-tET appears as the definitive benchmark in PANORAMA B – with 65-tET and 60-tET in close pursuit, a nominal Just-Noticeable Difference (JND) of (as promised) 7-8¢ limen [cf. Long 2014] in the case of 79 MOS 159-tET is arguably much more favorable in terms of authenticity the way I demarcated it in PANORAMA A. Otherwise, if one wishes to secure a modest level of intonational accuracy with minimal damage to makams while permitting no excess to accustomed pitches, the lesser-sized tolerable alternatives such as Yarman-24 and Yarman-36 that perform as good as or even better than AEU can be considered. There are evidently even more solutions in-between – such as the lightweight 34-tET and 41-tET also investigated as part of this study [cf. Yarman 2008], which boast higher moderate degrees of success.

Eventually, the whole ordeal could boil down to my long-standing argumentation that the optimal tuning actually depends on, and is inseparable from, the kind of pitch detail demanded by the makam musician; hence my persistence on NOT choosing one single tone-system for makams for more than a decade. Is this statement too shocking, after all, when one notices the continuance of the barebones situation with the fret placement on Folk Bağlamas as compared to the highly-elaborate yet still unsystematized confounded situation with the long necks of Tanburs?

Therefore, if one is hardpressed to establish which tuning is more optimal in the long run for Turkish Classical/Art/Folk music, this can only be soundly achieved through a direct comparison with master pitch histograms generated from the superposition of many audio measurements. Bear in mind that such an excursion yet places no significance on the transposition/modulation or potential polyphonization capabilities of any given theoretical model that might give it an upper edge in the final stage of evaluations. Notwithstanding, nothing less than a quantitative weighing of empirical data will suffice in order to reach a satisfactory conclusion about the makam-faithfulness and tractability of a tone-system. Such an up-to-date statistical analysis shall verily be attempted in this manuscript, whereby a FINAL PANORAMA serves to showcase the 7 best tunings per size from highest to lowest pitch detail.

The finesse of this study can be improved if i) the autopeak algorithms are developed further to detect peaks that are visible to the naked eye but anyhow missed during computations, ii) each perde of a given tuning is scaled according to the frequency of occurrence of its autopeak counterpart during weighing and averaging operations, iii) possible classification errors with given makams (e.g., when certain Hicaz pieces turn out to be in Uzzal instead) and non-stylistic performers (e.g., when early 20th Century non-Turkish musicians get mixed up with 21st Century Turkish musicians) are amended for truer histogram collation.

METHODOLOGY

For this paper too, sample collation was based on the automatic tonic frequency identification method developed by Bozkurt [2008], whereby the pitch histograms of all the pieces in a certain makam were superposed to yield a master pitch histogram. Afterwards, two types of peaks were extracted from these master histograms dubbed “Envelope” and “Average” – against which the corresponding theorized makam scales of the tone-systems were pitted. Details can be read in Bozkurt and Yarman et al. [2009]; for a synopsis, cf. APPENDIX A.

Given the relative pitches I_{ai} computed from the data automatically and the theorized scale tones I_{ti} , the maximum distance M and the average distance D between the two values for a given makam had been calculated as

$$M = \max\{|I_{ai} - I_{ti}|\}, i = 1, 2, 3 \dots N_x, \quad D = \frac{1}{N_x} \sum_{i=1}^{N_x} |I_{ai} - I_{ti}|,$$

where N_x is the total number of scale tones (*albeit only being valid within a 2.5 Holderian comma, or Hc, vicinity for the older analyzed batch, and within a 2 Hc=45.3¢ vicinity for the newer analyzed batch that I consider hereunder*) for a given makam that correspond to a measured relative pitch.

In addition to the distance, an efficiency measure, E , had been provided, which is the ratio, in percentage, of the number of theorized scale tones within a 2.5 Hc (*or, for the newer analysis hereunder, 2 Hc*) vicinity of the measured relative pitches, N_x , to the number of tones of the makam scale defined in the tuning, N_t .

$$E = (N_x / N_t) * 100$$

To portray the complexity of a given scale in respect to its tuning, one last measure had been provided: C , which is the ratio, normalized to a percentage, of the number of unused scale tones (i.e., “amount of peak-matching relative pitches” minus the “total number of tones in the tuning”), $N_z - N_x$, to the total number of tones in the tuning, N_z .

$$C = (1 - N_x / N_z) * 100$$

Notice, M , D , E and C were calculated for *envelope* and *average* histogram peaks separately – but their means will be brought together at the final stage. Thus, the mean of the entire set of maximum differences and the mean of the entire set of averages of differences will also be computed for each tone-system. Last but not the least, further manipulations shall yield complexity and/or efficiency scaled grand averages, as well as one final machination which I call the FINAL PANORAMA that showcases the best players. All these will be tabulated further below.

Scaling via the complexity measure is different in this paper in comparison to the preceding study [Bozkurt and Yarman et al. 2009]. Because a direct multiplication by any complexity percentage results in the diminishing of all cent offsets, the solution is to choose the lowest complexity percentage in the list as the basis for the following upscaling operation:

$$\{ (Current\ complexity\ percentage/100) + (1 - [smallest\ among\ the\ list\ of\ complexity\ percentages/100]) \} \times error\ in\ \phi$$

The lhs thus gives sensible coefficients for a fair portrayal of complexity-weighted cent errors. When all is said and done, efficiency upscaling can then be introduced to brutally curb down advantageous tunings due to their finer granularity. Since multiplying with any full efficiency would preserve the error while multiplying with half the efficiency would just decrease the error, the correct approach is to divide an input value by the corresponding efficiency percentage so as to arrive at PANORAMA B and then the FINAL PANORAMA.

METHODOLOGICAL CAVEATS

Now, one may inquire as to what happens when the analyzed pitches constitute vibratos or portamentos. To this I respond as follows... The histogram peaks are already extracted from audio recordings that include such features by master performers; if the inflexions and microtonal ornamentations were amiss, then we would observe narrow spikes. This is yet not an issue with the current contribution. In the case of even more vibratos & portamentos, the autopeaks would ordinarily be less pronounced (their kurtosis would decrease – i.e., the skirts of such elevations would horizontally spread). Since these are all normalized to 1 (i.e., highest amount of occurrence), and because they are the result of collations of many recordings deemed to be in a given makam, their heights or positions on the pitch space would not change by much, if at all.

So how do these aspects actually reflect in the computations? Are the contours and shades surrounding the immediately perceived pitch (such as attack culminations or minute inflections of the melodic curve) taken substantially into account? Well, yes! These subtleties of pitch – depending on the style, mannerisms, artistic skill and technical capability – are part of the natural performance by the masters on their instruments that is under scrutiny. The pitch measurement and autopeak generation method aptly takes into consideration this reality of the audio recordings. The expected results are then outlined in the previous paragraph.

Yet, I did not quite delineate what would happen if other recordings were included in the search... In reality, it depends. If the analyzed historical epoch and class of artists had conspicuous variance in terms of style, mannerisms or instrumentation; if – say – a group of Maghribi or Iranian performers were brought into the mix with Turkish performers, then one would most likely expect to see wild results in the histograms – such as with “perde segâh” having many distinct peaks in a makam that shouldn't have it in the classical Turkish understanding, for instance. Likewise, if *twelvulated polyphonalist executants* of Turkey were included along with traditional Turkish musicians, one might falsely conclude that “perde segâh” in – say – Hüseyni makam is actually closer to a tempered whole tone above the tonic, for instance. To do plausible objections in this regard any justice, one has to restrict the sample set to only the class of musicians that autochthonously belong to the genre that is the topic of research. In such a case, while earlier or later periods may reveal some deviations in the peak heights and positions on the pitch space, ordinarily one would not expect it to be by too much (e.g., if “tradition” means anything!). This is especially so when the sample set includes many collations in given makams. As more of the same class of performers and makams are thrown into the mix, the result should be similar to what is already presented in [Bozkurt and Yarman et al. 2009] as well as in the current paper. In other words, with the available dataset, one already may be entitled to speak of a “homogenized autopeak panorama” for the makams of concern.

NEWLY ANALYZED TUNINGS

Because of the lack of any formally defined makam scales under 72-tone Equal Temperament (72-tET), the closest matching degrees to the histogram autopeaks – in just the same way as for 29-tET, 34-tET, 41-tET and 60-tET – were handpicked. This “6-fold detailed 12-tET” resolution is particularly applied to Turkish Qanuns due to the prevalent usage in Turkey of electronic tuners imported from abroad of late (the way I had explained right at the onset [Yarman 2006] of my doctorate dissertation [Yarman 2016] – whereby the halftone mandal is situated at an equal semitone, and the remaining space to the nut mandal is divided into 6 equidistant parts [cf. <http://ozanyarman.com/wpress/2013/03/119> under Yarman and Sethares et al. 2019]. This resolution, being a multiple of 12-tET, also incorporates 24-tET and 36-tET as rigorous subsets; the former of which is the notorious Arabic quarter-tone scale [Touma 1934], and the latter of which was (sort of) a preliminary proposal in my master’s thesis [Yarman 2002, 44-56]. Suffice it to say, one may manipulate the pertinent MS Excel spreadsheet in the [LINK] to fiddle around with these and other tuning proposals not considered as part of this study.

Coming next, Mehmet Yektay, grandson of the famed theorist Rauf Yekta (1871-1935), sometimes gave a wholetone or a major third moved scales without any mention, and sometimes failed to correctly identify the optimal makam scale pitches from his 65-tET proposal, leading to conspicuous divergences from the histogram peaks [Yektay 2012]. His original scales are tabulated in another MS Excel document accompanying the one just mentioned [LINK]. These shortcomings have been compensated herein by taking separately the best available 65-tET degree matches to the measured peaks. Such a high resolution was anyway proposed by Yektay as the “true sixer-mandal system” in place of 72-tET following in the Pythagorean footsteps of 53-tET (which I happened to contest in a private e-mail to Yektay dated 13 May 2009 for being one of the worst tunings of such great size for approximating simple superpartient and epimoric 7-limit intervals like 7:4, 10:7, 7:5, 9:7 and 7:6 that take place in Segah, Hicaz and Saba genera & scales all over – with respective absolute errors of 8.826ϕ , 8.26ϕ , 8.26ϕ , 7.993ϕ and 8.41ϕ , which are altogether quite unfavorable, inasmuch as adversely impacting, among other things, particularly the Hicaz genus in my opinion).

A similar situation arose in the case of the “formally defined” makam scales under my 79 MOS 159-tET, as well as under Yarman-36; with the best-matching subsets being hence proposed besides for the sake of fairness. Note that 79 MOS 159-tET makam scales were all transposed on C4=262 Hz because of my trust in the mathematical symmetry and completeness of the system (cf. APPENDIX B). Thence, moving the scales on any other degree should more or less yield the same results to all intents and purposes.

As a side note, the rather unpropitious juxtaposition of the “formal scale pitches” of these tunings with the histogram autopeaks may evince my ineptitude, as a Western Classical music acclimatized Pianist, of recognizing the proper traditional or modern application of makams (which happens to be just as bothersome a situation for Yektay and Yavuzoğlu!), or my penchant to capture an even truer authenticity the way I professionally envision (such as, for instance, concerning my ongoing personal belief in the historical Nihavend being a 5-limit Just Intonation minor and the historical Buselik being instead a characteristically 3-limit Pythagorean minor or even a supraminor).

Owing to the fact that Durgun60 is the same 60-tET resolution as that initially defended by Yavuzoğlu in [1991] – which Yavuzoğlu seemingly abandoned during the course of time in favor of 48-tET [Yavuzoğlu 2008] (and which had been identified in the precursor to this study [Bozkurt and Yarman et al. 2009] as having the worst overall rank among the five competing tone-system candidates) – and seeing as different makam scales can be later extrapolated to add to the confusion, I have once more preferred to adopt only the best correlations with histogram average and envelope peaks.

Moving on, my Yarman-24 series of tunings operate within a maximum of “one comma inflexion margin” for any given pitch just as I have claimed for years, and as evidenced by the data, too. In any case, all Yarman-24 variants perform comparably better than AEU. To keep track of which variant was brought forward and when, another MS Excel document named above as *Chronicles_Yarman24.xls* is included in the [LINK]. APPENDIX B also provides additional information in this regard.

Again, be mindful that the results of this paper say nothing about the transposition/modulation or prospective polyphonization capabilities of any given tone-system, or, for that matter, unique bonus features such as the 12-tone cyclic subset or AEU imitation subset availability in the case of my 79-tone Qanun tuning the way I particularize under APPENDIX B. Additional measures may need to be devised to weigh such capabilities against a theoretical model’s ultimate representational success.

Numbers are in APPENDIX C. Rast scale distributions of the theoretical models contra autopeaks are given in *Table 1*, and mismatches against 16 collated pitch-histograms of RAST are plotted in *Figure 1*; Nihavend scale distributions of the theoretical models contra autopeaks are given in *Table 2*, and mismatches against 12 collated pitch-histograms of NİHAVEND are plotted in *Figure 2*; Kürdilihicazkar scale distributions of the theoretical models contra autopeaks are given in *Table 3*, and mismatches against 17 collated pitch-histograms of KÜRDİLİHİCAZKAR are plotted in *Figure 3*; Uşşak scale distributions of the theoretical models contra autopeaks are given in *Table 4*, and mismatches against 11 collated pitch-histograms of UŞŞAK are plotted in *Figure 4*; Hüseyni scale distributions of the theoretical models contra autopeaks are given in *Table 5*, and mismatches against 15 collated pitch-histograms of HÜSEYNİ are plotted in *Figure 5*; Hicaz scale distributions of the theoretical models contra autopeaks are given in *Table 6*, and mismatches against 17 collated pitch-histograms of HİCAZ are plotted in *Figure 6*; Saba scale distributions of the theoretical models contra autopeaks are given in *Table 7*, and mismatches against 11 collated pitch-histograms of SABA are plotted in *Figure 7*; Segah scale distributions of the theoretical models contra autopeaks are given in *Table 8*, and mismatches against 16 collated pitch-histograms of SEGAH are plotted in *Figure 8*; lastly, Hüzzam scale distributions of the theoretical models contra autopeaks are given in *Table 9*, and mismatches against 13 collated pitch-histograms of HÜZZAM are plotted in *Figure 9*.

“PANORAMA A” and “PANORAMA B” grand averages are presented in Table 10 and Table 11 respectively. Table 12 features the “FINAL PANORAMA” where 7 different tone-systems especially rise to the forefront.

CODE AND DATA

The MS Excel spreadsheet document named as *WeighingAgainstHistograms-newbatch2020.xls* referred to in this study [LINK] employs specially crafted formulas to facilitate the computation of the rightmost values (the last four columns) throughout Tables 1-9 after a simple copy-pasting of tabulated quantities; wherefrom the rest of the averaging and complexity and/or efficiency weighing can be accomplished straightforwardly. To begin with, in the HÜZZAM sheet for instance, the formula in cell C24

```
=IF(D4>0,IF(ABS(C4-C$19)<ABS(D4-C$19),ABS(C4-C$19),ABS(D4-C$19)),ABS(C4-C$19))
```

automatically looks at two neighboring cells containing the scale tones for “*perde çargâh*” and picks the one that is the closest match to the histogram autopeak value so as to take its absolute difference from the peak’s cent. All the way to the end of the row under consideration operates in the same fashion until one stumbles upon the end of the table, which necessitates the formula in cell Q24

```
=IF(Q$19<>P$19,ABS(Q4-Q$19),IF(P24=0,ABS(Q4-Q$19),0))
```

that conditionally computes the absolute difference between the scale tone of the last column with the nearest of the two final neighboring autopeak values in said row.

After the differences are calculated as such, the expression

```
=SUMPRODUCT(MAX((C24:Z24<45.3)*C24:Z24))
```

finds the maximum difference lower than 45.3¢ (2 *Holderian commas*) throughout the given row, and

```
=SUMIF(C24:Z24,"<45.3",C24:Z24)/ROUND(SUMPRODUCT(--(C4:Z4<>"")*(C$19:Z$19<>"")/COUNTIF(C$19:Z$19,C$19:Z$19&"")),0)
```

returns the average of the differences in said row based on the number of scale tone matches to the histogram peaks as the divisor. The procedure up to this point is then repeated for the other type of autopeak.

Once the formula bit for the number of scale tone matches to the number of peaks

=ROUND(SUMPRODUCT(--(C4:Z4<>"")*(C\$19:Z\$19<>"")/COUNTIF(C\$19:Z\$20,C\$19:Z\$19&"")),0)

is divided by another formula, i.e.,

=SUMPRODUCT((C4:Z4<>"")/COUNTIF(C4:Z4,C4:Z4&""))

that establishes the total number of suggested tones in the theoretical model for that makam, we get the efficiency measure – which can be multiplied by 100 to display it in percentage.

For the complexity measure, remember that one multiplies by 100 the ratio of the unused scale tones to the total number of tones in the tuning. The second longest and rounded formula bit above already gives the number of unused tones if we subtract the known number of pitches per octave from it (in this case, $79-9=70$) – wherefore, dividing this last part by the known number of pitches per octave and multiplying by 100 yields the complexity (e.g., $[70/79]*100=88.6\%$).

Proper scaling by this complexity was already explained under the Methodology section. Additional upscaling by efficiency is simply done via dividing the complexity-weighted result by the efficiency percentage value as previously mentioned.

And that's basically it.

As stated in the previous section, the treasure trove of data computed by these formulae is reproduced below in APPENDIX C.

I may now proceed to discussing them in the next and final section.

DISCUSSION OF RESULTS

Going forward on a makam-by-makam basis across all the Tables and Figures (cf. APPENDIX C), we see that 79 MOS 159-tET (hereinafter the “peak-matching version”) is among the few models that represents RAST best when the divergences are unweighted (cf. Table 1 & Figure 1). This, and the case with other makams also, is on par with my more than a decade long perseverance to NOT force upon people what makam scales should BE.

When divergences are complexity-weighted, though, Yarman-24b comes out on top; here the proximity of Yarman-24b and Yarman-24/31c to RAST is quite noticeable (cf. Table 1 & Figure 1).

For NİHAVEND, 72-tET and 79 MOS 159-tET just surpass Sait Durgun's 60-tET, insofar as sharing the pedestal when the divergences are unweighted. The situation is similar when they are complexity-weighted, too (cf. Table 2 & Figure 2).

Same with KÜRDİLİHİCAZKAR; save that 79 MOS 159-tET excels over the rest when the divergences are complexity-weighted (cf. Table 3 & Figure 3).

Unweighted UŞŞAK is still better represented by 79 MOS 159-tET, and complexity-weighted UŞŞAK is much more neatly represented by 72-tET (cf. Table 4 & Figure 4). Of particular note for this makam are Yarman-24/42e's comparatively small average deviations from the peaks.

Sait Durgun's 60-tET is the winner for HÜSEYNİ in both venues (cf. Table 5 & Figure 5), with 79 MOS 159-tET followed by 72-tET and 65-tET in close pursuit.

79 MOS 159-tET is the winner for HİCAZ in both venues (cf. Table 6 & Figure 6), while 41-tET competes admirably.

SABA too is the undisputed domain of 79 MOS 159-tET in both venues (cf. Table 7 & Figure 7), whereas 65-tET, 72-tET, 41-tET, 34-tET and even 29-tET in turn exhibit a worthwhile credibility for this makam.

60-tET and 72-tET compete for dominance over SEGAH in both venues (cf. Table 8 & Figure 8), with 79 MOS 159-tET and 65-tET and even Yarman-24/42e just barely shy of them.

Mehmet Yektay's 65-tET is the "king of HÜZZAM" in both venues (cf. Table 9 & Figure 9). Be that as it may, the 79-tone tuning, 72-tET, 60-tET and Yarman-24/42e are perceptibly runners-up; with 72-tET and 60-tET overshadowing the rest (except 65-tET) when the divergences are complexity-weighted.

In Table 10, where the 79-tone Qanun tuning is the penultimate champion, PANORAMA A shows how intelligently increasing the number of pitches in an octave can expedite a well-crafted temperament to outclass small contenders as well as to overshadow rival biggies. The situation with 72-tET, 65-tET and 60-tET coming in second place demonstrates this clearly.

Yet, PANORAMA B in Table 11 communicates instead that, if one keeps increasing pitches after a certain point, it will not be in that tone-system's favor anymore. In other words, for the present study, one comes to settle on 72-tET as the benchmark at a score of 100% with regards to the entirety of efficiency-upscaled grand averages of weighted maximums and differences: It boasts the lowest upscaled cent values across the board – with 65-tET and 60-tET just on its heels.

Here, out of the entire list of given tunings, 72-tET thence seems to be more or less the tipping point (e.g., *bulk vs. peak-matching performance benchmark*) before things start to get worse for ever finer divisions of the octave. Among the given list, too few pitches don't seem to work well in terms of makam-fidelity either.

This panorama also reveals that music theorists bungle a lot when trying to impose their formal scales on traditional and modal art forms. Just look at the formalisms of particularly Karadeniz, Yektay and Yavuzoğlu...³ Furthermore, the mediocre performances of several cherished middle-ground tunings such as 53-tET and Yarman-36 are indeed disappointing.

To recapitulate, I wish to draw attention to the FINAL PANORAMA in Table 12, where one may especially notice how Yarman-24/42e falls behind 34-tET of an equivalent milieu, and Yarman-24/31c falls behind 29-tET of the same league, and how *Mus2okur*'s 53-tET cannot compete against the earliest Yarman-24 variants ("a" and "b") less than half its size. Once again, this panorama either demonstrates unforgivable blunders of music theorists in their makam scale formalism, or hints at an insidious shift in the modern Turkish intonation soundscape in accordance with what I some years ago christened as *temperialism*: "Conscious or inadvertent equal temperament infusion through cultural imperialism".

On the other hand, I did not anticipate how useless a pursuit Yarman-24/42e would prove to be with respect to the ever-so-delicate prevalence of 41-tET over it. Apparently, even with considerable transpositional sacrifices resulting in much irregularity, one should find it very hard to compete against suitable equal temperaments of identical caliber.

What was rather unexpected for me was the slight worsening in discrepancies under Yarman-24/31c (cf. PANORAMA A under Table 10) as compared to the earlier Yarman-24 variants. While I knew that the "d" variant did not resonate so well digitally, I still expected the "c" variant to be an improvement over the "a" and "b" variants. Could it be that the overpowering climate of *temperialism* is adversely affecting this author also?

Much more can be said about the numbers in the FINAL PANORAMA as well as PANORAMA B. What I found particularly surprising is how 34-tET performed better than 41-tET on the whole or even singularly with respect to some "crunchy"⁴ makams like Uşşak and Saba.

³ which incidentally reminds me of a couple of thought-provoking past comments by my detractors that goes like: "*This Qanun has no educational significance!*" or "*First you will learn Turkish music and only then speak on Turkish music!*" or "...*Ekrem Karadeniz, who is the only other system-possessing music theorist!*...", etc...

⁴ What I mean by it is "*intonation-wise sticking out by liberally bent perdes*". In SABA and HİCAZ in particular, whose characteristically variegated supple perde corresponds to the makam's name (for instance, SABA gets its name from "perde saba" or vice versa – which, on the Ney, is the same hole for "perde hicaz" of HİCAZ), one may see Maghribis play it "semitonally" above *perde çargâh* in both cases, and Turks as well as Iranians "sesqui-semitonally" in SABA and "semitonally" or even "quarter-tonally" in HİCAZ – forming thus a justly intoned major third versus either a super-Pythagorean major third for SABA or a neutral third for GARİP HİCAZ above the tonic respectively.

But may the reader look at just how good 29-tET performs in comparison to AEU or even its 53-tET encapsulation under Mus2! Such an outcome is definitely surprising.

In addition to these, PANORAMA A divergences for 29-tET and 53-tET are very much comparable, too (cf. Table 10).

With respect to the Yarman-24 variants, the “near-Pythagorean” 29 equal divisions of the octave does not require a notational paradigm shift either. In other words, the habitual AEU accidentals symbolism can be applied to it right away.

One then only wonders why this resolution was not chosen a century ago as the barebones container of makams. Given the current theoretical mess, it seems a pity indeed...

The results especially reflect how there is still no well-performing middle-ground division of the octave between the resolutions of 34 pitches to the octave and 60 pitches to the octave.

This is significant if one wishes to compete against the bulwark success of voluminous tone-systems surpassing 53-tET.

Ultimately, the FINAL PANORAMA can be said to reveal the predominance of 1) 79 MOS 159-tET over all else, followed by 2) 72-tET, followed by 3) 65-tET, followed by 4) 60-tET, followed by 5) 34-tET, followed by 6) 29-tET, and at last followed by 7) Yarman-24a.

Acknowledgements

I am grateful to M. Uğur Keçecioglu and Anthony Prechtel for their guidance towards my preperation of the cumbersome formulae used in the MS Excel worksheets referred to in this manuscript that facilitated tedious calculations tremendously. I also wish to thank my three exceptional reviewers who commented very positively and constructively.

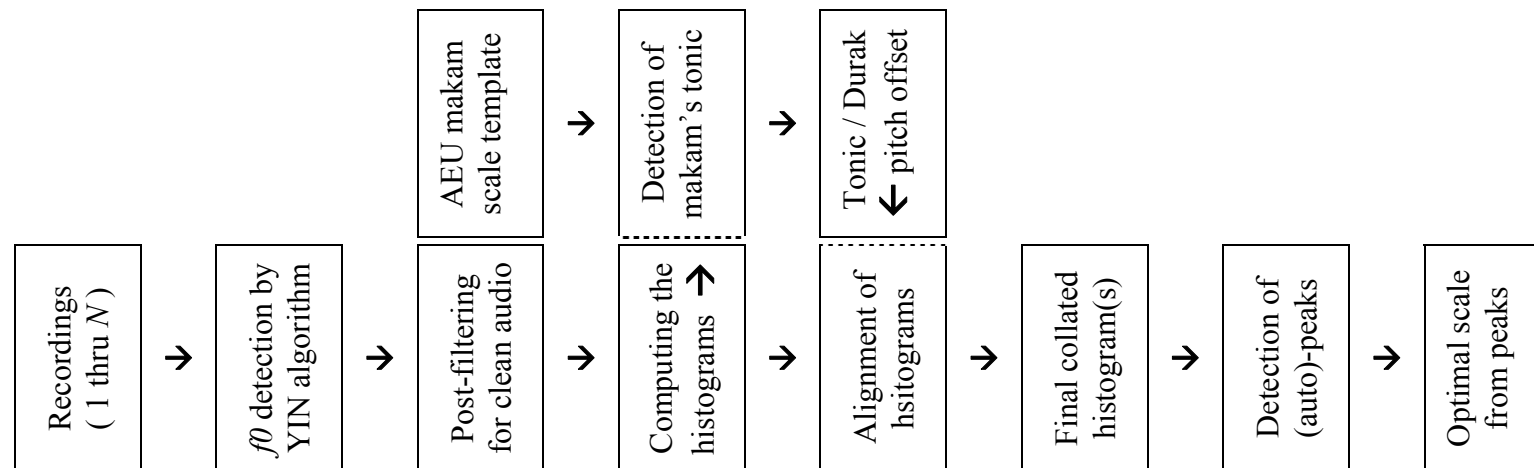
Finally, I thank, in the person of Dr. Amine Beyhom, the Editorial team of the NEMO Journal for their painstaking efforts to elevate the quality of this contribution to the highest level. The finalization of this article coincided with the chaotic wake of the massive chemical explosion at Beirut on 4 August 2020 concurrent with the second wave of the Covid-19 pandemic; and even so, I benefitted immensely from the professional camaraderie of my colleagues.

APPENDIX A

A summary of the frequency analysis procedure pertaining to both the older Bozkurt and Yarman et al. [2009] paper and the current contribution is presented below (cf. *Figure 0.1*). The addition of a peak detection algorithm to the earlier set of signal processing tools developed by Bozkurt [2008] for traditional Turkish music has allowed the straightforward extraction of the “optimal musical scale” from any digitized audio input against which to compare a theory. The entire algorithm was coded under MatLab by Bozkurt and is named as “*The MakamToolBox*”.

The sample set upon which Bozkurt’s batch operations were executed is, to reiterate, the same for either the Bozkurt and Yarman et al. [2009] paper and this contribution. In other words, the makam categories were and still are RAST (16 collated samples), NİHAVEND (12 collated samples), KÜRDİLİHİCAZKAR (17 collated samples), UŞŞAK (11 collated samples), HÜSEYİNİ (15 collated samples), HİCAZ (17 collated samples) SABA (11 collated samples), SEGAH (16 collated samples) and HÜZZAM (13 collated samples), constituting a total of 128 audio files that led to the production of 9 distinct histogram plots. The dataset in question comprises performances with highly characteristic microtonal inflexions by Tanburi Cemil (tanbur, kemençe, violoncello), Mesut Cemil (tanbur, violoncello), Ercüment Batanay (tanbur), Fahrettin Çimenli (tanbur), Udi Hrant (violin), Yorgo Bacanos (ud), Aka Gündüz Kutbay (ney), Kani Karaca (vocal), Bekir Sıdkı Sezgin (vocal), Necdet Yaşar (tanbur), İhsan Özgen (kemençe) and Niyazi Sayın (ney); thus spanning a historical period from 1910 to 2001.

Figure 0.1: Flowchart of the signal processing and histogram generation procedure that Bozkurt’s *The MakamToolBox* operates on.



In *Figure 0.1* above, I illustrated the automatic procedure used by Bozkurt's *The MakamToolBox* when analyzing a group of digitized audio files.

After feeding a given monophonic audio file into the code, one first finds the fundamental frequency f_0 and the rest of the pitches using the popular YIN pitch detection algorithm. One then sees that the f_0 raw data must be re-processed to fix the “mistakes” of YIN, such as correcting for the doubling/halving of octaves in this algorithm's mishandling of the Turkish makam zeitgeist, as well as to remove unwanted noise. Said post-filter too had been developed by Bozkurt [2008].

After the post-filter is complete, one sees that the corresponding histogram gets generated and is then calibrated in alignment with the best match to an Arel-Ezgi-Uzdilek makam scale template in order that the tonic of the performance is established for later collation with alike histograms.

Here, the pitch histogram of concern is just a 2D drawing where the datatable of detected frequencies gets dumped onto a graph representation based on their related incidences. Put in other terms, the histogram is basically a “90 degree hour-glassed melogram”. Thus, the one-to-one correlation for the final plot is that where the f_0 values are categorized under bins according to the formula

$$Hf_0[n] = \sum_{k=1}^K m_k ,$$

$$\text{with } m_k = 1, f_n \leq f_0[k] < f_{n+1}$$

$$\text{or } m_k = 0, \text{ otherwise;}$$

where the minima and maxima (f_n, f_{n+1}) represent boundary values that define the f_0 range for the n^{th} bin of our histogram representation.

The choice of the bin-width ($f_{n+1} - f_n$) – that is to say, the width of each category – demarcates the resolution of the histogram. For our purposes, it was, and for this contribution still is, desirable to use uniform sampling of the whole f_0 range. Through trial and error, the proper bin-width was established to be 1 degree of 159-tET (1/3rd the Holderian comma, or Hc , equalling 7.55ϕ), which is thought to optimize between the appearance of spurious peaks due to ultrafine discreteness and the undesirable loss of essential peaks on account of choosing a coarser grid.

One caveat must be mentioned at this point: All histogram graphics in the previous study [Bozkurt and Yarman et al. 2009] were originally drawn at $53 \times 12 = 636$ -tET resolution as the lowest best-fit workable grid for the adequate representation of the whole of the evaluated theoretical models. This constrained misrepresentations to a maximum of less than 1 cent absolute error concerning any pitch of any theoretical model considered therein. Thus, all pitch histograms were 4-fold upsampled for merging. Since I am not re-drawing histograms for my new analysis, it is not relevant here. It would be relevant if I or someone else decided to draw them based on the statistical findings hereunder.

Even so, the figures in APPENDIX C feature – for better or for worse – such 636-tET resolution plots from the previous study for visual comparison (albeit vertically squashed due to lack of publication space).

Another caveat is that, the MatLab code *The MakamToolBox* that was initially deployed by Bozkurt in our preparation of the original 2009 publication in *Journal of New Music Theory* operated within the 0.33 Holderian comma (Hc) sensitivity of the pitch measurement device. That is to say, for a scale tone at, say, $5 Hc$, all the frequency possibilities up to $\pm 0.17 Hc$ around that value collapsed to $5 Hc$. All this goes without saying how the histogram auto-peaks would minutely diverge due to systematic machine errors if a separate pitch measurement run were to be conducted.

Nevertheless, the outcome would at any rate – and I stress this part – only diminutively differ from earlier pitch measurement runs, and would not affect the previous or current conclusions in any significant way.

After the histograms are aligned based on the makam’s tonic as per Bozkurt [2008], simple averaging of the histograms, where they are summed up and divided by their amount, as well as the normalization of the result according to the highest pitch incidence equalling “1”, leads to the first of the two final histograms called the “average histogram”. The second of the two final histograms uses, prior to normalization, the maximum function leading to what is called the “envelope histogram”, that is otherwise the direct superposition of all histograms. A three-tap moving average filter then smoothens the ragged edges and allows for the robust detection of local maxima in terms of relative frequencies (i.e., the so-called “autopeak-ave.” and “autopeak-env.”). These final histograms are presented together – albeit in a squashed way – on top of all the figures in APPENDIX C as I stated above for visual comparison against the findings of the current contribution.

Last, but not the least, mismatches between the two types of auto-peaks and the suggested scale tones of a theoretical model in any intervallic unit (such as Hc or $cents$) can be shown. Knowing the relative frequencies I_{ai} of the autopeaks computed from the data automatically and the theorized scale tones I_{ti} of a tone-system, the maximum distance M and the average distance D between the two values for a given makam can be computed as

$$M = \max\{|I_{ai} - I_{ti}|\}, i = 1, 2, 3 \dots N_x, \quad D = \frac{1}{N_x} \sum_{i=1}^{N_x} |I_{ai} - I_{ti}|,$$

where N_x is the total number of scale tones for a given makam out of all the pitches of the tuning that match a measured relative pitch. Everything else from this point onward regarding data evaluation is detailed under the Methodology and Code & Data sections of the present paper.

APPENDIX B

A NEW MANDAL LAYOUT PLAN BY GÜNALÇİN AGAINST THE 79-TONE TUNING AND WEISS'S RATIONAL "Q9" QANUN

Serkan Günalçin recently spotlighted in his doctorate dissertation [Güenalçin 2019] a novel Just Intonation (JI) approach to installing mandals on the Turkish Qanun according to pitch measurements he meticulously gathered from 72 solo performances of Tanburi Cemil Bey. In the same spirit, Güenalçin had previously defended the abandonment of any equal tempered solution for this instrument in [Güenalçin 2013] after making a comparison with the electroacoustic assessments by Karl Signell of idiosyncratic intervals between the frets of the late Necdet Yaşar's Tanbur [Signell 1977, pp. 37-47, 151-61]. Yet, Güenalçin too, like many others, incessantly keeps portraying my 79-tone strategy as a structure with entirely equal intervals [Güenalçin 2019, pp. 11-2]. I now wish to critique Güenalçin's project in the light of the superior points of my 79-tone tuning and Stefan Pohlit's earlier doctoral work on the late Julien Jalaladdin Weiss's rational Qanun christened "Q9" [Pohlit 2011 & 2012].

In his exceptionally well-articulated doctorate study, Güenalçin identifies the following crucial elements:

- 1) The Qanun has remained, even up-to-this-day according to some, a *nâ-kâmil* (under-developed) instrument that is incapable of correctly producing the genuine perdes of Turkish Makam music – unless when in the hands of legendary performers like Kanuni Hacı Arif Bey, who successfully determined accidented pitches with the pressure of their thumb nail or finger pinches on the string courses;
- 2) Following the introduction of the advantageous mandal mechanism by the late 19th Century⁵ (also cf. Yarman and Sethares et al. 2019), the number of mandals per course increased dramatically throughout the decades – but even so, some renowned musicians shied away from the Qanun for its dearth of desired intonation at the initial stage;
- 3) Modern Qanuns today are mostly prepared in accordance with a voluminous and haphazard subset of sixfold stacked twelve-tone equal temperament resolution (for which Güenalçin unfortunately still does not accord to me due credit in being the first person who drew attention, and with necessary technical detail, to the fact that Qanun-makers affix the semitone mandal at 100 cents owing to the prevalent usage of Eurogenously manufactured electronic tuners, only to visually apportion the remaining distance to the nut to basically 6 equidistant portions to arrive at virtually 72-tET⁶ [cf. Yarman 2006 & Yarman 2016 & Yarman and Sethares et al. 2019]);

⁵ On the regular diatonically tuned Qanun, mandal technology was first implemented, according to Turkish musicologist Rauf Yekta, some 30 years prior to his submission of his invited monograph on Turkish Music to the 1922 edition of Albert Lavignac's *Encyclopédie de la Musique et Dictionnaire du Conservatoire* [cf. Yekta 1922, pp. 92-3].

⁶ to the extent that Güenalçin's rather perfunctory statement in his webinar presentation cited along with [Güenalçin 2019] that the microtones other than the naturals are indeterminate is baseless in the face of all my elucidations since more than a whole decade.

- 4) Because 72-tET does not approximate 53-tET degrees well – which, in turn, exceptionally houses Yekta-Arel-Ezgi-Uzdilek with only under 1 cent maximum absolute error at any degree [Yarman 2010, pp. 22, 128, 130-31, 159] – and discrepancies as much as half a comma thereby arise, alternative approaches surfaced some decades ago, such as the 53-tET mandal scheme by Ethem Ruhi Üngör and the hybrid Pythagorean + equipartitioned mandal scheme by İsmail Baha Süreلسan, although they have mostly fallen out of notice in general when confronted with modern 12-tET nucleated mandal installation suggestions, such as by Sait Durgun (who defends 60-tET that I presently analyze in this study) and by Nail Yavuzođlu (who previously defended 60-tET [Yavuzođlu 1991], but now defends 48-tET [Yavuzođlu 2008] – yet without giving any due mention to his predecessor Edward J. Hines – whereby 48-tET had already been debunked in Bozkurt and Yarman et al. [2009]);
- 5) Tanburi Cemil Bey is judged to be a ubiquitously-agreed-upon reference to pinpoint genuine Turkish Makam music intonation (although he is taken as the sole exemplar by Günelçin in contrast to the 12 distinct masters taken into consideration under the present study);
- 6) Praxis seems to involve the blend of two well-defined structures: i) A Pythagorean plane for transpositions and modulations that must eventually be limited in scope because exact 3-limit intervals never conjoin at the octave, ii) a greater prime-limit Just Intonation plane for capturing the *mujannabat*⁷ alongside special tetrachordal genera over certain degrees (regarding which the reader might wish to refer to [Yarman & Karaosmanođlu 2014] that I analyze herein as a clever attempt to bridge the commatic world with the quarter-tonal);
- 7) Rauf Yekta and Suphi Ezgi acknowledge the existence of these *mujannabat*, whereas Hüseyin Saadettin Arel completely ignores them later on (which is somewhat of a false statement by Günelçin, because both Yekta and Ezgi specifically indicate that the “unsystematized” *mujannab* ratios of old are quite adequately superseded by the 24-tone Pythagorean tuning they espouse⁸ [Yekta 1924, p. 13 & Ezgi 1933, pp. 57-8, 139 & 1940, pp. 210-1]);
- 8) Owing to the confluence of these facts, and despite the Makam music pitch-space being rather “unquantized” in practice, it is necessary to abandon 53-tET and combine a cornucopia of just intervals with Pythagorean ratios for especially the Qanun;

⁷ “*Mujannabat*” (Pl. of *Mujannab* in Arabic: “The ones who are situated next to...”), as had been first coined in extant Islamic music theory literature by the acclaimed Safiyuddin Urmavi [Arslan 2007b, pp. 336], and later on picked up by Yalçın Tura as *mücenneb bölgesi* or the *mujannab zone* [Tura 1981], are a group of “semitonal to sequisemitonal” fingerboard positions (being at least four in total, with all of them christened “*mujannab-i sabbaba*”) bridgeward the open string on the Oud, corresponding to the pressure by the index finger at an anterior location compared to the standard wholetone location by the same finger (i.e., *sabbaba*) [cf. Ibn Sina 1030, pp.109-12 & Farmer 1957 & Kutluđ 2000, pp.31-3 & Forster 2010]. They delineate a “microtonal continuum” in the pitch-space (with such a quotidian interpretation yet possibly amounting to merely an anachronism!), where especially the fractions 256/243 (90¢), 18/17 (99¢), 162/149 (145¢) and 54/49 (168¢) are associated with the feel of a “*mujannab* interval” (and where the latter two ratios, along with the addition of the Farabian 12/11 (151¢), are nearer to the contemporary sequisemitonal understanding of this interval type).

⁸ The reader is encouraged to consult the concomitantly cited references, where Yekta – for his prioritization of TAHKİKİ (well-determined – i.e., *Pythagorean*) ratios instead of TAKRİBİ (approximate) ratios – plainly dismisses to notate 12/11 (his so-called “*nakıs büyük mücenneb*”, or diminished large middle second), while Ezgi openly rejects even the possibility of 11/10 (let alone 12/11) in Uşşak and Saba. Needless to say, I was probably the first person to academically highlight the (politically calculated?) disregard of such “acknowledged” out-of-the-ordinary macrotones by Yekta and Ezgi in my doctoral defense dated June 2008 [cf. Yarman 2016, p. 421].

- 9) The intermarriage of Pythagoreanism with just intervals would restore the time-honored hint & clue relationship between praxis and theory, even with regards to previously available transpositions (such as Kâni Karaca’s famous Saba modulation over *perde saba* while executing an ordinary Saba, as mentioned by Günelçin) whose historical links had been severed due to the draconian hemiolic limitations imposed by Arel (although the responsibility for such a rupture is actually shared by Yekta and Ezgi too the way I delineated in my doctorate thesis under the heading “*Rise of the ‘Yekta-Arel-Ezgi School’*” [Yarman 2016, pp. 15-24]);
- 10) Such an intermarriage seems already implied in the tractates of Urmavi [cf. Arslan 2007a & 2007b], where Urmavi casually maps his JI or highly complex rational genera to extended transpositions over his archetypal 17-tone Pythagorean grid – to the extent that one would then appear to find the need to shift frets on demand (as happens to be just the subject I frequently communicated to colleagues like Prof. Arslan since more than a decade [cf. Yarman 2007, pp. 3-4]), thus cementing the notion that the traditional Turkish music tone-system is open-ended instead of close-ended (although this is pretty much obvious so long as one is deprived of taking means geometrically or logarithmically!)⁹;
- 11) Since transpositions are necessarily(!) Pythagorean and plausible just intervals so numerous at any natural degree, there is no way to avoid the emergence of an overwhelming mass of extra pitches in this open-ended system – whereby one must increase the mandal space while condoning some sacrifices in pitch exactness to gain the ability to transpose makams over the common *Ney Ahenks*¹⁰;
- 12) Thusly, with occasional mandal revisions as much as 4.1 cents on the original “Model 1” proposal, one gains the ability to exceed the commonplace *Bolahenk Nısfıye*, *Kız* and *Mansur Ahenk* restrictions to achieve concert pitch additions such as *Müstahsen*, *Sipürde* and *Davud* (but not *Şah?*) – whereby, with the inclusion of double-sharp mandals (going all the way up to 23 mandals per course(!) compared to the 79-tone Qanun’s maximum of 19), one then has 10+9(+5) mandals for G’s, 10+9 mandals for A’s, 10+6 mandals for B’s, identical 10+9(+5) mandals for C’s and D’s, selfsame 10+9 mandals for E’s, and homologous 10+6 mandals for F#’s (while, surprisingly enough, Günelçin does not exploit the opportunity to take here an F as the “natural” the way I had done) as space permits throughout A2-E5, resulting in a total of at least 91 distinct pitches per octave! – i.e., 17 Pythagorean plus 74 just ratios [Günelçin 2019, pp. 238-51];

⁹ It is indeed regrettable that, although Günelçin on the one hand commends Yalçın Tura as having tackled the matter “in the best way” – e.g., in terms of Tura’s interpretation of Urmavi’s 17-tone Pythagorean division as 17-tET at a pre-logarithmic era no less! – he keeps going on about the necessity for an open-ended tone-system for Classical Turkish music. While such a route might have been justified in the face of the Early Republican regime’s targeting of “quarter-tones” as “Byzantine” and “Arabic” with an agenda to promote solely Western equal-temperament norms under the slogan of “Universal Music”, why should there any more be a *sine qua non* to forego Modern Age mathematical tools for the decent fractional exponentiation of a consonant interval to make things more regular and widely transposable? Günelçin’s argumentation is clearly an outmoded ideological device under the post-logarithmic present day circumstances (especially after Michael Stifel’s 1544 “*Arithmetica Integra*”).

¹⁰ “Concert Pitches” like *Bolahenk* with *perde rast* (second partial blown from all fingerholes of the Ney closed) at D; *Davud* with *rast* at E; *Şah* with *rast* at F; *Mansur* with *rast* at G; *Kız* with *rast* at A; *Müstahsen* with *rast* at B; and *Sipürde* with *rast* at C. Observe, that *perde rast* can be made to correspond to any tone of Western common-practice music, including all the half-tones in-between the naturals.

- 13) “Enharmonic respellings” may then allow for transpositions at *Bolahenk-Sipürde mabeyni* (perde *rast* at C#/Db) and *Şah-Mansur mabeyni* (perde *rast* at F#/Gb), as well as other far-off keys (which Günelçin baselessly claims is a novelty not thought of or considered before – although my 79-tone Qanun tuning recipe [cf. Yarman 2010, p. 60 & Yarman 2016 (author’s website)] based on enharmonic equivalences that he himself outlined in [Günelçin 2019, p. 12] is a stark refutation of such a claim);
- 14) Given the “purity and authenticity of intonation” Günelçin purportedly achieves through his ponderous method, which he personally implemented on a Qanun whose mainbody was manufactured by Mustafa Sağlam (that involves some incomprehensible latent mandal additions and revisions under his “Model 2” [cf. Günelçin 2019, pp. 247-51]), other implementations such as my 79-tone Qanun do not, according to him, reflect practice just as well (despite the fact that Günelçin verbally admits 79 MOS 159-tET as very closely verging on ALL of his Pythagorean and “natural” ratios)¹¹;

In a broad sweep, the weaknesses of Günelçin’s point of departure are as follows...

He presumes his solitary exemplar (Tanburi Cemil Bey) is authoritatively representative of all of Turkish Classical/Art/Folk music – such as regarding the supposed absence, in praxis, of the 256/243 *limma* amounting to an interval size of 90¢ (except when one goes up some fifths and plays at a different key, or for completing a tetrachord) that he interprets as Cemil Bey’s escape attempt from Pythagoreanism. Yet, were he to include other masters who, in particular, perform on different instruments – as is done under the present study – Günelçin would probably have witnessed the happenstance of such a *limma* regularly, as well as the execution of tetrachords and pentachords in his list of “proper genera” over many more tones than he gives license [cf. Günelçin 2019, pp. 176, 182, 193, 215].

He dismisses the merits of other theoretical models without investigating their success in matching the pitch measurements from his chosen exemplar. In other words, he does not weigh the body of historical *mujannabat* ratios [cf. Arslan 2007a & 2007b, p. 336] and tetrachordal divisions that agree with his pitch measurements against the thus-far implemented Qanun mandal configurations of Üngör, Sürelsan, Durgun, Weiss and Yarman, to say nothing of the “piyasa Kanun’u” (12-tET nucleated “marketplace Qanun”). Out of all of these, the intonational success of especially 72-tET as well as the Weiss and Yarman implementations are not at all properly scrutinized – even though Günelçin particularly states that the 79-tone tuning very closely approximates the “natural” intervals that are under his focus [Günelçin 2019 (webinar link)].

¹¹ Regrettably once more, Günelçin maunders that one is obliged to explain the tone-system of Classical Turkish music by either dividing the octave “equally” (why?!), or by limiting the number of ratios, or by sanctioning an excess of Pythagorean and just mandals for extended transpositions. Yet, as it so happens, 79 MOS 159-tET is not an entirely equal construct (e.g., it partitions 4/3 instead into 33 equal portions) while still permitting regularized and tolerable transpositions over ALL degrees. This only goes to show that the prevailing mindset is inexcusably “pre-logarithmic” or “12-tET nucleated”, seeing as Turkish Qanuns are, for the most part, still being prepared in accordance with multiples of twelve-tone equal temperament the way I had first described, or “traditionalist academical alternatives” are, almost without exception, inclined toward an arithmetic historicism of fractional interval usage or an equipartitioning of the 100¢ “equal semitone” as referred to Eurogenuous electronic tuners or popular score engraver computer programs.

He wants to give the impression that Yekta and Ezgi actually condoned the usage of *mujannabat* outside the bounds of their 24-tone Pythagorean cast – and hence, extant tetrachordal genera featuring such “middle seconds” – while Arel supposedly unilaterally forbade them altogether. Not only is this an inadmissible anachronism, but it is plainly wrong; and so is Günelçin’s insinuation that Yekta actually expressed the applicability of Greek-Islamic genera to quotidian praxis instead of seeing them confined to dusty books and shelves [cf. Yekta 1922, pp. 60-3¹²].

Günelçin similarly misrepresents Tanburi Cemil Bey when he quotes him as allegedly saying “Tanbur is a fretless instrument”; whereas Cemil Bey rather states (English translation is mine): “... *These frets are not fixed upon the neck as is the case with Mandolin and Guitar, and are oiled in such a way as to be able to be moved either way while there is enough space on the neck to allow for this and that any desired fret may be added to the Tanbur. The Tanbur thence possesses the means of expression unique to fretless instruments as such.*” [Cemil Bey 1925, p. 22]. In other words, contrary to what Günelçin asserts, the re-positioning and/or increase of frets serves to “microtonalize” the Tanbur, but not really to make it “fretless per se”; as is also the case with the Qanun via minutiae granted by a multiplicity of fixed mandals. So, Günelçin does not truly answer the question: “why exceed Cemil Bey’s more-or-less-predetermined 36 Tanbur frets per two octaves [cf. Günelçin 2019, pp. 134-7] if one is ultimately limiting oneself in terms of a few transpositions and modulations over a few *Ahenks*?”

Günelçin hence assumes transpositions and modulations must eventually be limited on the pretext that an infinite number (*sic*) of “natural” ratios can be advanced and that the traditional Turkish music tone-system should be open-ended (i.e., not be “cyclic”, and not therefore be based on tempered perfect fifths – like in 56-tET that I lately think is delectable). Yet, he does not seem to realize that such a presupposition rests solely on the premise of totally neglecting tolerable geometric and logarithmic divisions when equipartitioning simple epimoric consonant intervals like 2/1 or 3/2. Given that the danger of getting the tradition branded as “Arabic” or “Byzantine” with an intent to cast it out of society no longer exists, Günelçin has no visible recourse to freeze the transpositional and modulational development of Makam music at late 19th and early 20th Centuries so as to extol an itinerary of pure arithmeticism in music theory compared to higher mathematical devices as in taking roots or taking logarithms, which are proven to be beneficial worldwide in music-making and toward the advancement of music in general.

He thus opines, and without any basis whatsoever, the precedence of a pre-logarithmic mindset to a post-logarithmic mindset in Makam music; imagining moreover that post-logarithmic options solely constitute “equal divisions of the octave”. He, just like many of my peers, does not seem to understand the structure and function of especially the “hybrid modified meantone cores” of my 24-tone and 36-tone tuning suggestions.

¹² On page 63 of his abovementioned monograph, Yekta contrariwise writes (English translation and emphases are mine): “*It may thence be asked of us <How many harmonious tetrachords have been obtained (by Hellenistic and Islamic music theorists) after such tiresome labors?> To this we reply, and with some embarrassment, ONLY FOUR (i.e., A. 9/8 x 9/8 x 256/243, B. 9/8 x 10/9 x 16/15, C. 15/14 x 7/6 x 16/15, D. 12/11 x 7/6 x 22/21) that have been judged as consonant. The others have been relegated to remain in tractates; yet, even so, after so many centuries, they have muddled the minds of European theorists wanting to apply them in unproductive works whilst desiring to demystify the enigma of genera in Greek music!*”

Furthermore, Günelçin does not appear to genuinely exploit “enharmonic equivalences” when he affixes as much as 23 mandals per course. It only suffices to visually compare his scheme (he unfortunately does not yet provide a complete list of his ratios and/or temperings in an octave) with the nominal 19 mandals per course on the 79-tone Qanun (with my last 4 mandals serving as double-sharps). Surely, any criticism as to “unplayability” in the case of the 79-tone Qanun applies with even greater force against Günelçin’s “Model 1” or “Model 2” given his minimum of 91 pitches per octave!

When all is said and done, Günelçin’s smallest occurring interval between any two neighboring mandals is an impracticably tight-packed 7.71ϕ [Günelçin 2019, pp. 243-6]. For people criticizing how the 79-tone Qanun’s smallest interval (15.1ϕ) in comparison to 72-tET’s smallest (16.7ϕ) is troubling from the viewpoint of musical performance, half of what I propose at already the very limits of mandal installation for the register A2-E5 is without any doubt much more unfeasible.

Despite so much detail, Günelçin’s configuration – due to the curtailed Pythagorean tuning at its core – cannot let the sharps and flats meet and overlap circularly (e.g., through a cycle-of-fifths) should the need arise (such as in cases of chromaticism or in accompaniment with Western-style ensembles and orchestras). In contradistinction, the 79-tone tuning permits this [cf. Yarman 2016, pp. 115-6]: Mode 6 7 7 6 7 6 7 6 7 7 6 7 of 79 MOS 159-tET, equalling $91+106+106+91+106+91+113+91+106+106+91+106$ consecutive cents, extracts a workable 12-tone cyclic subset – which is one of several alike possibilities – and contains only one “wolf fifth” that may very well be considered tame. (In addition, it is conceivable to satisfactorily encapsulate Arel-Ezgi-Uzdilek as mode 6 1 5 1 7 1 4 2 4 2 6 1 5 1 6 1 5 1 7 1 4 2 4 2 under 79 MOS 159-tET, which thus equals $91+15+76+15+106+15+61+30+61+30+91+15+76+21+91+15+76+15+106+15+61+30+61+31$ consecutive cents.)

And while 79 MOS 159-tET can approximate every one of Günelçin’s list of *Djemilian* tetrachords (i.e., derived from Tanburi Cemil Bey) in the Tables 4.80 & 4.81 of his doctorate dissertation [Günelçin 2019, pp. 193, 215] with a maximum of 7-8 cents absolute error at any given degree [cf. Yarman 2016, pp. 95-100], the added bonus of unlimited transpositions cannot be matched with his “Model 2” – let alone his “Model 1”.

Finally, Günelçin acquiesces to adopt the inconsistent Arel-Ezgi-Uzdilek notation (i.e., the Turkish Classical/Art music accidentals symbolism in effect) for his irregular megalithic edifice [Günelçin 2019, pp. 239, 257]. However, by doing so, he pulverizes any venue for executing advanced or experimental techniques that might involve calculated xenharmony on his Qanun. In such a way, Günelçin prevents his Qanun from becoming an instrument that may serve to expand and cosmopolitanize microtonal musical expression while preserving tradition – especially in the face of institutional and constitutional modern education requirements. In contrast, the 79-tone Qanun is accompanied by a re-purposed complementary “Sagittal Notation” originally developed by David Keenan and the late George Secor, which can hence serve as a gateway to future “makam polyphony” while being backwards-compatible with 65-tET and 72-tET [Yarman 2016, pp. 4, 106-9].

I now propose to compare Günelçin’s *rast-çargah* tetrachordal layout with Weiss’ commensurate “Q9” tetrachordal layout. See Table 0.1 below:

Table 0.1: Comparison of the *rast-çargah* mandal area between Günalçin’s “Model 2” and Weiss’ commensurate “Q9” rational Qanun (in bold).

<i>çargah</i>	8192/6561	512/405	80/63	448/351	104/81	128/99	176/135	21/16	320/243	<i>4/3</i> <i>G4</i>	<i>27/20</i>	<i>121/96</i>	<i>567/416</i>	<i>351/256</i>	<i>224/176</i>	<i>89/64</i>	<i>45/32</i>	<i>729/512</i>	<i>81/66</i>	Maximum absolute diff.: 7.71 cents (¢) Average of abs. diffs. $\approx 150/58 = 2.74¢$ Root-mean-square $\approx \sqrt{(760/58)} = 3.78¢$ Harmonic mean of abs. diffs. = 5.81¢ Balanced sumtotal average $\approx -42/58$ = -0.89333 ¢				
CENTS	384	406	414	422	433	445	459	471	477	498	<i>520</i>	<i>527</i>	<i>536</i>	<i>546</i>	<i>558</i>	<i>575</i>	<i>590</i>	<i>612</i>	<i>639</i>					
<i>çargah</i>	8192/6561	512/405		448/351	2816/2187	4096/3159	952/729	320/243		4/3														
CENTS	384	406		422	438	450	462	477		498														
DIFF.	0	0	8	0	-5	-5	-3	-6	0	0														
<i>buselik</i>	7/6	32/27	6/5	135/112	63/52	39/32	27/22	99/80	5103/4096	<i>81/64</i> <i>F#4</i>	6561/5120	295245/229376	137781/106496	85293/65536	59049/45056	216513/163840	10935/8192	177147/131072	19623/14336	45927/32768	147323/1048576	2391468/1677216	50049/40960	43046721/29360128
CENTS	267	294	316	323	332	342	355	369	381	408	429	437	446	456	468	483	500	522	549	584	592	614	631	662
<i>buselik</i>	<i>16</i>	32/27	6/5		63/52	11/9	16/13	119/96	5/4	<i>81/64</i>	<i>6561/5120</i>	<i>137781/106496</i>	<i>2073/2048</i>	2187/1664	86751/65536	10935/8192	177147/131072							
CENTS	<i>267</i>	294	316		332	347	359	372	386	408	<i>429</i>	<i>446</i>	<i>461</i>	473	486	500	522							
DIFF.	-2	0	0	7	0	-5	-4	-3	-5	0	0	8	0	-5	-5	-3	0	0						
<i>dügah</i>	28/27	256/243	16/15	15/14	14/13	13/12	12/11	11/10	567/512	<i>9/8</i> <i>E4</i>	729/640	32805/28672	15309/13312	9477/8192	6561/5632	24057/20480	1215/1024	19683/16384	2187/1792	5103/4096	164025/131072	2657205/2097152	6561/5120	4782969/3670016
CENTS	63	90	112	119	128	139	151	165	177	204	225	233	242	252	264	279	296	318	345	381	388	410	429	459
<i>dügah</i>	<i>16</i>	256/243	16/15		14/13	88/81	128/117	119/108	10/9	<i>9/8</i>	<i>729/640</i>	<i>15309/13312</i>	<i>207/256</i>	243/208	9639/8192	1215/1024	19683/16367	upper	upper	upper	upper	upper	upper	upper
CENTS	<i>63</i>	90	112		128	143	156	168	182	204	<i>225</i>	<i>242</i>	<i>257</i>	269	282	296	319	347	380	386	402	429	461	
DIFF.	2	0	0	7	0	-4	-5	-3	-5	0	0	8	0	-5	-5	-3	0	-1	-2	-5	2	2	0	-2
<i>rast</i>	<i>224/243</i>	<i>2049/2187</i>	<i>126/135</i>	<i>20/31</i>	<i>112/117</i>	<i>26/27</i>	<i>32/33</i>	<i>44/45</i>	<i>63/64</i>	<i>80/81</i>	<i>D4</i>	64/63			28/27	25/24		135/128	16/15	243/224				
CENTS	<i>141</i>	<i>114</i>	<i>92</i>	<i>84</i>	<i>76</i>	<i>65</i>	<i>57</i>	<i>50</i>	<i>47</i>	<i>42</i>	0	27			63	71		92	112	141				
<i>rast</i>											<i>C4</i>	81/80	46/45	33/32	27/26		91/87	135/128	2187/2048	upper				
CENTS											0	22	38	53	65		78	92	114	141				
DIFF.											0	5			-2	6		0	-2	-2				

Shaded cells are either out of range or unavailable. For instance, the 225¢, 242¢ and 257¢ mandals are omitted on both “Q8” and “Q9” to expedite “flexibility and ease of modulation” [cf. Pohlit 2011, pp. 76-7], but they nevertheless remain relevant theoretically and are described at any rate. Likewise, there are no correspondences in Gnalin (according to his nominal *Bolahenk* starting on D4) for the 46/45, 33/32 and 91/87 mandals found on “Q9” (according to the nominal *Siprde Ahenk* starting on C4), and I disregarded to evaluate them for the sake of fairness.

Julien Weiss’ “Q9”, just like his previous “Q8” implementation (with inconsequential differences in regards to some convergent intramandal ratios), contains a standard of 14 mandals per course throughout (except the aforesaid omissions under some string courses), and Stephen Pohlit [2011, pp. 75-84, 262-4] gives the particulars of this rational layout in one octave as both fractions and cents. What is relevant here for our purposes is the tetrachordal span starting on perde *rast* (C4).

By comparison, I was able to extract the tuning information out of what Gnalin dubs “*mandal sets 1-3*” [Gnalin 2019, pp. 243-51 & webinar link] through considerable difficulty and via checking and re-checking his online presentation. These correspond to Fa/do (C4/G4) for set 1, Sol/re (D4/A4) for set 2, and La/Si/mi (E4/F#4/B4) for set 3. Extended revisions (constituting his “Model 2”) lead to E4/F#4/B4 being assigned to the “modified set 1” (now having 23 mandals instead of the previous 18!), C4/G4 being assigned to the “modified set 2” (now having 19 mandals instead of the previous 15 or 16), and D4/A4 being assigned to the “modified set 3 (now having 16 mandals instead of the previous 15).

Closest matches of “Q9” ratios (in bold) have thus been juxtaposed against Gnalin’s ratios that I extracted unto Table 0.1. Notice that the largest absolute difference (marked with red) in-between them for any perde occurrence is less than 8 cents (while any kind of average of the modulus of differences is about 3 to 6 cents) – just as in the case of the approximation capabilities of my 79-tone Qanun tuning. Such is, to all intents and purposes, near or at the “acoustic limen” for the entirety of the pragmatical ambitus of the Qanun [cf. Long 2014].

This basically signifies that the whole enterprise by Gnalin – despite his painstaking efforts to uphold makam fidelity – practically amounts to what Weiss had already accomplished with even lesser mandals (at yet the expense of the lack of double-sharps as well as the 28/27 approach to the natural of the lower course when all mandals of the upper course are lowered) – aside from the fact that either choice can be much more advantageously substituted with 79 MOS 159-tET. This is especially true for the latter’s ability to approximate – and I cannot stress this part enough – any given ratio from either former case at any level of transposition with only a maximum of 7-8 cents absolute error; not to mention the 79-tone tuning’s avoidance of reckless schismatic aberrations – such as the 500 cent 10935/8192 ratio in both former cases not being exactly enharmonically equivalent to the 498 cent 4/3 ratio at their upper courses.

Mind that Gnalin moreover appears to have altered his doctoral scheme for the upended “mandal set 2” corresponding to the G&C courses [cf. Gnalin 2019 (webinar link)] in order to squeeze in one more mandal at only 5.76¢ away from its nearest neighbor! I highlighted its location in yellow in Table 0.1.

To wrap up this sub-section, I wish to point out the instructional video titled “*Tuning Theory 3: Moment of Symmetry ("Microtonal" Theory) --- John Moriarty*” by John Moriarty from the “Xenharmonic Alliance” in order to better illuminate the concept of “Moment-of-Symmetry” (“MOS”, as had been first coined and articulated by Ervin Wilson), since it happens to be an intrinsic and essential feature of the 79-tone tuning [cf. Yarman 2010, pp. 32-63 & YouTube link on “MOS”]; which owes its mathematical integrity and transpositional regularity as such to the presence of just two (one large “L” and one small “S”) types of commas derived from a single generator interval (e.g., seventy-eight instances of 15.1ϕ and a single final instance of about 22ϕ cents occurring throughout *yegah-neva* coincident to *Sipürde Ahenk* at G3-G4).

For a recapitulation of the unique aspects of the 79-tone Qanun tuning, I outline in Table 0.2 below the octave structure and reasonably adequate fractional approximation possibilities under 79 MOS 159-tET:

Table 0.2: *Rast-gerdaniye* octave detail of 79 MOS 159-tET in the proposed standard of *Sipürde Ahenk*.

Degree	Integer Cents	159-tET subset	17 “traditional” perde zones	Simplified Frequencies	Cents	Frequencies (A4=440Hz)	Cents	Consecutive intervals	Approximated ratios with at most 7.5 cents error
0:	0	0	<i>Rast - C</i>	262	0.000	261.911	0.000	(with prev.)	1/1 (Do)
1:	15	2	<i>dik rast</i>	264 1/2	16.441	264.204	15.094	15.094	126/125,100/99,81/80
2:	30	4	(<i>sarp rast</i>)	266 3/4	31.106	266.518	30.189	15.095	64/63,3125/3072,55/54
3:	45	6	(<i>rast+irha</i>)	269	45.647	268.852	45.283	15.094	128/125,36/35,33/32
4:	60	8	(<i>alt şûri</i>)	271 1/4	60.068	271.206	60.377	15.094	729/704,28/27,27/26
5:	75	10	<i>şûri</i>	273 3/4	75.951	273.581	75.472	15.095	25/24,117/112,22/21
6:	91	12	<i>nim zengûle</i>	276 1/4	91.689	275.977	90.566	15.094	20/19,256/243,135/128
7:	106	14		278 1/2	105.733	278.394	105.660	15.094	17/16,16/15,2187/2048
8:	121	16		281	121.204	280.832	120.755	15.095	15/14,14/13
9:	136	18	<i>zengûle cluster</i>	283 1/2	136.538	283.291	135.849	15.094	14/13,27/25,13/12
10:	151	20		286	151.738	285.771	150.943	15.094	88/81,12/11,35/32
11:	166	22		288 1/2	166.805	288.274	166.038	15.095	11/10,54/49
12:	181	24	<i>dik zengûle</i>	291	181.743	290.798	181.132	15.094	65536/59049,10/9
13:	196	26	<i>Dügâh - D</i>	293 2/3	197.535	293.345	196.226	15.094	28/25,9/8 (Re)
14:	211	28	<i>dik dügâh</i>	296	211.236	295.914	211.321	15.095	9/8,26/23
15:	226	30	(<i>sarp dügâh</i>)	298 3/4	227.246	298.505	226.415	15.094	256/225,8/7
16:	242	32	<i>nim kürdi</i>	301 1/2	243.109	301.119	241.509	15.094	144/125
17:	257	34	(<i>nim nihâvend</i>)	304	257.405	303.756	256.604	15.095	37/32,81/70,125/108

18:	272	36	<i>alt kürdi</i>	306 3/4	272.996	306.416	271.698	15.094	7/6
19:	287	38	<i>kürdi</i>	309 1/4	287.048	309.099	286.792	15.094	33/28,13/11,32/27
20:	302	40	<i>dik kürdi</i>	312	302.375	311.806	301.887	15.095	32/27,25/21,81/68
21:	317	42	<i>nihâvend</i>	314 3/4	317.567	314.536	316.981	15.094	6/5,19683/16384
22:	332	44	<i>hicâzî segâh</i>	317 1/2	332.628	317.291	332.075	15.094	63/52,40/33,17/14
23:	347	46	<i>uşşâkî segâh</i>	320 1/4	347.558	320.069	347.170	15.095	39/32,11/9,27/22
24:	362	48	<i>sâbâî segâh</i>	323	362.361	322.872	362.264	15.094	16/13,100/81,21/17
25:	377	50	<i>Segâhçe (Segâh swap?)</i>	326	378.366	325.699	377.358	15.094	31/25,41/33,46/37,5/4
26:	392	52	Segâh(çe?) - E	328 3/4	392.909	328.552	392.453	15.095	(Mi) 5/4,64/51,59/47
27:	408	54	<i>bûselik (E#)</i>	331 3/4	408.636	331.429	407.547	15.094	81/64,19/15,33/26
28:	423	56	<i>nişâbür</i>	334 1/2	422.927	334.331	422.642	15.095	14/11,23/18,32/25
29:	438	58	<i>(dik nişâbür)</i>	337 1/2	438.385	337.259	437.736	15.094	9/7
30:	453	60	<i>(bûselik+irha)</i>	340 1/2	453.706	340.212	452.830	15.094	35/27,13/10
31:	468	62	<i>(nişâbür+irha)</i>	343 1/2	468.892	343.191	467.925	15.095	38/29,21/16
32:	483	64	<i>alt çargâh</i>	346 1/2	483.946	346.197	483.019	15.094	33/25,37/28
33:	498	66	Çargâh - F	349 1/3	498.045	349.228	498.113	15.094	4/3 (Fa)
34:	513	68	<i>dik çargâh</i>	352 1/2	513.668	352.287	513.208	15.095	39/29,35/26,27/20
35:	528	70	<i>(sarp çargâh)</i>	355 3/4	529.556	355.371	528.302	15.094	19/14,49/36
36:	543	72	<i>nim (garip) hicaz</i>	358 3/4	544.094	358.483	543.396	15.094	26/19,48/35,11/8
37:	558	74	<i>(nim sâbâ)</i>	362	559.707	361.623	558.491	15.095	11/8,29/21
38:	574	76	<i>alt hicaz</i>	365	573.996	364.789	573.585	15.094	25/18,32/23,39/28
39:	589	78	<i>hicaz</i>	368 1/4	589.342	367.984	588.679	15.094	7/5,1024/729,45/32
40:	604	80	<i>uzzâl</i>	371 1/2	604.554	371.206	603.774	15.095	24/17,17/12
41:	619	82	<i>sâbâ</i>	374 3/4	619.634	374.457	618.868	15.094	10/7
42:	634	84		378	634.583	377.736	633.962	15.094	23/16,36/25,49/34
43:	649	86	<i>sâbâ-bestenigâr cluster</i>	381 1/4	649.405	381.044	649.057	15.095	16/11,8192/5625,35/24
44:	664	88		384 3/4	665.225	384.381	664.151	15.094	22/15,69/47,72/49
45:	679	90		388	679.788	387.746	679.245	15.094	37/25,40/27
46:	702	93	Nevâ - G	393	701.955	392.851	701.887	22.642	3/2 (Sol)
47:	717	95	<i>dik nevâ</i>	396 1/4	716.213	396.291	716.981	15.094	53/35,50/33,1024/675
48:	732	97	<i>(sarp nevâ)</i>	400	732.520	399.761	732.075	15.094	32/21,29/19,75/49

49:	747	99	(nevâ+irha)	403 1/2	747.602	403.262	747.170	15.095	192/125,20/13,54/35
50:	762	101	(alt bayâti)	407	762.554	406.793	762.264	15.094	45/29,59/38,14/9
51:	777	103	bayâti	410 1/2	777.378	410.356	777.358	15.094	25/16,47/30,11/7
52:	792	105	nim hisar	414	792.077	413.949	792.453	15.095	30/19,128/81,19/12
53:	808	107		417 1/2	806.651	417.574	807.547	15.094	43/27,8/5,6561/4096
54:	823	109		421 1/4	822.132	421.231	822.642	15.095	37/23
55:	838	111	hisar/hüzzam cluster	425	837.475	424.919	837.736	15.094	34/21,81/50,13/8
56:	853	113		428 3/4	852.684	428.640	852.830	15.094	44/27,18/11,105/64
57:	868	115		432 1/2	867.760	432.394	867.925	15.095	28/17,33/20
58:	883	117	dik hisar (hisârek)	436 1/4	882.706	436.180	883.019	15.094	32768/19683,5/3
59:	898	119	Hüseyni - A4	440	897.524	440.000	898.113	15.094	5/3,42/25,27/16 (La)
60:	913	121	dik hüseyni	444	913.191	443.853	913.208	15.095	27/16,39/23,17/10
61:	928	123	(sarp hüseyni)	447 3/4	927.752	447.740	928.302	15.094	128/75,41/24,12/7
62:	943	125	nim acem	452	944.107	451.661	943.396	15.094	50/29,216/125,64/37
63:	958	127	(nim dik acem)	455 3/4	958.411	455.616	958.491	15.095	125/72,40/23,47/27
64:	974	129	alt acem	459 3/4	973.539	459.606	973.585	15.094	7/4,225/128
65:	989	131	acem	463 3/4	988.537	463.630	988.679	15.094	23/13,16/9
66:	1004	133	dik acem	467 2/3	1003.097	467.691	1003.774	15.095	16/9,25/14
67:	1019	135	sarp acem	472	1019.064	471.786	1018.868	15.094	9/5,59049/32768
68:	1034	137		476	1033.674	475.917	1033.962	15.094	29/16,20/11
69:	1049	139	eviç/arazbar cluster	480 1/4	1049.063	480.085	1049.057	15.095	11/6
70:	1064	141		484 1/2	1064.316	484.289	1064.151	15.094	37/20,50/27,13/7
71:	1079	143	alt eviç (Eviç instead?)	488 1/2	1078.550	488.530	1079.245	15.094	28/15
72:	1094	145	Eviç (Mâhur swap?) - B	492 3/4	1093.547	492.808	1094.340	15.095	(Si) 15/8,32/17,17/9
73:	1109	147	(dik?) mâhur (B#)	497 1/4	1109.285	497.124	1109.434	15.094	256/135,243/128,40/21
74:	1125	149	dik(çe?) mâhur	501 1/2	1124.019	501.477	1124.528	15.094	21/11,23/12,48/25
75:	1140	151	(mâhurek)	506	1139.485	505.868	1139.623	15.095	27/14,29/15,31/16
76:	1155	153	(dik mâhurek)	510 1/4	1153.965	510.298	1154.717	15.094	37/19,39/20,125/64
77:	1170	155	(sarp mâhurek)	514 3/4	1169.166	514.767	1169.811	15.094	49/25,55/28,6144/3125
78:	1185	157	alt gerdâniye	519 1/4	1184.235	519.275	1184.906	15.095	2025/1024,105/53
79:	1200	159	Gerdâniye - C	524	1200.000	523.822	1200.000	15.094	2/1 (Do)

The 79-tone Qanun tuning thus distinctively embodies the following intertwined assets:

- 1) A theoretically proper *Rast* “ascending scale” can be mapped to a “Just Intonation C Major” without breaking the chain of fifths via using two different kinds of perfect fifths (694¢ and 702¢) in the manner F (702¢) C (702¢) G (694¢) D (702¢) A (694¢) E (702¢) B;
- 2) Such a *Rast* scale can be transcribed on the staff (even when using the complementary Sagittal Notation) without any accidentals to begin with in compliance to the historical notion of *Rast* being the “mother-of-all-makams” – delineating therefore the primacy of *Sipürde Ahenk* as the gravitational center of all transpositions (instead of *Bolahenk*) where *perde hüseyini* corresponds to A4=440 Hz;
- 3) Moreover, a theoretically proper *Mahur* “ascending scale” can similarly be mapped to a “Pythagorean C Major” instead without again breaking the generator chain of fifths – via relying on three different kinds of perfect fifths this time (694¢, 702¢ and 709¢) in the manner F (702¢) C (702¢) G (694¢) D (702¢) A (709¢) E‡ (702¢) B‡, where such an unbroken modulation follows from the direct alteration of *segâh-eviç* to *buselik-mahur* (I hesitate regarding the “*Arelian*” *mahur*, think it to be 1 degree lower at *eviç*, and its fifth to be *segâhçe*);
- 4) Likewise, *dügâh-hüseyini* can be altered up by one *mandal* each to facilitate yet another Major scale without breaking the chain of fifths;
- 5) Even once more, the *buselik-mahur* *perdes* can be altered up by yet another *mandal* each to facilitate a “Super-Pythagorean C Major”;
- 6) This described feature can be repeated over several keys, where – in agreement with traditional guidelines – *buselik* and *mahur* become accidented pitches (*nim perdeler*) and are notated as such;
- 7) One can also turn to a few distinct options to extract a cyclic subset for chromaticism – where, in particular, mode 6 7 7 6 7 6 7 6 7 7 6 7 out of 79 MOS 159-tET, equalling 91+106+106+91+106+91+113+91+106+106+91+106 consecutive cents, extracts a workable 12-tone cyclic subset (e.g., with overlapping “sharps” and “flats”) which contains only one “wolf fifth” that can very well be considered tame;
- 8) In addition, it is conceivable to adequately encapsulate *Arel-Ezgi-Uzdilek* too as mode 6 1 5 1 7 1 4 2 4 2 6 1 5 1 6 1 5 1 7 1 4 2 4 2 under 79 MOS 159-tET, which thus equals 91+15+76+15+106+15+61+30+61+30+91+15+76+21+91+15+76+15+106+15+61+30+61+31 consecutive cents (where “sharps” and “flats” do not any more overlap);
- 9) Lastly, the overarching Sagittal Notation consistently maps the quarter-tone to 3 steps (/|, \|/), the *limma* to 6 steps(#, b), the *apotome* to 7 steps (/|#, \|b), etc... – wherefore xenharmony and makam polyphony is encouraged, since all kinds of intervals (and especially the *mujannabat*) can be situated at any level of transposition, be they inside or outside tetrachordal or pentachordal genera.

In the light of the foregoing theoretical and physical drawbacks for *Güналçin*, and especially with regards to such an inordinate *mandal* inflation gaining us fundamentally next to nothing, which moreover ought to render the Qanun quasi-functional and inoperable in practice, it is apparent to me that *Güналçin*’s project falls short of its goals in comparison to the quotidian alternatives at hand. I henceforth ignore it in this study.

THE GENERAL PROFILE OF “YARMAN-24” VARIANTS

To continue, see Table 0.3 below to discern the “a” and “c” variants from the Yarman-24 idea [Yarman 2010, pp. 64-99 & 2018] side-by-side:

Table 0.3: Octave detail of *Yarman-24a* versus *Yarman-24c* in the proposed standard of *Sipürde Ahenk*.

Perde names & note	Yarman-24a	consecutive intervals	Yarman-24c	consecutive intervals	Diffs.	AEU53tET
RAST (C)	1/1 (0 cents)	(with previous in ϵ)	1/1 (0 cents)	(with previous in ϵ)	0	0 (<i>k. çargah</i>)
nim-zengule / şuri	84.36 cents	84.36	85.06 cents	85.06	-0.7	4 commas
zengule	38/25 (142.32)	58.01	143.62 cents	58.56	-1.3	5 "
dik-zengule	192.18 cents	49.81	191.77 cents	48.15	0.41	8 "
DÜGAH (D)	9/8 (203.91)	11.73	9/8 (203.91)	12.14	0	9 "
kürdi / nihavend	292.18 cents	88.27	292.41 cents	88.50	-0.23	13 "
dik-kürdi / uşşak	17/14 (336.13)	43.95	348.34 cents	55.93	-12.21	14 "
segah (d)	16/13 (359.47)	23.34	362.5 cents	14.16	-3.03	14 "
SEGAHÇE (E)	5/4 (386.31)	26.84	156/125 (383.54)	21.04	2.77	17 "
buselik / nişabur (‡)	19/15 (409.24)	22.93	415.3 cents	31.76	-6.06	18 "
ÇARGAH (F)	4/3 (498.04)	88.80	4/3 (498.04)	82.74	0	22/23 "
nim-hicaz / uzzal	584.08 cents	86.03	581.38 cents	83.34	2.7	26 "
hicaz / saba	36/25 (631.28)	47.20	634.18 cents	52.80	-2.9	27/28 "
dik-hicaz / bestenigar	696.09 cents	64.81 (<i>in favor of this</i>)	16/11 (648.68)	61.70 (<i>relate to 36/25</i>)	47.41	28/31 "
NEVA (G)	3/2 (701.96)	5.87 (<i>maybe forego it</i>)	187/125 (697.33)	6.070	4.63	31 "
nim-hisar / bayati	788.27 cents	86.31	788.74 cents	86.78	-0.47	35 "
hisar / hüzzam	18/11 (852.59)	64.32	853.06 cents	64.33	-0.47	36 "
dik-hisar / hisarek	888.27 cents	35.68	887.66 cents	34.59	0.61	39 "
HÜSEYNİ (A)	27/16 (905.87)	17.60	27/16 (905.87)	18.21	0	40 "
acem / nevrüz	16/9 (996.09)	90.22	16/9 (996.09)	90.22	0	44 "
dik-acem / arazbar	20/11 (1035)	38.91	1043.62 cents	47.53	-8.62	45 "
evc (d)	13/7 (1071.7)	36.71	1071.94 cents	28.32	-0.24	48 "
MAHUR (B)	15/8 (1088.27)	16.57	234/125 (1085.5)	13.55	2.77	48 "
dik-mahur (‡)	21/11 (1119.46)	31.19	1124.74 cents	39.25	-5.28	49/52 "
GERDANIYE (c)	2/1 (1200)	80.54	2/1 (1200)	75.26	0	52/53 "

Since the initial two Yarman-24 variants *a* and *b* – which were conceived as rudimentary replacements for *Arel-Ezgi-Uzdilek* – are basically a list of uncomplicated ratios enveloping a temperament ordinaire core in the style of Jean Philippe Rameau [Yarman 2010, pp. 64-99], I shall describe mainly the *c-d-e* variants to conserve space. For a better understanding, the reader can refer to *YA24-to-Mus2.xls* and *Chronicles_Yarman24.xls*; in addition, the reader should be able to decipher the optimization intent behind variant “*d*” under *Yarman24d_equalizationOFmeantonefifth.xls* and variant “*e*” under *Yarman24E.pdf*. All of these documents are mentioned in the introduction and provided in the [LINK].

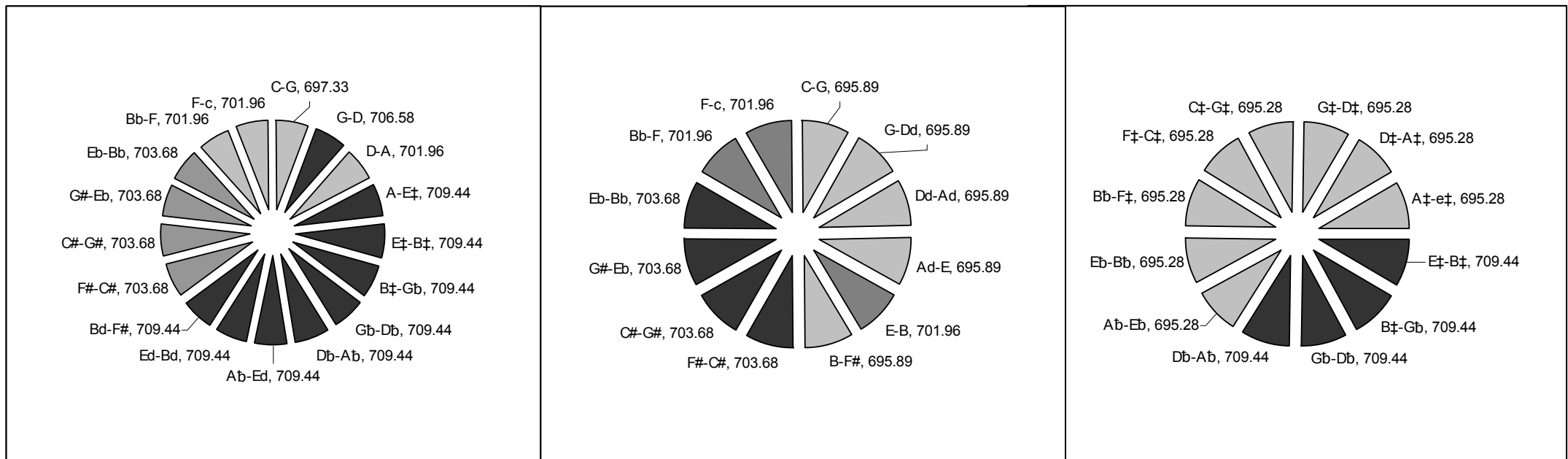
A comparison of the extension to *Yarman-24c* called *Yarman-24/31c* (built by exploiting all official accidentals over every natural note) against the *Arel-Ezgi-Uzdilek* (AEU) tone-system is given in Table 0.4 and it is elaborated in Figure 0.2 underneath [cf. Yarman 2018]:

Table 0.4: Octave detail of AEU versus the extension to *Yarman-24c* called *Yarman-24/31c* in the proposed standard of *Sipürde Ahenk*.

Perde names & note	Arel-Ezgi-Uzdilek ratios and ζ	cons. intervals	53-tET subset	Yarman-24/31c	cons. intervals	Diffs.
RAST (G)	1/1 (0 cents)	(with previous)	0 (rast on C)	1/1 (0 cents)	(with previous)	0
---			1-2	34.18 cents	34.18	---
nim-zirgule	256/243 (90.22)	90.22	4	85.06 cents	50.88	5.16
zirgule	2187/2048 (113.69)	23.46	5-6-7	143.62 cents	58.56	-29.93
dik-zirgule	65536/59049 (180.45)	66.76	8	191.77 cents	48.15	-11.32
DÜGAH (A)	9/8 (203.91)	23.46	9	9/8 (203.91)	12.14	0
			10	224.74 cents	20.83	---
kürdi	32/27 (294.13)	90.22	13	292.41 cents	67.67	1.72
dik-kürdi	19683/16384 (317.60)	23.46	14-15	348.34 cents	55.93	-30.74
---			16-17	362.5 cents	14.16	---
segah (d)	8192/6561 (384.60)	66.76	17	156/125 (383.54)	21.04	1.06
BUSELİK (B)	81/64 (407.82)	23.46	18	415.3 cents	31.76	-7.48
dik-buselik (d)	2097152/1594323 (474.58)	66.76	21	477 cents	61.70	-2.42
ÇARGAH (C)	4/3 (498.04)	23.46	22	4/3 (498.04)	21.04	0
			23-24	538.9 cents	40.86	---
nim-hicaz	1024/729 (588.27)	90.22	26	581.38 cents	42.48	6.89
hicaz	729/512 (611.73)	23.46	27-28	634.18 cents	52.80	-22.45
dik-hicaz	262144/177147 (678.49)	66.76	29-30	16/11 (648.68)	14.50	29.81
NEVA (D)	3/2 [440 Hz] (701.96)	23.46	31	187/125 (697.33)	48.65	4.63

			90.22	32	729.46 cents	32.13	---
nim-hisar	128/81	(792.18)		35	788.74 cents	59.27	3.44
hisar	6561/4096	(815.64)	23.46	36-37-38	853.06 cents	64.33	-37.42
dik-hisar	32768/19683	(882.40)	66.76	39	887.66 cents	34.59	-5.26
HÜSEYİNİ (E)	27/16	(905.87)	23.46	40	27/16 (905.87) 440 Hz	18.21	0
			90.22	41	920.02 cents	14.16	---
ACEM (F)	16/9	(996.09)		44	16/9 (996.09)	76.07	0
dik-acem	59049/32768	(1019.55)	23.46	45-46	1043.62 cents	47.53	-24.07
---			66.76	47	1071.94 cents	28.32	---
eviç (#)	4096/2187	(1086.31)		48	234/125 (1085.5)	13.55	0.81
mahur	243/128	(1109.78)	23.46	49-50	1124.74 cents	39.25	-14.96
dik-mahur (d)	1048576/531441	(1176.54)	66.76	52	1186.45 cents	61.70	-9.91
GERDANIYE (g)	2/1	(1200)	23.46	53	2/1 (1200)	13.55	0

Figure 0.2: *Yarman-24/31c* cycles of fifths (left: 17-tone cycle on C, middle: 12-tone “core” cycle on C; right: 12-tone cycle on E comma sharp).



The degrees of *Yarman-24c* in its main cycle of fifths around the 12-tone modified meantone temperament core (which is altogether compatible with Baroque-to-Classical common practice) are 0-14-3-17-8-22-11-1-15-5-19-10-0. In contrast, the degrees for the 17-tone cycle (reminiscent of Urmavi and quotidian Bağlamas of Thrace and Anatolia) are 0-14-4-18-9-23-12-2-16-7-21-11-1-15-5-19-10-0. To expand to *Yarman-24/31c*, a subsidiary 12-tone modified meantone cycle starting on E \sharp (whose “home key” can otherwise be considered as C \sharp) helps exploit all accidentals of the official *Arel-Ezgi-Uzdilek* notation over every natural as shown in Figure 0.2.

Eventually, 187/125 replaces the G at 695.89 ϕ found by equally dividing the 156/125 *segâh*+2 octaves into four parts, and 16/11 replaces Gd.

The mathematical optimization that leads to *Yarman-24/31d* is effectuated when the three idiosyncratic sizes of fifths (i.e. $\approx 696\phi$, $\approx 704\phi$, $\approx 709\phi$) involved in said setup, aside from the pure fifth, are equalized around their respective medians in the following way:

$$4x + 8z = A = 8400 \phi$$

$$8x + 4y = B = 8490.22499567306 \phi \quad (\text{i.e., 7 octaves plus a Pythagorean } \textit{limma})$$

$$5z + 4y = C = 6294.13499740384 \phi \quad (\text{i.e., 5 octaves plus a Pythagorean minor third})$$

$$x = \frac{5A + 8B - 8C}{84} = \frac{78658254501151}{110918840956} = \mathbf{709.151428406592} \phi$$

$$y = \frac{10A - 5B - 16C}{84} = \frac{624919759933015}{887350727648} = \mathbf{704.253392105080} \phi$$

$$z = \frac{A - B + 2C}{21} = \frac{154271311506449}{221837681912} = \mathbf{695.424285796704} \phi$$

Lastly, Table 0.5 below delineates a new configuration of suchlike class of fifths leading to the construction of *Yarman-24/42e*:

Table 0.5: Two octaves detail of *Yarman-24/42e* as derived from the sporadic perde designations of maestro Fikret Karakaya.

Fikret Karakaya's perde name and its 8th	Ozan Yarman's interpretation	Yarman-24/42e notes & cent values	Fikret Karakaya's perde name and its 8th	Ozan Yarman's interpretation	Yarman-24/42e notes & cent values
YEGÂH – NEVÂ	YEGÂH – NEVÂ	7-RE 190.709 cents	DÜGÂH – MUHAYYER	DÜGÂH 440 – MUHAYYER	31-LA 900.000 cents
— — — — Pest bayâtî – Bayâtî Pest hisar – Hisar Pest hüzzam – Hüzzam Pest arazbar – Arazbar	—Dik Yegâh —Dik Nevâ Pest bayâtî – Bayâtî Pest nim hisar – Nim hisar Pest hisârek – Hisârek Pest hisar/hüzzam – Hisar/hüzzam Pest arazbar – Arazbar	8-Re † 225.183 cents 9-Re † 265.526 cents Re # / Mi b 289.731 cents 11-Mi / b 320.537 cents 12-Mi † 348.410 cents 13-Mi d 362.347 cents	Dilârâ – Tiz dilârâ Dik dilârâ – Tiz dik dilârâ Kürdî – Nim sümbüle Dik Kürdî – Sümbüle Nim uşşak – Tiz nim uşşak Uşşak – Tiz uşşak Nim segâh – Tiz nim segâh	Dik Dügâh – Dik Muhayyer Alt kürdî – Alt sümbüle Kürdî (nihâvend) – Sümbüle Dik kürdî – Dik sümbüle — — Uşşak – Tiz uşşak Segâhçe – Tiz segâhçe	32-La † 920.537 cents 33-La † 967.481 cents 34-La # / Si b 993.888 cents 35-Si / b 1029.828 cents — <i>tempered to below</i> 36-Si † 1043.765 cents 37-Si d (1057.701 cents)
Pest dik hisar – Dik hisar HÜSEYNÎ-AŞÎRAN – HÜSEYNÎ	PEST DİK HİSAR – DİK HİSAR (Hüseyinî-)Aşîran – Hüseyinî	14-Mİ 381.418 cents 15-Mi † 401.955 cents	Segâh – Tiz segâh BUSELİK – TİZ BUSELİK	SEGÂH – TİZ SEGÂH Büselik – Tiz büselik	38-Sİ 1076.772 cents 39-Si † 1111.246 cents
Pest dilâviz – Dilâviz Pest dik dilâviz – Dik dilâviz	Dik (h.) aşîrân – Dik hüseyinî Alt Acemaşîrân – Alt Acem	16-Mi † [415.892 cents] 17-Fa d [476.772 cents]	Dik buselik – Tiz dik buselik Dilkeş – Tiz dilkeş	Dik büselik – Tiz dik büselik Alt Çârgâh – Tiz alt Çârgâh	40-Si † 1125.183 cents 41-Do d [1186.063 cents]
ACEM-AŞÎRAN – ACEM	ACEMAŞÎRAN – ACEM	18-FA 4/3 498.045 cents	ÇÂRGÂH – TİZ ÇÂRGÂH	ÇÂRGÂH – TİZ ÇÂRGÂH	0=> 42-DO 0, 1200 cents
Dik acem-aşîran – Dik acem Pest nevrüz – Nevruz Irak – Evc Geveşt – Mahur Dik geveşt – Dik mahur	Dik Acemaşîran – Dik Acem Pest nevrüz – Nevruz Irak – Eviç Geveşt/rehavî – Mahur Alt Rast – Alt Gerdâniye	19-Fa † 539.119 cents 20-Fa † [566.992 cents] Fa # / Sol b 580.929 cents Fa = / Sol † 620.537 cents 23-Sol d [648.410 cents]	Dik çârgâh – Tiz dik çârgâh Nim hicaz – Tiz nim hicaz Hicaz – Tiz hicaz Dik hicaz – Tiz dik hicaz Sabâ – Tiz sabâ Bestenigâr – Tiz bestenigâr	Dik Çârgâh – Tiz dik Çârgâh Nim uzzâl – Tiz nim uzzâl Nim hicaz – Tiz nim hicaz Uzzâl – Tiz uzzâl Hicaz/sabâ – Tiz hicaz/sabâ (Dik hicaz) – Tiz bestenigâr	1-Do † 34.474 cents 2-Do † 62.347 cents 3-Do # / Re b 76.284 cents 4-Re / b 115.892 cents 5-Re † 129.828 cents 6-Re d [143.765 cents]
RAST – GERDANIYE	RAST – Gerdâniye	24-SOL 695.354 cents	NEVÂ – TİZ NEVÂ	NEVÂ – TİZ NEVÂ	7-RE 190.709 cents
— — — — Nim zengüle – Nim şehnaz Zengüle – Şehnaz Dik zengüle — — Dik şehnaz	—Dik Rast —Dik Gerdâniye —Şûrî —Tiz şûrî Nim zengüle – Nim şehnaz Alt zengüle – Tiz alt şehnaz Zengüle (şeddisabâ) – Şehnaz Dik zengüle – Dik şehnaz	25-Sol † 729.828 cents 26-Sol † 763.571 cents Sol # / La b 780.440 cents 28-La / b 811.246 cents 29-La † 839.119 cents 30-La d (886.063 cents)	Blue color signifies that I have foregone to include the suggested perde so as to be notationally consistent.	Red color quantities signify criticality for the exploitation of all <i>small semitone sharps</i> in the 17-tone cycle as well as the subsidiary 12-tone cycle.	Green color quantities signify criticality for the exploitation of all <i>comma flats</i> to acquire the intermediary 31-tone cast, which is attained when red and gray values are omitted.
DÜGÂH – MUHAYYER	DÜGÂH [440 Hz] – MUHAYYER	31-LA 900.000 cents			

Yarman-24/42e is hence an attempt to adopt into the *Yarman-24/31* manifold the maximum amount of traditional perdes identified by maestro Fikret Karakaya (who is the founder and director of the “*Bezmarra Ensemble*”), by allowing only one more microtonal sharp & flat pair while shifting *perde rast* back unto G in accordance with prevalent habits [cf. *Yarman24E.pdf* in the LINK].

DERIVATION OF THE TRIPLE 12-TONE BIKE-CHAIN CONSTRUCT NAMED “YARMAN-36”

When coming face to face with the universal penchant to eschew 53-tET (despite its unparalleled success in housing Yekta-Arel-Ezgi-Uzdilek with less than 1 cent absolute error at any degree [cf. Yarman 2007a]) in favor of 72-tET or similarly complex divisions of the octave in the praxis of Turkish Makam music, one can easily come to understand that critical “middle seconds” associated with the historical *mujannabat* are not befittingly captured by the “Holderian comma system”.

Therefore, if – in prioritizing a minimalistic approach when confronted with the inadequacy of 53-tET – one should consign to represent the relevant “middle seconds” in terms of merely two interval classes (e.g., a minor wholetone and a neutral second) in practically the same vein as the Yarman-24 framework built upon a 12-tone temperament ordinaire core, one arrives at the triplex modified meantone solution dubbed *Yarman-36* [Yarman & Karaosmanoğlu 2014], which has the advantage of being entirely tunable by ear contingent upon solely counting simple (i.e., 0, 1, 2) integer beats starting from a preordained reference frequency [cf. *Yarman36_ahenkler-PB-beats.xls* in the LINK].

The triplex structure of *Yarman-36*, thusly involving a triple bike-chain (i.e., three independent cycles) of 12-tone modified meantone temperaments for suitable makam sonority at *Sipürde*, *Bolahenk*, *Davud*, *Mansur* and *Kız Ahenks*, is shown in Table 0.6 below:

Table 0.6: Derivation of *Yarman-36* by listening to integer beats, starting from a special reference frequency to get a pure fifth between G#-Eb.

LAYER I	C4-C5 Hertz	5th beat per sec.	LAYER II	C#4-C#5 Hertz	5th beat per sec.	LAYER III	C#4-C#5 Hertz	5th beat per sec.
+Eb	311.2375227	-2	Eb	307.3580471	-1	-Eb	301.8454475	-1
+Bb => Bb	465.8562841 / 2	-1	Bb => Bb	460.5370707 / 2	0 (via +C# 5:3)	-Bb => Bb	452.2681712 / 2	0
+F	348.8922131	-2	F	345.402803	0	-F	339.2011284	0
+c => C	522.3383196 / 2	-1	c => C	518.1042046 / 2	-2	-c => C	508.8016926 / 2	-1
+G => G	391.2537397 / 2	-1	G => G	387.5781534 / 2	-1	-G => G	381.1012695 / 2	-1
+D	292.9403048	-2	D	290.183615	-1	-D	285.3259521	-1
+A => A	438.4104572 / 2	-1	A => A	434.7754226 / 2	-1	-A => A	427.4889281 / 2	-1
+E	328.3078429	-2	E	325.5815669	-2	-E	320.1166961	-2 (via +G 9:11)
+B => B	491.4617643 / 2	-1	B => B	487.3723504 / 2	-1	-B => B	479.1750442 / 2	-1
+F#	368.0963232	1	F#	365.0292628	-1	-F#	358.8812831	-2
+c# => C#	552.6444848 / 2	1	c# => C#	547.0438942 / 2	-1	-c# => C#	537.3219247 / 2	-1
+G# => G#	414.9833636 / 2	0 (pure)	G# => G#	409.7829206 / 2	0.0417132905	-G# => G#	402.4914435 / 2	-0.0462703165
+Eb	311.2375227	(-2 to Bb)	Eb	307.3580471	(-1 to Bb)	-Eb	301.8454475	(-1 to Bb)

PERDE NOMENCLATURE UNDER “MUS2OKUR” AND OTHER HIGH-RESOLUTION EQUAL DIVISIONS OF THE OCTAVE

In concluding this Appendix, the reader is directed to scrutinize Table 0.7 below regarding the perde nomenclature under *Mus2okur* with respect to the official AEU notation (cf. Yarman and Karaosmanoğlu 2009) and other voluminous equal divisions of the octave:

Table 0.7: *Mus2okur*'s 53-tET compliant perde and accidental usage with respect to AEU notation, and its relation to other high-resolution equal divisions of the octave evaluated under the present study.

53-tET degs & cents	AEU subset	Mus2okur	Perde name	72-tET	65-tET	60-tET	41-tET	34-tET	29-tET	
0	0.00	C Dbb		KABA ÇÂRGÂH	0	0	0	0	0	
1	22.64		C‡ Db=		16.7, 33.3	18.5, 36.9	20	29.3	35.3	41.4
2	45.28		#2		33.3, 50	36.9, 55.4	40	58.5	35.3	41.4
3	67.92		#3		66.7	73.8	60	58.5	70.6	82.8
4	90.57	C# Db		Kaba Nîm Hicâz	83.3	92.3	80, 100	87.8	70.6, 105.9	82.8
5	113.21	C≡ Db		Kaba Hicâz	100, 116.7	110.8	120	117.1	105.9	124.1
6	135.85		d3		133.3	129.2, 147.7	140	146.3	141.2	124.1
7	158.49		d2		150, 166.7	147.7, 166.2	160	146.3	141.2	165.5
8	181.13	C## Dd		Kaba Dik Hicâz	183.3	184.6	180	175.6	176.5	165.5
9	203.77	D Ebb		YEGÂH (220 Hz)	200	203.1	200	204.9	211.8	206.9
10	226.42		D‡ Eb=		216.7, 233.3	221.5	220	234.1	211.8, 247.1	206.9, 248.3
11	249.06		#2		233.3, 250	240, 258.5	240	234.1, 263.4	247.1	248.3
12	271.70		#3		266.7	276.9	260	263.4	282.4	289.7
13	294.34	D# Eb		Kaba Nîm Hisâr	283.3, 300	295.4	280, 300	292.7	282.4	289.7
14	316.98	D≡ Eb		Kaba Hisâr	316.7	313.8	320	322.0	317.6	331.0
15	339.62		d3		333.3	332.3	340	351.2	317.6, 352.9	331.0
16	362.26		d2		350, 366.7	350.8, 369.2	360	351.2	352.9	372.4
17	384.91	D## Ed		Kaba Dik Hisâr	383.3	387.7	380	380.5	388.2	372.4
18	407.55	E Dx		HÜSEYNÎ AŞÎRÂN	400	406.2	400	409.8	423.5	413.8
19	430.19		E‡		416.7, 433.3	424.6	420, 440	439.0	423.5	413.8, 455.2
20	452.83		d2		450	443.1, 461.5	460	468.3	458.8	455.2
21	475.47		Fd		466.7, 483.3	461.5, 480	480	468.3	458.8	455.2
22	498.11	F Gbb		ACEM AŞÎRÂN	500	498.5	500	497.6	494.1	496.6

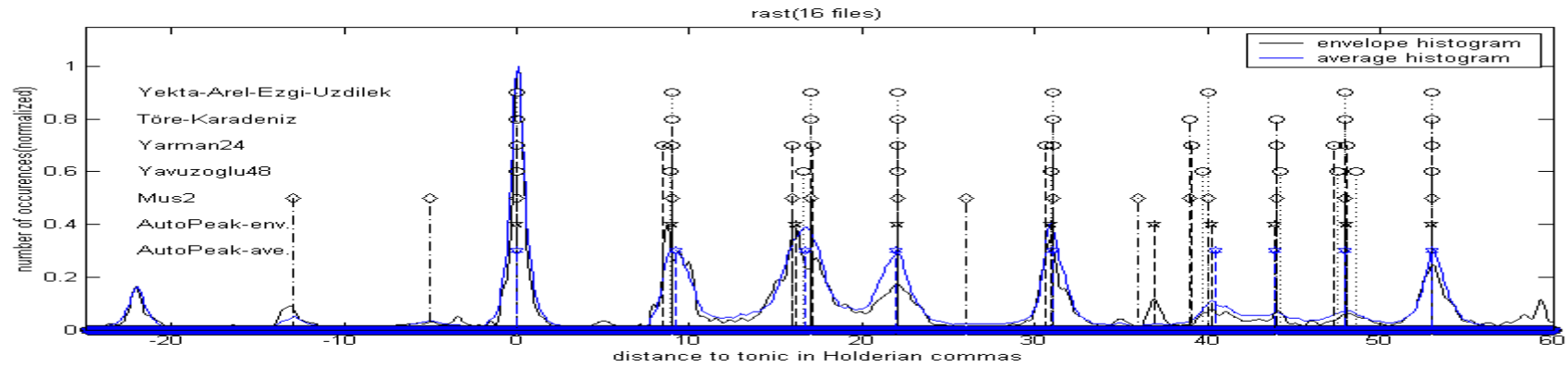
APPENDIX C

Table 1: Mismatches in cents of the scale tones of various tunings with RAST auto-peaks (16 collated histograms) and the resultant *efficiency* (E) and *complexity* (C) percentages. “M” denotes the maximum difference and “D” denotes the mean of differences, with subscript “e” delineating values in reference to *Auto-Peak envelope* datapoints and subscript “a” delineating values in reference to *Auto-Peak average* datapoints, where best values are highlighted and in bold (while red, blue and purple text colors are cosmetic). Higher E and lower C are better.

RAST	Distance to tonic in cents														M _e	D _e	M _a	D _a	E	C	
79 tone-formal	196.2			377.3	392.4	498	702		898.2			1003.8	1079.3	1094.4	12.9	7.04	16.7	6.87	77.8	91.1	
79 t-matching	196.2	211.3	362.2	377.3	392.4	498	702	837.8	898.2	913.2	988.7	1003.8	1079.3	1094.4	7.5	3.52	7.4	3.04	57.1	89.9	
Yarman-24a		203.9	359.5	386.3		498	702			905.9	996.1		1071.7	1088.3	5.7	2.33	9.5	3.99	77.8	70.3	
Yarman-24b		203.9	364.7	386.3		498	702			905.9	996.1		1074.6	1088.3	5.2	1.59	9.5	3.99	77.8	70.3	
Yarman24/31c		203.9	362.5	383.5		498	697.3			905.9	996.1		1071.9	1085.5	5.2	2.17	9	4.29	77.8	77.4	
Yarman24/31d		203.9	360.8	381.7		498	702			905.9	996.1		1069.9	1083.7	5.8	2.8	9	3.61	77.8	77.4	
Yarman24/42e		204.6	362.3	381.4		504.6	695.4			906.6		1002.7	1071.6	1085.6	7.8	4.34	8.8	5.93	77.8	83.3	
Yarm36a-form	198.7			381.6		501.4	699.7		896.8				1080		16.4	8.22	18.1	7.83	100	83.3	
Yarm36a-mtch	198.7		352.3	381.6		501.4	699.7	853.1	896.8			1001.9	1080		16.9	8.71	18.1	7.81	88.9	77.8	
Yektay65-form	184.6	203.1	295.4	387.7		498.5	683.1		886.2		996.9			1181.5	24.9	7.57	28.7	7.19	77.8	89.2	
Yektay65-mtch		203.1	369.2	387.7		498.5	701.5	830.8		904.6	996.9			1089.2	6.5	2.73	10.3	4.4	88.9	87.7	
Durgun60-mtch		200	360	380		500	700	840		900		1000	1080		11.1	5.18	14.9	6.43	88.9	88.9	
72 tET-matching		200	366.7	383.3		500	700	833.3		900		1000		1083.3	11.1	4.19	14.9	6.43	77.8	91.1	
41 tET-matching		204.9	351.2	380.5		497.6	702.4	848.8		907.3	995.1		1082.9		14	5.22	7.6	2.99	88.9	80.5	
34 tET-matching		211.8	352.9	388.2		494.1	705.9	847.1		917.6	988.2			1094.1	12.3	7.44	11.4	5.24	88.9	76.5	
29 tET-matching		206.9		372.4		496.6	703.4	827.6		910.3	993.1		1075.9		13.6	5.07	11.1	3.4	100	72.4	
AutoPeak-env.		203.8		365.2		497.9	699.2	836.2		911.1		994.9		1089.5							
AutoPeak-ave.		207.6		376.8		495.8	702.3			914.9		994.2		1087.0							

Table 1 continued: Complexity-weighted (WM, WD) and Efficiency-scaled (WEM, WED) means of M’s & D’s

41 tET-matching	WM: 11.84	WD: 4.5	WEM: 13.32	WED: 5.06
34 tET-matching	WM: 12.52	WD: 6.7	WEM: 14.08	WED: 7.53
29 tET-matching	WM: 12.55	WD: 4.3	WEM: 12.55	WED: 4.3



17.81	8.37	22.89	10.76
8.87	3.91	15.52	6.84
7.6	3.16	9.77	4.06
7.35	2.79	9.45	3.58
7.57	3.44	9.73	4.42
7.89	3.42	10.14	4.4
9.34	5.78	12.01	7.43
19.41	9.03	19.41	9.03
18.72	8.84	21.05	9.94
31.73	8.74	40.8	11.23
9.82	4.16	11.04	4.68
15.06	6.72	16.94	7.56
15.35	6.27	17.27	7.05
WM	WD	WEM	WED

Table 1 continued: Complexity and Efficiency scaled means of M's & D's

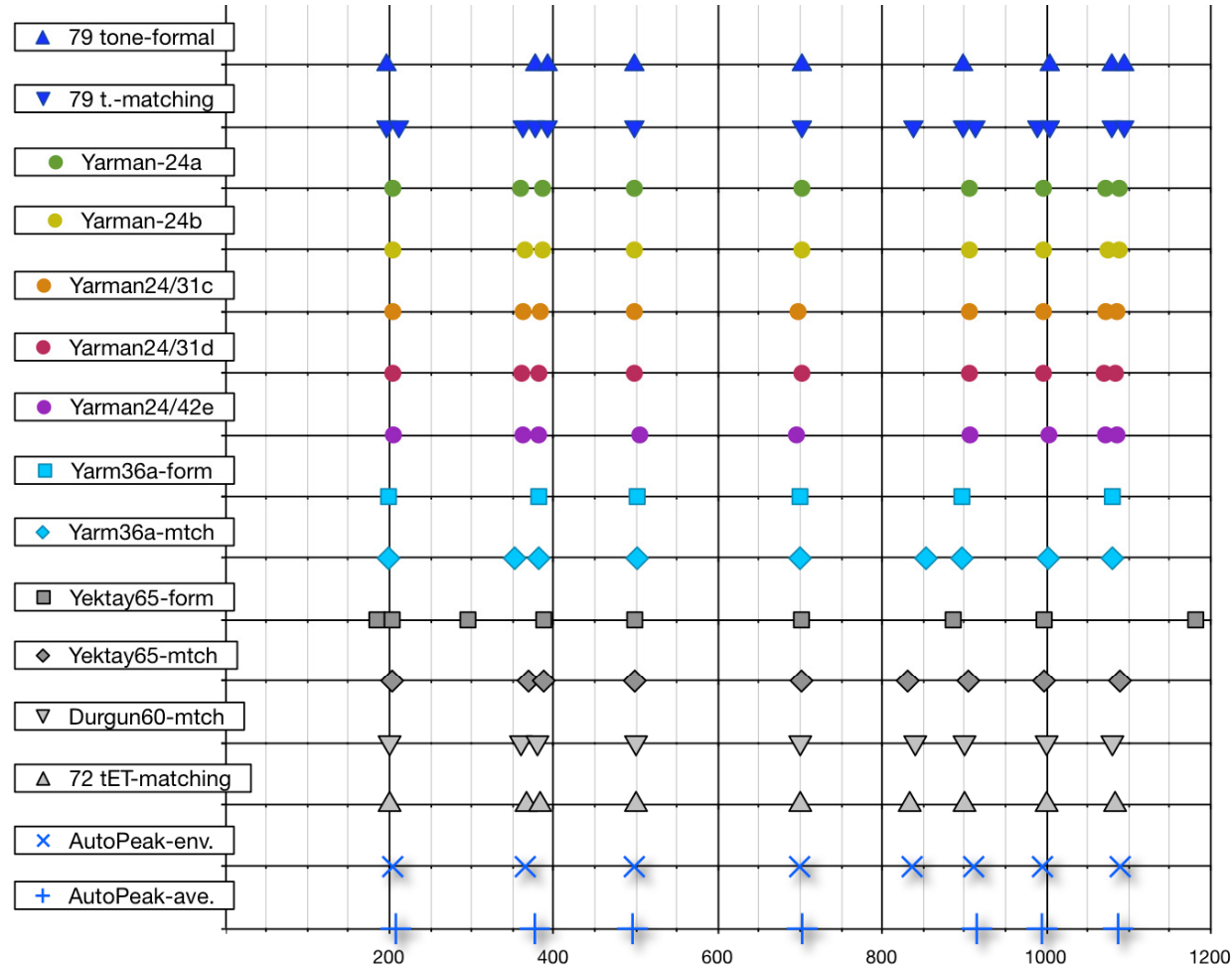


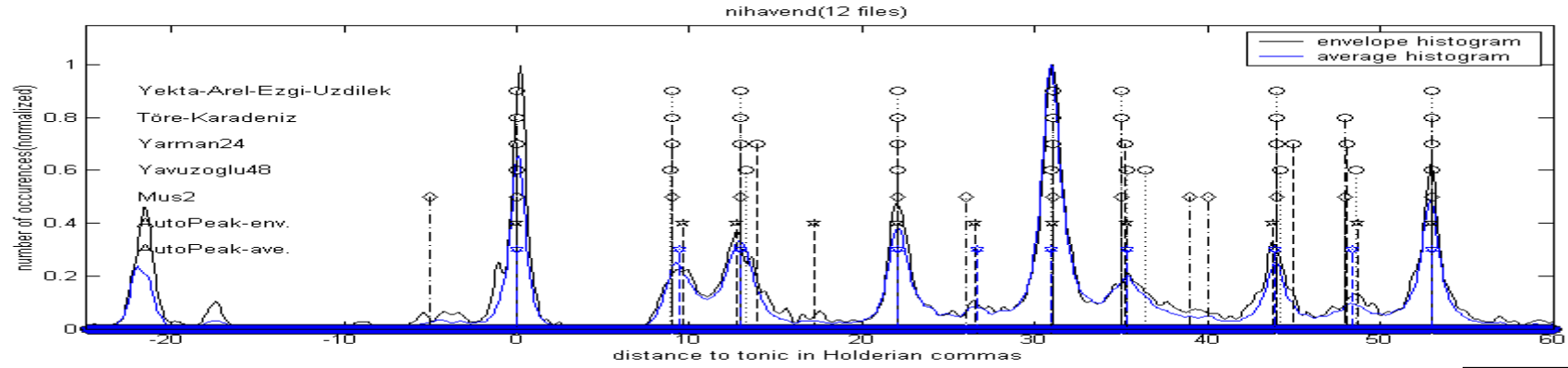
Figure 1 : Plotting the data of Table 1 in comparison with the relevant histogram graphic in the precursor to this study [Bozkurt and Yarman et al. 2009, JNMR:38/1 pp.45-70]

Table 2: Mismatches in cents of the scale tones of various tunings with NIHAVEND auto-peaks (12 collated histograms) and the resultant *efficiency* (E) and *complexity* (C) percentages. “M” denotes the maximum difference and “D” denotes the mean of differences, with subscript “e” delineating values in reference to *Auto-Peak envelope* datapoints and subscript “a” delineating values in reference to *Auto-Peak average* datapoints, where best values are highlighted and in bold (while red, blue and purple text colors are cosmetic). Higher E and lower C are better.

NIHAVEND	Distance to tonic in cents															M _e	D _e	M _a	D _a	E	C
79 tone-formal	196.2			316.9			498		702		822.7		1003.8	1079.3	1094.4	28.4	13.17	24.8	10.93	87.5	91.1
79 t.-matching	196.2	211.3	286.8	301.8	316.9	392.4	498	603.7	702	807.6	822.7	988.7	1003.8	1079.3	1094.4	7.2	3.56	8.1	3.06	60	88.6
Yarman-24a	203.9		292.2				498		702	788.4		996.1		1088.3		13	6.84	11.1	4.34	100	70.8
Yarman-24b	203.9		292.2				498		702	788.3		996.1		1088.3		13	6.86	11.2	4.36	100	70.8
Yarman24/31c	203.9		292.4				498		697.3	788.7		996.1		1085.5		15.6	7.23	10.8	4.73	100	77.4
Yarman24/31d	203.9		291.8				498		702	787.6		996.1		1083.7		17.4	7.56	11.9	5.14	100	77.4
Yarman24/42e	204.6		298.5				504.6		695.4	794.4			1002.7	1085.6		15.5	9.43	9.3	6.67	100	83.3
Yarm36a-form	198.7			303.6			501.4		699.7	801.7			1001.9		1094.5	18.2	7.87	13.7	5.37	100	80.6
Yarm36a-mtch	198.7		281.9	303.6		396.1	501.4		699.7	801.7			1001.9	1080	1094.5	18.2	6.49	13.7	5.19	80	77.8
Yektay65-form	203.1		295.4				498.5		701.5	793.8	867.7	886.2	996.9	1089.2		13.8	6.6	9.3	3.99	77.8	89.2
Yektay65-mtch	203.1	221.5	295.4			387.7	498.5	609.2	701.5	793.8		996.9		1089.2	1107.7	9.7	4.94	9.1	4.1	81.8	86.2
Durgun60-mtch	200	220	280	300		400	500	600	700	800			1000		1100	9.2	3.68	7.9	3.92	81.8	85
72 tET-matching	200	216.7	283.3	300		400	500	600	700	800			1000		1100	9.2	2.99	7.9	3.51	81.8	87.5
41 tET-matching		204.9	292.7			380.5	497.6	614.6	702.4	790.2		995.1		1082.9	1112.2	15.1	7.68	12	5.47	90	78
34 tET-matching		211.8	282.4			388.2	494.1	600	705.9		811.8	988.2			1094.1	11.4	5.11	12.3	5.61	100	73.5
29 tET-matching		206.9	289.7			372.4	496.6	620.7	703.4	786.2		993.1		1075.9	1117.2	21.2	9.7	19	8.04	90	59
AutoPeak-env.		216.9		288.5		390.8	499.9	599.5	701.9		800.4		991.7		1101.1						
AutoPeak-ave.		212.4		292.1			499.7	604.1	700.8		799.5		994.9		1094.9						

Table 2 continued: Complexity-weighted (WM, WD) and Efficiency-scaled (WEM, WED) means of M’s & D’s

41 tET-matching	WM:	14.78	WD:	7.17	WEM:	16.42	WED:	7.97
34 tET-matching	WM:	12.39	WD:	5.61	WEM:	12.39	WED:	5.61
29 tET-matching	WM:	20.1	WD:	8.87	WEM:	22.33	WED:	9.85



32.5	14.72	37.14	16.83
9.15	3.96	15.25	6.6
12.28	5.7	12.28	5.7
12.33	5.71	12.33	5.71
14.32	7.01	14.32	7.01
15.89	6.89	15.89	6.89
14.18	9.21	14.18	9.21
17.8	7.39	17.8	7.39
17.36	6.35	21.69	7.94
13.89	6.37	17.86	8.18
11.02	5.3	13.46	6.48
9.92	4.41	12.13	5.39
10.13	3.85	12.39	4.71
WM	WD	WEM	WED

Table 2 continued: Complexity and Efficiency scaled means of M's & D's

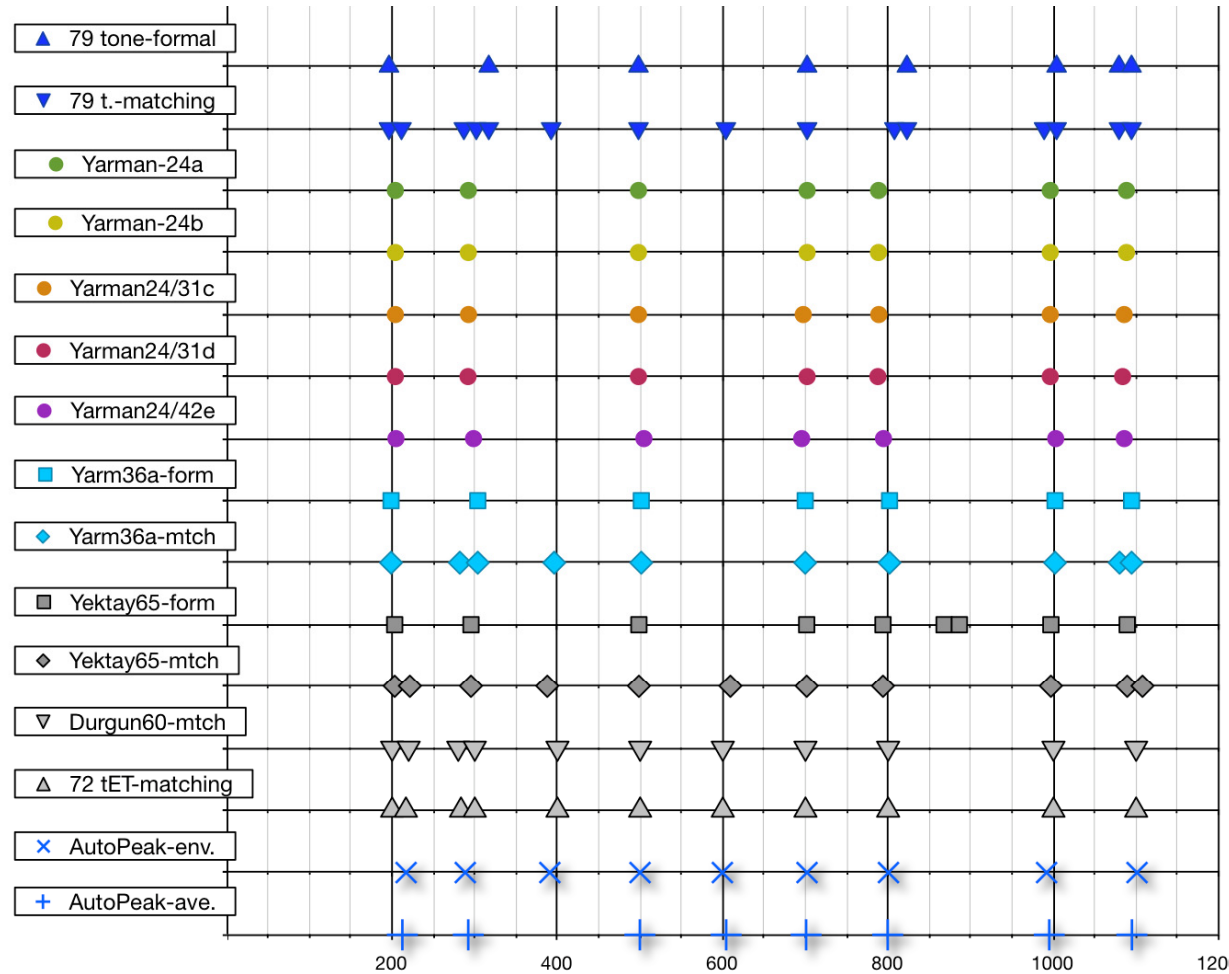


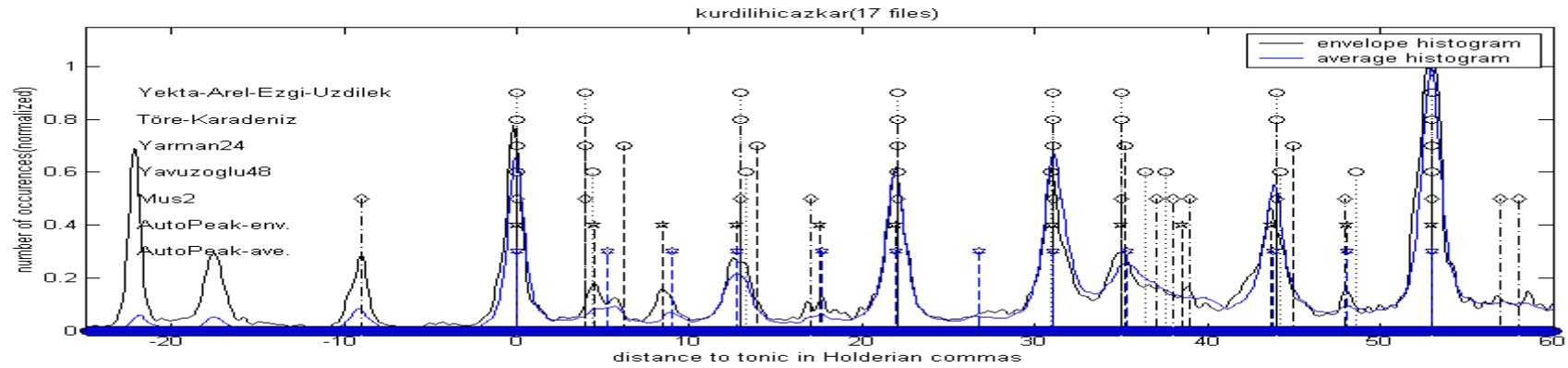
Figure 2: Plotting the data of Table 2 in comparison with the relevant histogram graphic in the precursor to this study [Bozkurt and Yarman et al. 2009, JNMR:38/1 pp.45-70]

Table 3: Mismatches in cents of the scale tones of various tunings with KÜRDİLİHİCAZKAR auto-peaks (17 collated histograms) and the resultant *efficiency* (E) and *complexity* (C) percentages. “M” denotes the maximum difference and “D” denotes the mean of differences, with subscript “e” delineating values in reference to *Auto-Peak envelope* datapoints and subscript “a” delineating values in reference to *Auto-Peak average* datapoints, where best values are highlighted and in bold (while red, etc... text colors are cosmetic). Higher E and lower C are better.

K.HİCAZKAR	Distance to tonic in cents														M _e	D _e	M _a	D _a	E	C		
79 tone-formal	105.6	120.7		286.8	392.4	498		702	807.6	822.7				1003.8	1094.4	15.6	5.51	12.8	5.06	90	88.6	
79 t.-matching	105.6	120.7	196.2	286.8	392.4	498	603.7	702	792.5		868		988.7		1094.4	6.2	2.38	7.9	4	100	84.8	
Yarman-24a	84.4	142.4		292.2	386.3	498		702	788.3					996.1	1088.3	17.9	5.09	23.3	7.84	100	62.5	
Yarman-24b	84.4	145.1		292.2	386.3	498		702	788.3					996.1	1088.3	17.9	5.09	26	8.18	100	62.5	
Yarman24/31c	85.1	143.6		292.4	383.5	498		697.3	788.7					996.1	1085.5	17.2	6.11	24.5	9.16	100	71	
Yarman24/31d	83.3	142.5		291.8	381.7	498		702	787.6					996.1	1083.7	19	6.24	23.4	8.94	100	71	
Yarman24/42e	85.1	115.9		298.5	381.4	504.6		695.4	794.4	825.2				1002.7	1085.6	16.6	8.19	18	8.68	90	78.6	
Yarm36a-form	97.6			303.6		501.4		699.7	801.7					1001.9		14.7	8.28	21.5	9.93	100	83.3	
Yarm36a-mtch	97.6	153.2	198.7	303.6	381.6	501.4	594.1	699.7	801.7		882.3	982	1001.9	1080	16.4	7.02	21.5	9.98	92.3	66.7		
Yektay65-form	92.3	110.8		295.4	387.7	498.5		701.5	793.8		867.7	886.2		996.9		10.3	4.79	11.7	6.49	90	86.2	
Yektay65-mtch		110.8	203.1	295.4	406.2	498.5	609.2	701.5	793.8		867.7	886.2		996.9	1089.2	11.1	4.42	8.3	4.63	100	81.5	
Durgun60-mtch	100	120	200	280	400	500	600	700	800			880	980	1000	1080	8.9	4.93	9	4.42	92.3	80	
72 tET-matching	100	116.7	200	283.3	400	500	600	700	800			883.3	983.3	1000	1083.3	10.5	4.38	7.7	3.78	92.3	83.3	
41 tET-matching	87.8	117.1	204.9	292.7	409.8	497.6	614.6	702.4	790.2		878		995.1		1082.9	14.5	5.23	10.4	5.04	100	70.7	
34 tET-matching	105.9		211.8	282.4	388.2	494.1	600	705.9		811.8		882.4	988.2		1094.1	19.8	7.42	13.2	6.71	100	67.6	
29 tET-matching	82.8	124.1	206.9	289.7	413.8	496.6	620.7	703.4	786.2		869		993.1		1075.9	19.5	6.53	15.27	6.95	100	58.6	
AutoPeak-env.	102.3	192		288.9	398.0	496.5		702.3	792		872.8		988.8		1088.2							
AutoPeak-ave.	119.1	203.8		287.8	399.4	495.8	605.434	704.1509	800.4				991		1087.9							

Table 3 continued: Complexity-weighted (WM, WD) and Efficiency-scaled (WEM, WED) means of M's & D's

41 tET-matching	WM:	13.96	WD:	5.76	WEM:	13.96	WED:	5.76
34 tET-matching	WM:	17.99	WD:	7.7	WEM:	17.99	WED:	7.7
29 tET-matching	WM:	17.38	WD:	6.74	WEM:	17.38	WED:	6.74



18.46	6.87	20.51	7.63
8.9	4.03	8.9	4.03
21.4	6.72	21.4	6.72
22.8	6.89	22.8	6.89
23.42	8.58	23.42	8.58
23.82	8.53	23.82	8.53
20.75	10.12	23.06	11.24
22.57	11.35	22.57	11.35
20.47	9.18	22.18	9.95
14.03	7.19	15.59	7.99
11.92	5.57	11.92	5.57
10.86	5.68	11.77	6.15
11.35	5.09	12.29	5.51
WM	WD	WEM	WED

Table 3 continued: Complexity and Efficiency scaled means of M's & D's

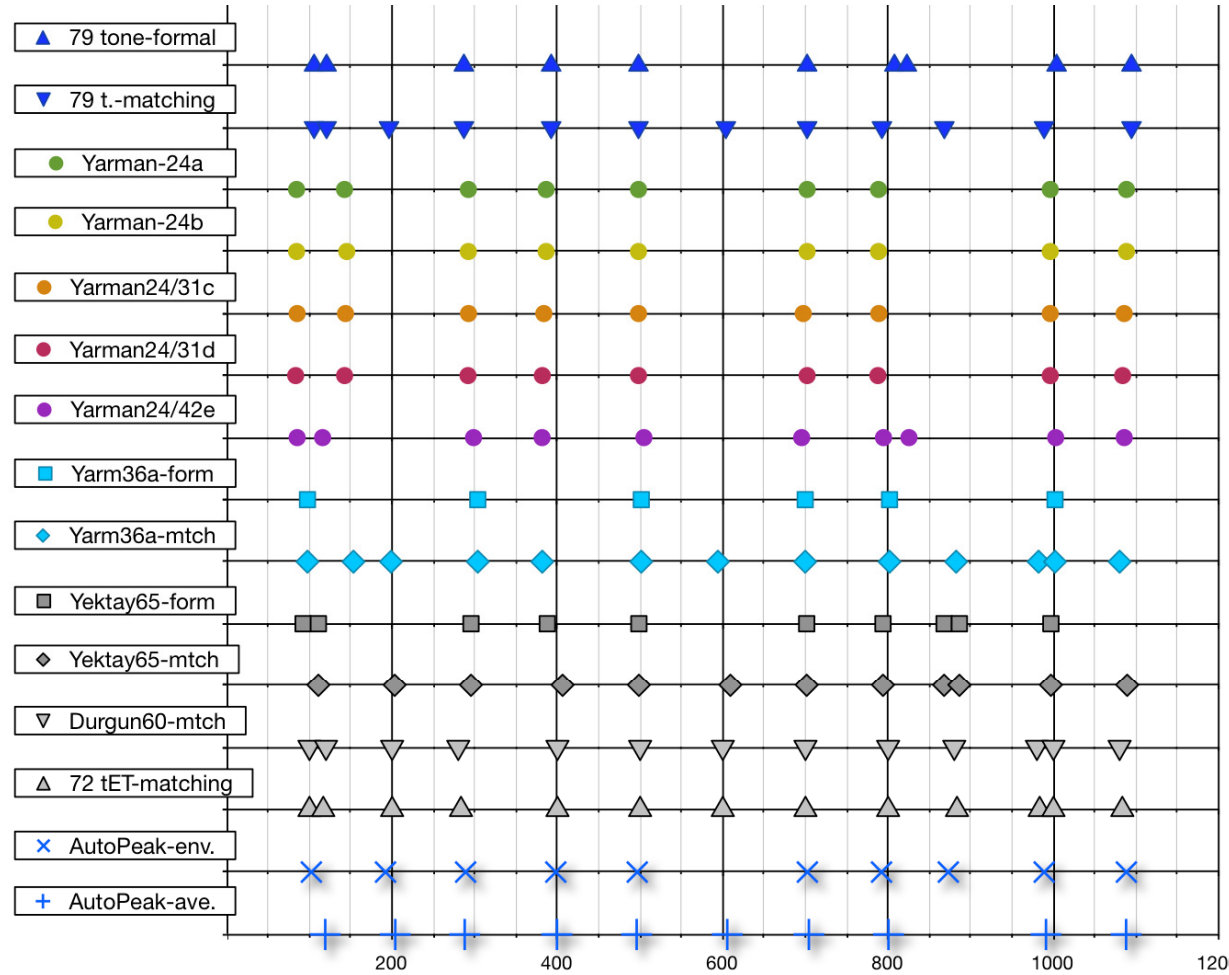


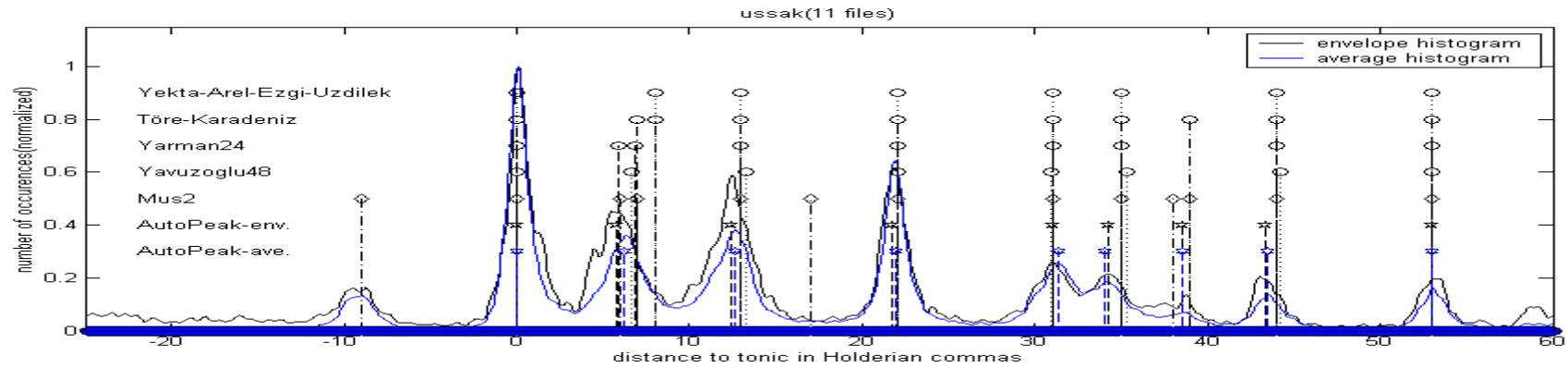
Figure 3: Plotting the data of Table 3 in comparison with the relevant histogram graphic in the precursor to this study [Bozkurt and Yarman et al. 2009, JNMR:38/1 pp.45-70]

Table 4: Mismatches in cents of the scale tones of various tunings with UŞŞAK auto-peaks (11 collated histograms) and the resultant *efficiency* (E) and *complexity* (C) percentages. “M” denotes the maximum difference and “D” denotes the mean of differences, with subscript “e” delineating values in reference to *Auto-Peak envelope* datapoints and subscript “a” delineating values in reference to *Auto-Peak average* datapoints, where best values are highlighted and in bold (while red, blue and purple text colors are cosmetic). Higher E and lower C are better.

UŞŞAK	Distance to tonic in cents														M _e	D _e	M _a	D _a	E	C		
79 tone-formal	150.9	166		286.8		498		702		807.6				1003.8	31.9	14.53	38	13.12	85.7	92.4		
79 t.-matching	135.8	150.9		286.8	301.8	498		702	777.4	792.5	807.6	868		988.7	1003.8	7.5	4.43	8	5.07	58.3	91.1	
Yarman-24 a	132.2	155.6			294.1	492.2		702		792.2		867.8			996.1	16.5	7.59	22.6	9.97	87.5	70.8	
Yarman-24 b	139	160.8			294.1	492.2		702		792.2		870.6			996.1	16.5	8.16	22.6	8.6	87.5	70.8	
Yarman24/31c	144.1	158.6		273.1	294.1	493.4		702		792.2		868		982.5	996.1	16.5	6.49	22.6	6.9	70	77.4	
Yarman24/31d	143.1	156.9		273.2	294.1	498		702		792.2		866		982.4	996.1	16.5	7.26	22.6	7.09	70	77.4	
Yarman24/42e	129.8	143.8		286.1	300	490.7		702	776.8		798	867			995.4	14.2	4.13	12.1	5.66	70	83.3	
Yarm36a-form		153.6			302.6	501		698			803.1				1001.3	23.9	15.66	18	12.74	83.3	86.1	
Yarm36a-mtch		153.6		285.2	302.6	501		698		783.3	803.1	881.3	895.8	987.2	1001.3	23.9	9.07	13.7	7.97	63.6	80.6	
Yektay65-form	110.8	147.7	184.6		295.4	498.5	683.1	701.5		793.8					996.9	18.1	12.15	24.2	10.73	66.7	90.8	
Yektay65-mtch	129.2	147.7		276.9	295.4	498.5		701.5	775.4	793.8		867.7	886.2		996.9	15.7	4.54	13.6	7.11	63.6	89.2	
Durgun60-mtch	120	140		280		500		700	760	780		880		980		9.7	4.81	10	6.11	77.8	88.3	
72 tET-matching	133.3	150		283.3		500		700	766.7	783.3		866.7		983.3		7.6	4.4	10	4.74	77.8	90.3	
41 tET-matching	117.1	146.3		292.7		497.6		702.4	761	790.2		878			995.1	14.5	10.57	11.8	7.78	66.7	85.4	
34 tET-matching		141.2		282.4		494.1		705.9	776.5				882.4	988.2		11.5	5.83	10	5.28	85.7	82.4	
29 tET-matching	124.1	165.5		289.7		496.6		703.4		786.2		869			993.1	11.9	7.33	18.1	9.92	75	79.3	
AutoPeak-env.	129.7			281	493.1	702.8		775.7				872.2		981.2								
AutoPeak-ave.	142.2			285.7	495.6	710.0		769.6				872.4		983.3								

Table 4 continued: Complexity-weighted (WM, WD) and Efficiency-scaled (WEM, WED) means of M’s & D’s

41 tET-matching	WM: 15.06	WD: 10.51	WEM: 22.59	WED: 15.76
34 tET-matching	WM: 11.99	WD: 6.2	WEM: 13.99	WED: 7.23
29 tET-matching	WM: 16.27	WD: 9.36	WEM: 21.7	WED: 12.47



42.49	16.81	49.57	19.61
9.32	5.71	15.98	9.8
19.55	8.78	22.34	10.03
19.55	8.38	22.34	9.58
20.84	7.13	29.77	10.19
20.84	7.64	29.77	10.92
14.79	5.5	21.13	7.86
24.15	16.37	28.98	19.64
20.63	9.35	32.42	14.69
25.37	13.72	38.05	20.58
17.35	6.9	27.26	10.84
11.57	6.42	14.88	8.25
10.51	5.46	13.51	7.02
WM	WD	WEM	WED

Table 4 continued: Complexity and Efficiency scaled means of M's & D's

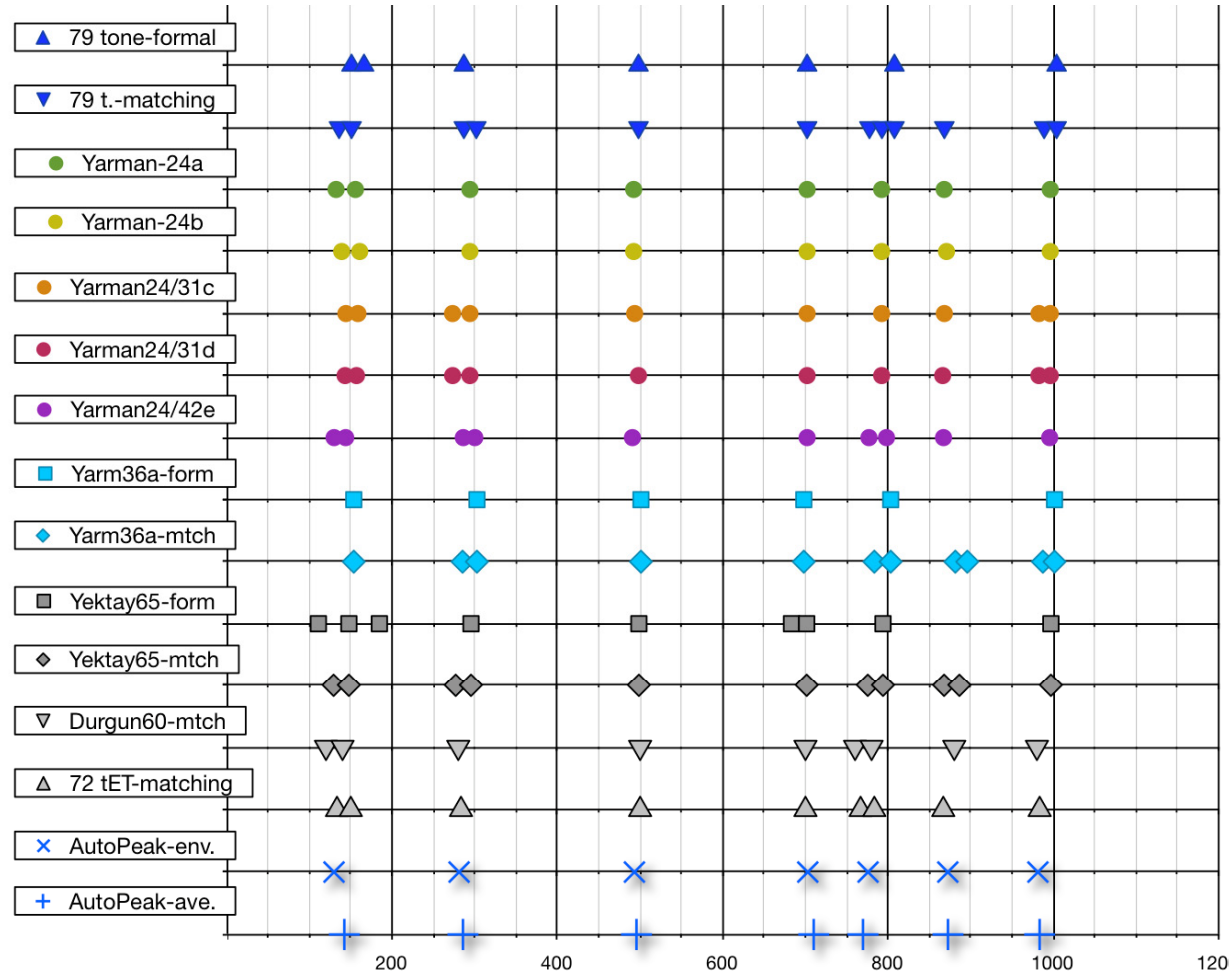


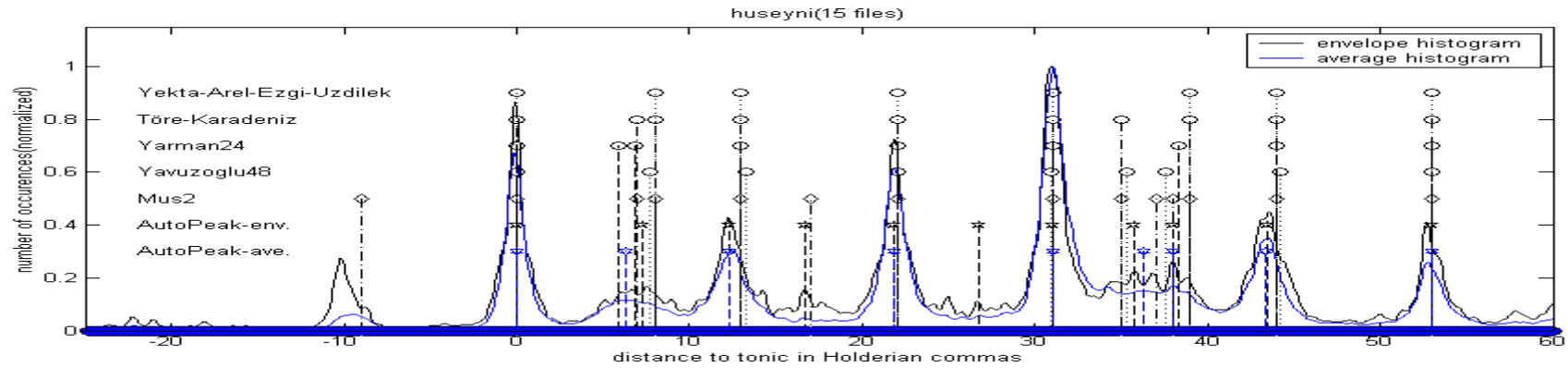
Figure 4: Plotting the data of Table 4 in comparison with the relevant histogram graphic in the precursor to this study [Bozkurt and Yarman et al. 2009, JNMR:38/1 pp.45-70]

Table 5: Mismatches in cents of the scale tones of various tunings with HÜSEYİNİ auto-peaks (15 collated histograms) and the resultant *efficiency* (E) and *complexity* (C) percentages. “M” denotes the maximum difference and “D” denotes the mean of differences, with subscript “e” delineating values in reference to *Auto-Peak envelope* datapoints and subscript “a” delineating values in reference to *Auto-Peak average* datapoints, where best values are highlighted and in bold (while red, blue and purple text colors are cosmetic). Higher E and lower C are better.

HÜSEYİNİ	Distance to tonic in cents															M _e	D _e	M _a	D _a	E	C
79 tone-formal		166		301.8			498		702			868			1003.8	22.6	9.6	22.2	13.23	100	92.4
79 t.-matching	150.9	166	271.1	286.8	301.8	377.3	498	603.7	702	807.6	822.7	852.9	868	988.7	1003.8	7.6	3.59	7.2	4.74	60	88.6
Yarman-24 a	155.6			294.1			498		702	792.2		867.8			996.1	16.3	9.47	30.6	12	100	70.8
Yarman-24 b		160.8		294.1			498		702	788.3		870.6			996.1	20.2	9.69	34.5	13.7	100	70.8
Yarman24/31c	144.4	158.6	273.1	294.1			493.4		702	792.2		868			996.1	16.3	7.27	30.6	8.74	77.8	77.4
Yarman24/31d	143.1	156.9	273.2	294.1			498		702	792.2		866			996.1	16.3	7.76	30.6	9.11	77.8	77.4
Yarman24/42e	143.8	157.7		286.1			490.7		702	798	839.1	867			995.4	13.2	6.83	16.3	6.87	77.8	83.3
Yarm36a-form	153.6	182.9		302.6			501		698			851.9	881.3		1001.3	23.4	12.17	23	12.03	75	83.3
Yarm36a-mtch	153.6	182.9		285.2	302.6	380.9	501	602.9	698	803.1		851.9	881.3	987.2	1001.3	11.2	5.76	19.7	8.63	69.2	75
Yektay65-form	147.7	184.6	203.1	295.4			498.5		701.5	793.8	812.3		886.2		996.9	25.6	11.74	26.3	11.07	70	89.2
Yektay65-mtch	147.7	166.2	276.9	295.4		387.7	498.5	609.2	701.5	793.8	812.3	867.7	886.2	978.5	996.9	8.7	3.9	10.5	4.84	64.3	86.2
Durgun60-mtch	140	160	280	300		380	500	600	700	800	820	860		980	1000	8.5	3.49	6.2	2.63	69.2	85
72 tET-matching	150	166.7	283.3	300		383.3	500	600	700	800	816.7	866.7	883.3	983.3	1000	8.2	4.36	6.8	4.74	64.3	87.5
41 tET-matching	146.3	175.6		292.7		380.5	497.6	614.6	702.4		819.5	878			995.1	17.4	8.96	18.1	7.77	90	78
34 tET-matching	141.2	176.5	282.4			388.2	494.1	600	705.9		811.8	847.1		988.2		13.5	6.4	12.8	5.61	90	73.5
29 tET-matching		165.5		289.7		372.4	496.6	620.7	703.4		827.6	869			993.1	19.1	8.42	21.3	8.56	100	89
AutoPeak-env.	164.8		279.2			379	493.8	605.9	701.4		808.5	860.6			982.2						
AutoPeak-ave.	144.2		279.6				493.8		703		822.8	859.9			981.7						

Table 5 continued: Complexity-weighted (WM, WD) and Efficiency-scaled (WEM, WED) means of M’s & D’s

41 tET-matching	WM: 19.36	WD: 9.12	WEM: 21.51	WED: 10.14
34 tET-matching	WM: 13.75	WD: 6.28	WEM: 15.28	WED: 6.98
29 tET-matching	WM: 20.2	WD: 8.49	WEM: 20.2	WED: 8.49



27.65	14.09	27.65	14.09
8.85	4.98	14.76	8.31
23.89	10.94	23.89	10.94
27.86	11.91	27.86	11.91
25.43	8.68	32.7	11.17
25.43	9.15	32.7	11.76
16.87	7.83	21.69	10.07
26.53	13.84	35.38	18.45
16.38	7.63	23.66	11.02
31.21	13.72	44.58	19.6
11.25	5.12	17.5	7.97
8.53	3.55	12.32	5.13
8.89	5.39	13.83	8.39
WM	WD	WEM	WED

Table 5 continued: Complexity and Efficiency scaled means of M's & D's

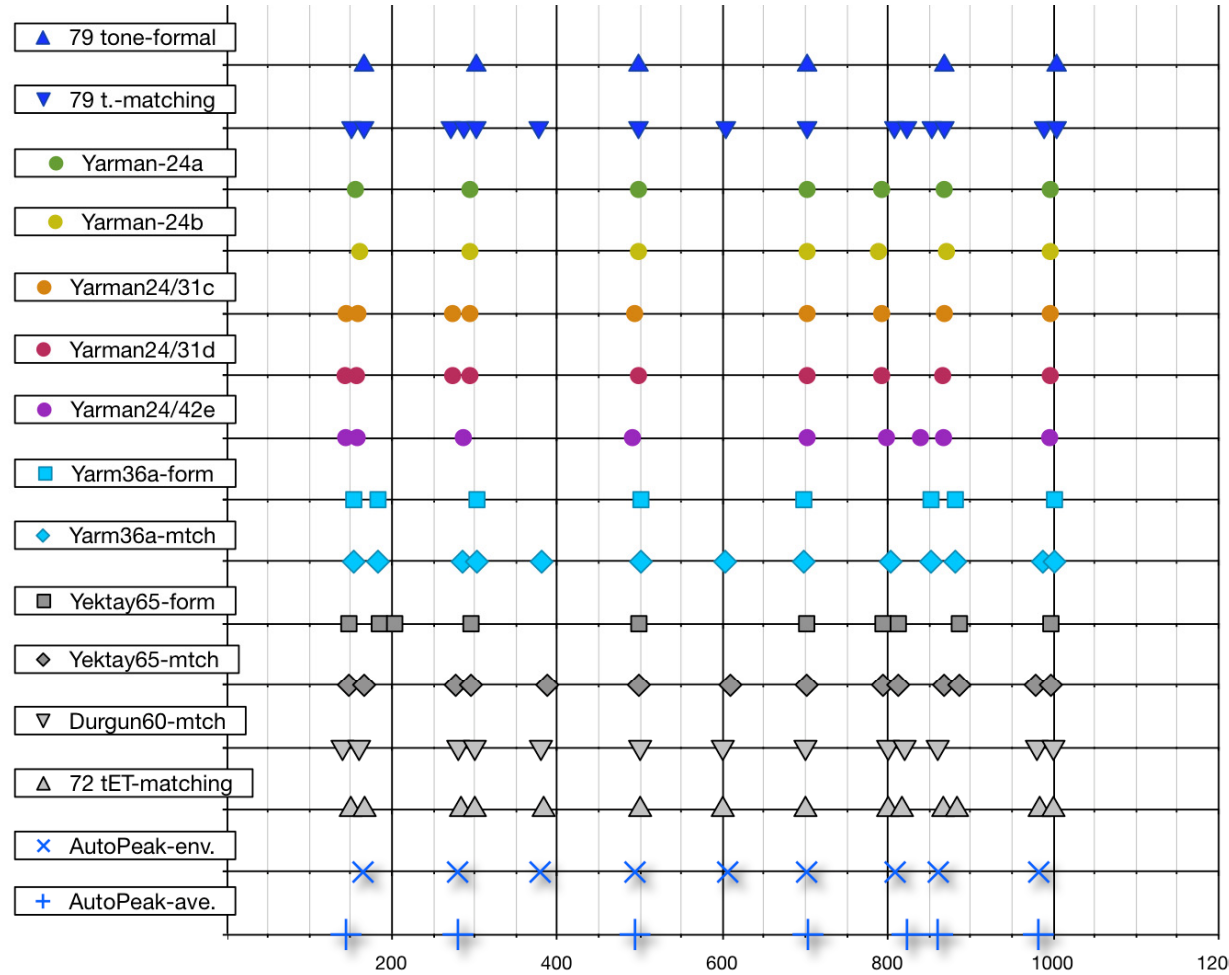


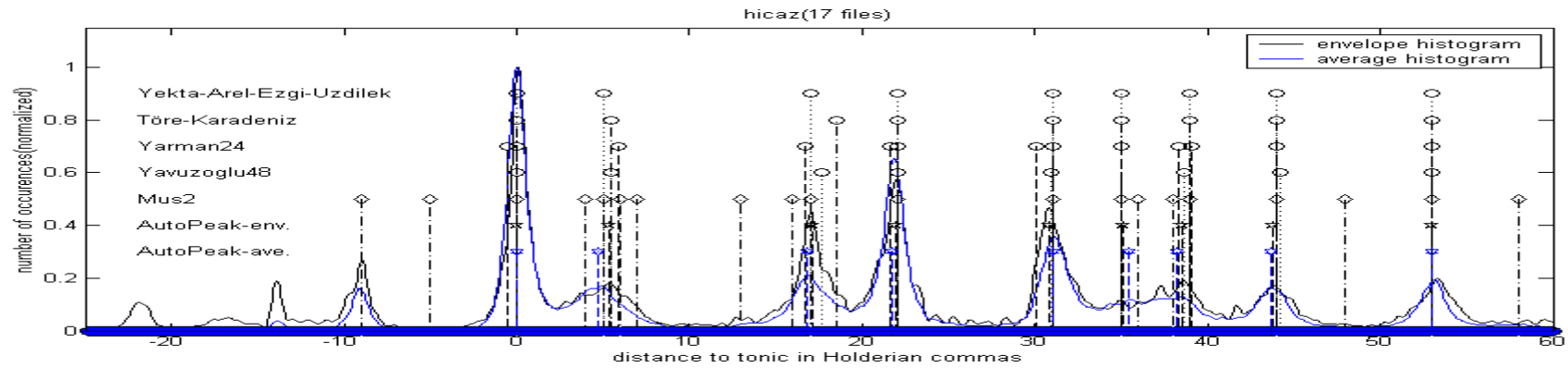
Figure 5: Plotting the data of Table 5 in comparison with the relevant histogram graphic in the precursor to this study [Bozkurt and Yarman et al. 2009, JNMR:38/1 pp.45-70]

Table 6: Mismatches in cents of the scale tones of various tunings with HİCAZ auto-peaks (17 collated histograms) and the resultant *efficiency* (E) and *complexity* (C) percentages. “M” denotes the maximum difference and “D” denotes the mean of differences, with subscript “e” delineating values in reference to *Auto-Peak envelope* datapoints and subscript “a” delineating values in reference to *Auto-Peak average* datapoints, where best values are highlighted and in bold (while red, blue and purple text colors are cosmetic). Higher E and lower C are better.

HİCAZ	Distance to tonic in cents													M _e	D _e	M _a	D _a	E	C	
79 tone-formal			120.7		392.4	498		702	777.4		868			1003.8	16.2	6.77	23.7	10.6	100	91.1
79 t.-matching		105.6	120.7	377.3	392.4	498		702	792.5	807.6	868		988.7	1003.8	6.6	3	6.5	2.81	63.6	91.1
Yarman-24a			132.2	380.2		498		702	792.2		867.8		996.1		12.2	5.09	26.9	7.37	100	70.8
Yarman-24b			139	380.4		498		702	792.2		870.6		996.1		19	5.63	33.7	8.71	100	70.8
Yarman24/31c			144.4	377.5		493.4		702	792.2		868	881.6	996.1		24.4	7.36	39.1	8.87	87.5	77.4
Yarman24/31d			143.1	375.2		498		702	792.2		866	879.7	996.1		23.1	7.49	37.8	9.39	87.5	77.4
Yarman24/42e		129.8	143.8	376.3		490.7		702	798		867	880.9	995.4		9.8	6.3	24.5	6.27	77.8	83.3
Yarm36a-form		104.9		380.9		501		698		803.1		881.3		1001.3	15.1	7.6	15.7	6.26	100	80.6
Yarm36a-mtch		104.9		380.9		501		698		803.1	851.9	881.3		1001.3	15.1	7.6	13.7	5.97	87.5	80.6
Yektay65-form	92.3	110.8	129.2		387.7	498.5	683.1	701.5	793.8	812.3		886.2	996.9		12.9	5.13	20.6	7.93	63.6	89.2
Yektay65-mtch		110.8	129.2		387.7	498.5		701.5	793.8		867.7	886.2	996.9		9.2	4.09	7.5	5.29	77.8	89.2
Durgun60-mtch		100	120	380		500		700		800	860	880	980	1000	9.4	4.81	9.4	4.64	70	88.3
72 tET-matching		100	116.7		383.3	500		700		800	866.7			1000	9.4	4.8	10.6	4.47	87.5	90.3
41 tET-matching			117.1	380.5		497.6		702.4	790.2			878	995.1		5.3	4.37	12.4	7.77	85.7	85.4
34 tET-matching		105.9			388.2	494.1		705.9		811.8	847.1	882.4	988.2		18.2	9.33	16.8	6.6	75	82.4
29 tET-matching			124.1	372.4		496.6		703.4	786.2		869		993.1		13.4	6.18	18.8	8.78	85.7	79.3
AutoPeak-env.		120		385.8	496.3	698.3		793.6		873.3			990.6							
AutoPeak-ave.		105.3		380.6	493.4	703.9		801.1		865.6			989.4							

Table 6 continued: Complexity-weighted (WM, WD) and Efficiency-scaled (WEM, WED) means of M’s & D’s

41 tET-matching	WM:	10.14	WD:	6.95	WEM:	11.83	WED:	8.11
34 tET-matching	WM:	19.52	WD:	8.88	WEM:	26.02	WED:	11.85
29 tET-matching	WM:	17.46	WD:	8.12	WEM:	20.38	WED:	9.47



24	10.45	24	10.45
7.88	3.5	12.38	5.5
19.55	6.23	19.55	6.23
26.35	7.17	26.35	7.17
33.84	8.65	38.68	9.88
32.46	8.99	37.09	10.28
19.29	7.07	24.81	9.09
16.9	7.6	16.9	7.6
15.8	7.45	18.06	8.51
19.83	7.73	31.16	12.15
9.89	5.55	12.71	7.13
11.05	5.56	15.78	7.94
11.94	5.54	13.65	6.33
WM	WD	WEM	WED

Table 6 continued: Complexity and Efficiency scaled means of M's & D's

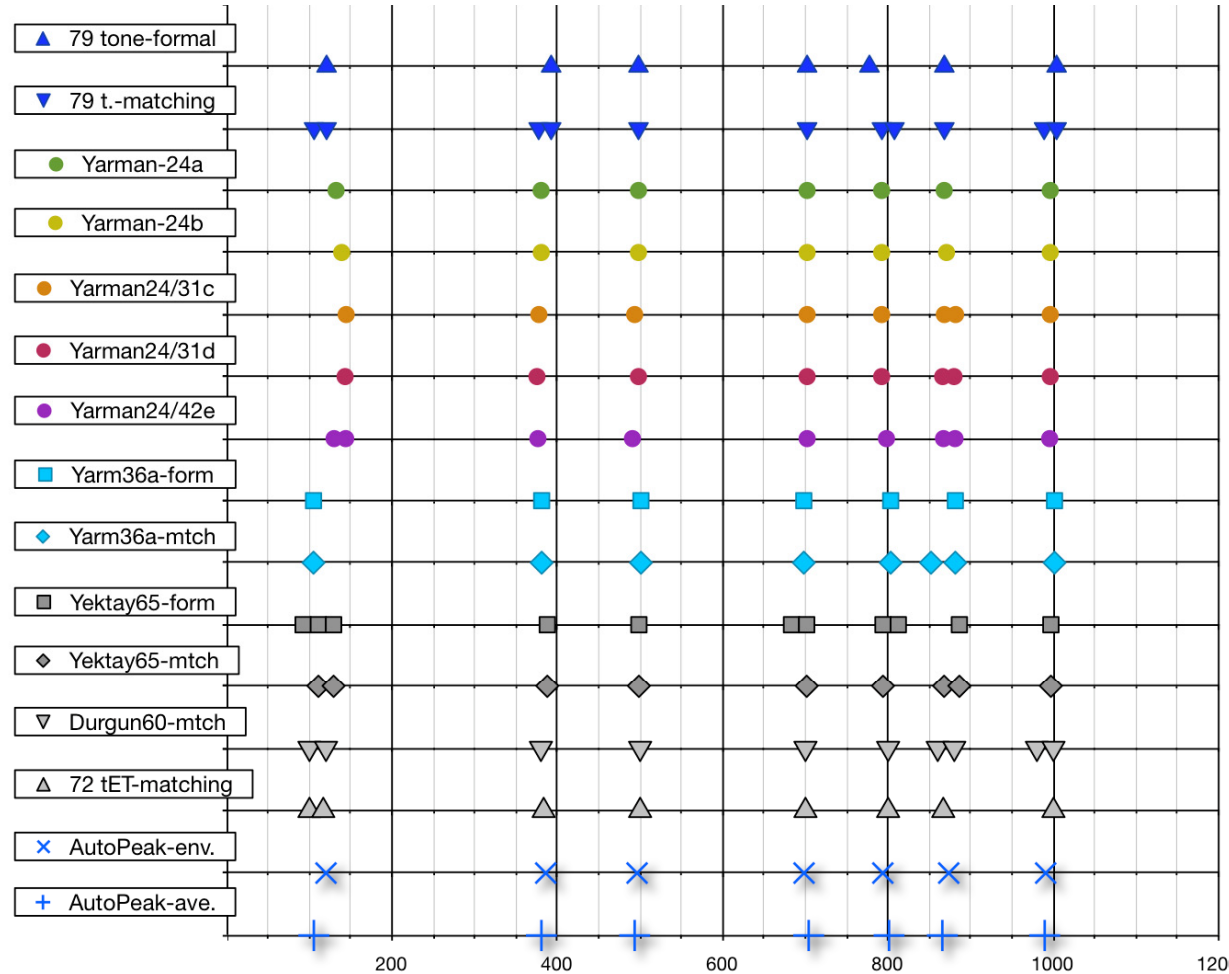


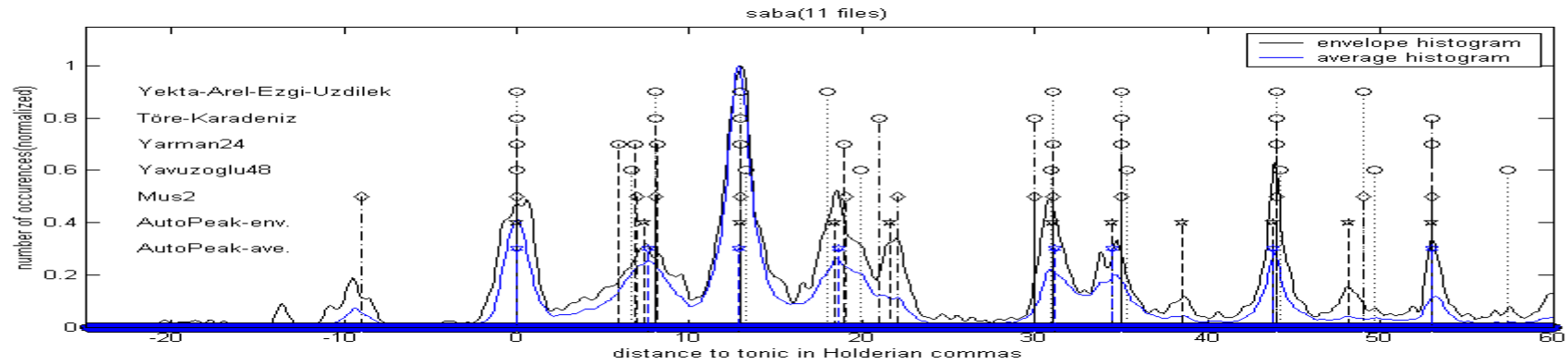
Figure 6: Plotting the data of Table 6 in comparison with the relevant histogram graphic in the precursor to this study [Bozkurt and Yarman et al. 2009, JNMR:38/1 pp.45-70]

Table 7: Mismatches in cents of the scale tones of various tunings with SABA auto-peaks (11 collated histograms) and the resultant *efficiency* (E) and *complexity* (C) percentages. “M” denotes the maximum difference and “D” denotes the mean of differences, with subscript “e” delineating values in reference to *Auto-Peak envelope* datapoints and subscript “a” delineating values in reference to *Auto-Peak average* datapoints, where best values are highlighted and in bold (while red, blue and purple text colors are cosmetic). Higher E and lower C are better.

SABA	Distance to tonic in cents																M _e	D _e	M _a	D _a	E	C	
79 tone-formal		150.9	166		301.8		437.7	452.8		702		807.6		1003.8		1154.7	25.8	9.93	25.6	12.23	77.8	91.1	
79 t.-matching		150.9	166	286.8	301.8		422.6			702	777.4	792.5		988.7	1003.8	1139.6	1154.7	5.5	3.01	6.3	3.47	58.3	91.1
Yarman-24a		155.6	182.4		294.1		427.4		492.2	702		792.2			996.1	1080.5	1138.4	11.7	6.24	10.2	6.02	80	56.7
Yarman-24b		160.8	182.4		294.1		431.4		492.2	702		792.2			996.1	1080.5	1141.2	14.3	6.09	10.2	6.68	80	56.7
Yarman24/31c		158.6	179.6		294.1		430.3		493.4	702		792.2			996.1	1081.1	1139.7	13.2	6.3	10.2	6.03	80	74.2
Yarman24/31d		156.9	177.8		294.1		429.4		491.5	702		792.2			996.1	1079.4	1138.6	12.3	6.38	10.2	5.58	80	74.2
Yarman24/42e		157.7	176.8	286.1	300	415.9	429.8		490.7	702	776.8	798	867		995.4	1080.4	1139.1	9.6	4.33	6.4	4.37	64.3	78.6
Yarm36a-form		153.6	182.9	285.2	302.6	395.4	455.5			698		803.1			1001.3		1154.4	21.7	10.71	28	13.43	70	80.6
Yarm36a-mtch		153.6	182.9	285.2	302.6	395.4	455.5		484.7	698	783.3	803.1	881.3	987.2	1001.3	1098.9	1154.4	21.7	8.54	28	9.35	60	75
Yektay65-form	110.8	147.7	184.6	295.4	387.7	406.2	424.6	443.1	480	701.5		793.8			996.9			17.3	7.91	12.3	6.62	58.3	89.2
Yektay65-mtch		147.7	166.2		295.4	406.2	424.6		498.5	701.5	775.4	793.8	867.7		996.9	1089.2		7.9	3.94	6.6	4.72	75	86.2
Durgun60-mtch		160	180	280	300	400	420		500	700	780		880		1000	1080		10	6.28	9.6	5.98	75	85
72 tET-matching		166.7	183.3	283.3	300	400	416.7		483.3	700	783.3		866.7		1000	1083.3		8.2	4.21	8.1	5.52	75	87.5
41 tET-matching		146.3	175.6		292.7	409.8		439	497.6	702.4		790.2	878		995.1	1082.9		8.4	5.44	13.6	5.68	81.8	78
34 tET-matching		141.2	176.5	282.4			423.5		494.1	705.9	776.5		882.4	988.2		1094.1		10.9	6.46	7.2	3.58	90	73.5
29 tET-matching		165.5		289.7		413.8			496.6	703.4	786.2		869		993.1	1075.9		14.1	4.08	9.6	3.93	100	69
AutoPeak-env.		167.3		291.8		417.1			490.6	701.2	781.8	871.5		992.8		1090							
AutoPeak-ave.		172.3		289.6		423.4				705.1	782.0			991.9									

Table 7 continued: Complexity-weighted (WM, WD) and Efficiency-scaled (WEM, WED) means of M’s & D’s

41 tET-matching	WM:	12.25	WD:	6.2	WEM:	14.97	WED:	7.57
34 tET-matching	WM:	9.67	WD:	5.36	WEM:	10.75	WED:	5.96
29 tET-matching	WM:	12.12	WD:	4.1	WEM:	12.12	WED:	4.1



31.99	13.79	41.13	17.73
7.34	4.03	12.59	6.91
10.95	6.13	13.69	7.66
12.25	6.39	15.31	7.98
12.58	6.63	15.73	8.29
12.1	6.43	15.12	8.04
8.95	4.87	13.93	7.57
28.3	13.75	40.43	19.64
26.92	9.69	44.87	16.15
18.14	8.9	31.1	15.27
8.66	5.17	11.55	6.9
11.6	7.25	15.46	9.67
9.85	5.88	13.13	7.84
WM	WD	WEM	WED

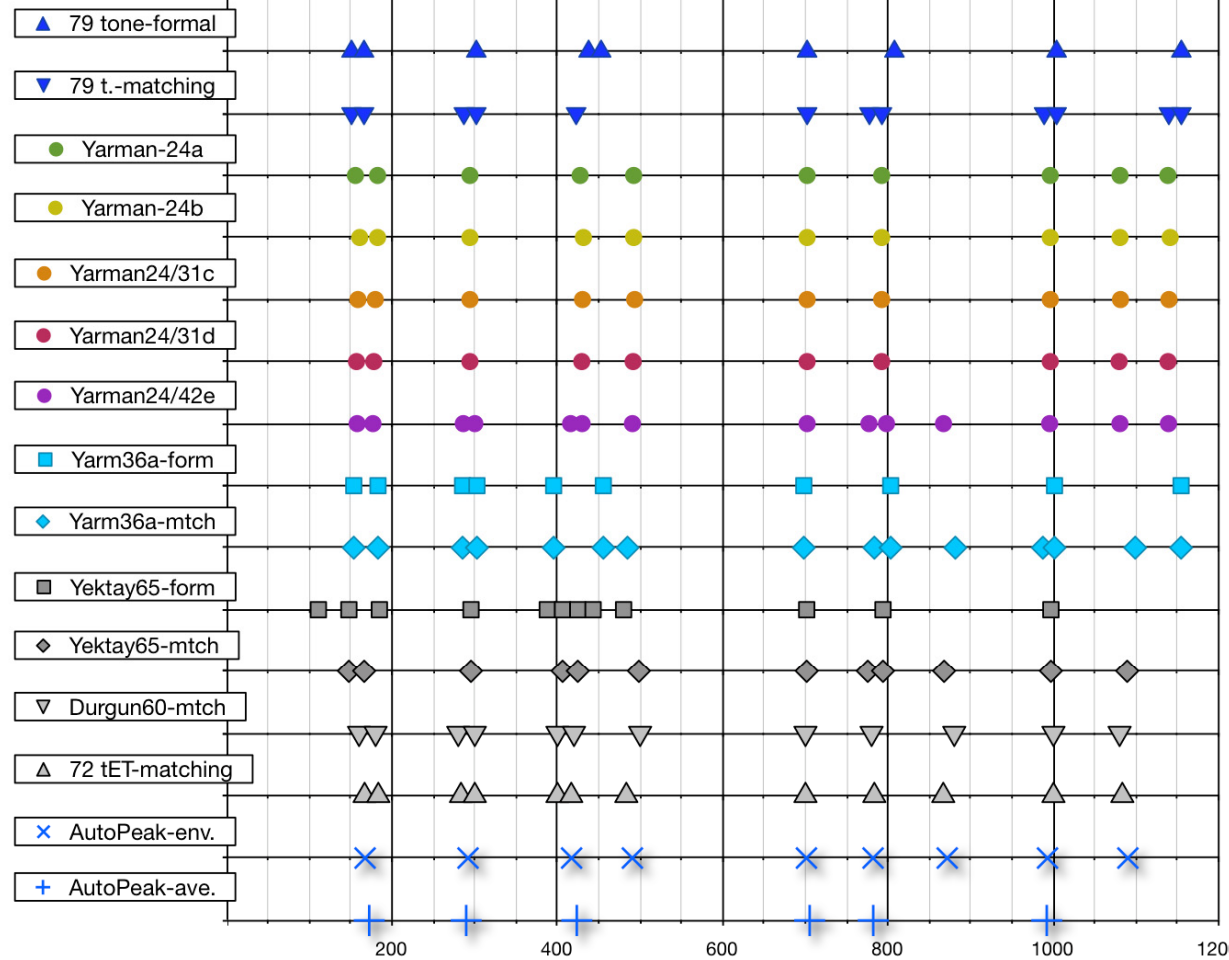


Figure 7: Plotting the data of Table 7 in comparison with the relevant histogram graphic in the precursor to this study [Bozkurt and Yarman et al. 2009, JNMR:38/1 pp.45-70]

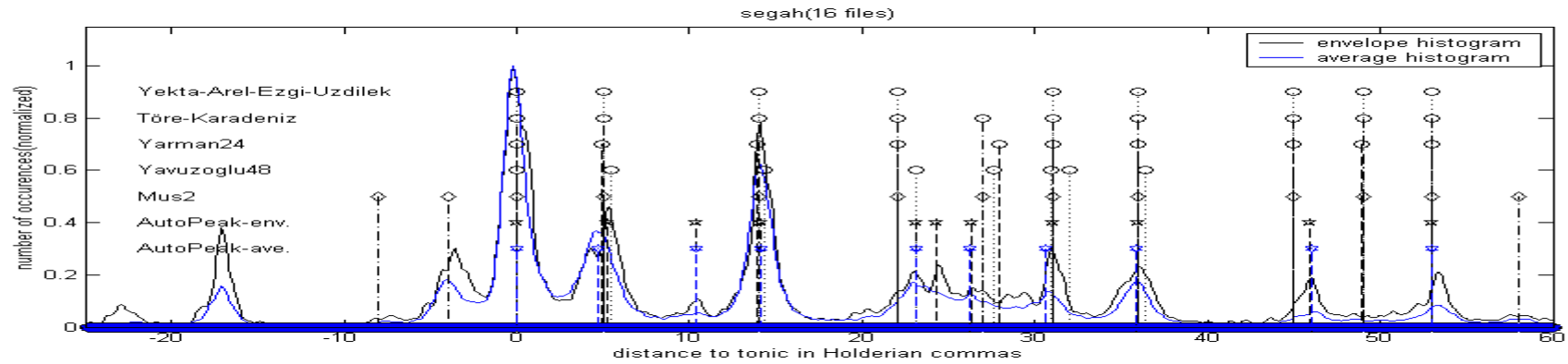
Table 7 continued: Complexity and Efficiency scaled means of M's & D's

Table 8: Mismatches in cents of the scale tones of various tunings with SEGAH auto-peaks (16 collated histograms) and the resultant *efficiency* (E) and *complexity* (C) percentages. “M” denotes the maximum difference and “D” denotes the mean of differences, with subscript “e” delineating values in reference to *Auto-Peak envelope* datapoints and subscript “a” delineating values in reference to *Auto-Peak average* datapoints, where best values are highlighted and in bold (while red, blue and purple text colors are cosmetic). Higher E and lower C are better.

SEGAH	Distance to tonic in cents															M _e	D _e	M _a	D _a	E	C
79 tone-formal	105.6			301.8		498			603.7		702	792.5	807.6	1003.8	1094.4	35.4	15.2	37.9	14.44	77.8	91.1
79 t.-matching	105.6	120.7	241.5	301.8	316.9	513.1	528.2	543.3	588.6	603.7	702	807.6	822.7	1034	1049.1	7.6	4.97	7.8	5.05	60	88.6
Yarman-24a	111.7		245		315.6		519.6			609.8	702		813.7	1017.6	1105.9	21.6	7.77	24.1	8.94	88.9	86.7
Yarman-24b	111.7		249		315.6		519.6			609.8	702		813.7	1017.6	1105.9	21.6	8.27	24.1	9.44	88.9	86.7
Yarman24/31c		114.5	250.6		313.8		522.3			612.5	702		816.5	1020.4	1041.2	16.8	6.18	17.7	7.61	88.9	74.2
Yarman24/31d		116.3	251.6		313.7		524.2			614.4	702		818.3	1022.2	1042.5	18.7	6.87	19.6	8.49	88.9	74.2
Yarman24/42e	109.3	123.2	239.1		313.9		525.2		600		704.2		818.6	1023.2	1043.8	6.5	4.27	9.3	4.83	80	81
Yarm36a-form		119.7		301.8		500.7				620.2	698.4		818.4	1017.1		24.5	13.86	25.4	16.13	100	80.6
Yarm36a-mtch	102.3	119.7	212.5	301.8	318.1	500.7	515.1	569	600.4		698.4		818.4	1017.1		22.1	9.69	24.6	9.2	75	75.0
Yektay65-form	110.8				313.8	498.5	516.9			609.2	701.5		812.3	1015.4	1107.7	23.8	8.57	26.3	9.07	77.8	89.2
Yektay65-mtch	110.8		240		313.8	498.5	516.9	553.8	590.8	609.2	701.5		812.3	1033.8		7.6	4.8	7.9	5.13	81.8	86.2
Durgun60-mtch	100	120	240		320	500	520	540	600		700		820	1040		9.7	3.79	7.8	4.56	81.8	85
72 tET-matching	100	116.7	233.3		316.7	500	516.7	550	600		700		816.7	1033.3	1050	5.9	3.08	8.3	4.76	75	87.5
41 tET-matching		117.1	234.1		322	497.6	526.8	556.1	585.4	614.6	702.4		819.5	1024.4		14.8	4.94	17.3	7.47	81.8	78
34 tET-matching	105.9		247.1		317.6	494.1	529.4	564.7	600		705.9		811.8		1058.8	19.6	8.86	17.1	6.83	90	73.5
29 tET-matching		124.1	248.3		331	496.6	537.9	537.9	579.3	620.7	703.4		827.6	1034.5		16.4	10.37	18.1	13.28	90	69
AutoPeak-env.	118.4	233.9	320.4		522.6	549.7	595.7	702.6	814		1039.2										
AutoPeak-ave.	106	233.7	318.8		523.2		594.8	694.9	812.2		1041.7										

Table 8 continued: Complexity-weighted (WM, WD) and Efficiency-scaled (WEM, WED) means of M’s & D’s

41 tET-matching	WM: 17.88	WD: 6.92	WEM: 21.85	WED: 8.45
34 tET-matching	WM: 19.61	WD: 8.38	WEM: 21.79	WED: 9.31
29 tET-matching	WM: 17.65	WD: 12.09	WEM: 19.61	WED: 13.44



45.62	18.45	58.65	23.72
9.39	6.11	15.65	10.18
22.85	8.36	25.71	9.4
22.85	8.86	25.71	9.96
18.55	7.41	20.87	8.34
20.59	8.26	23.17	9.29
9.03	5.2	11.29	6.5
28.42	17.08	28.42	17.08
25.3	10.23	33.73	13.64
30.7	10.81	39.47	13.9
9.26	5.93	11.32	7.25
10.35	4.94	12.66	6.04
8.58	4.74	11.44	6.32
WM	WD	WEM	WED

Table 8 continued: Complexity and Efficiency scaled means of M's & D's

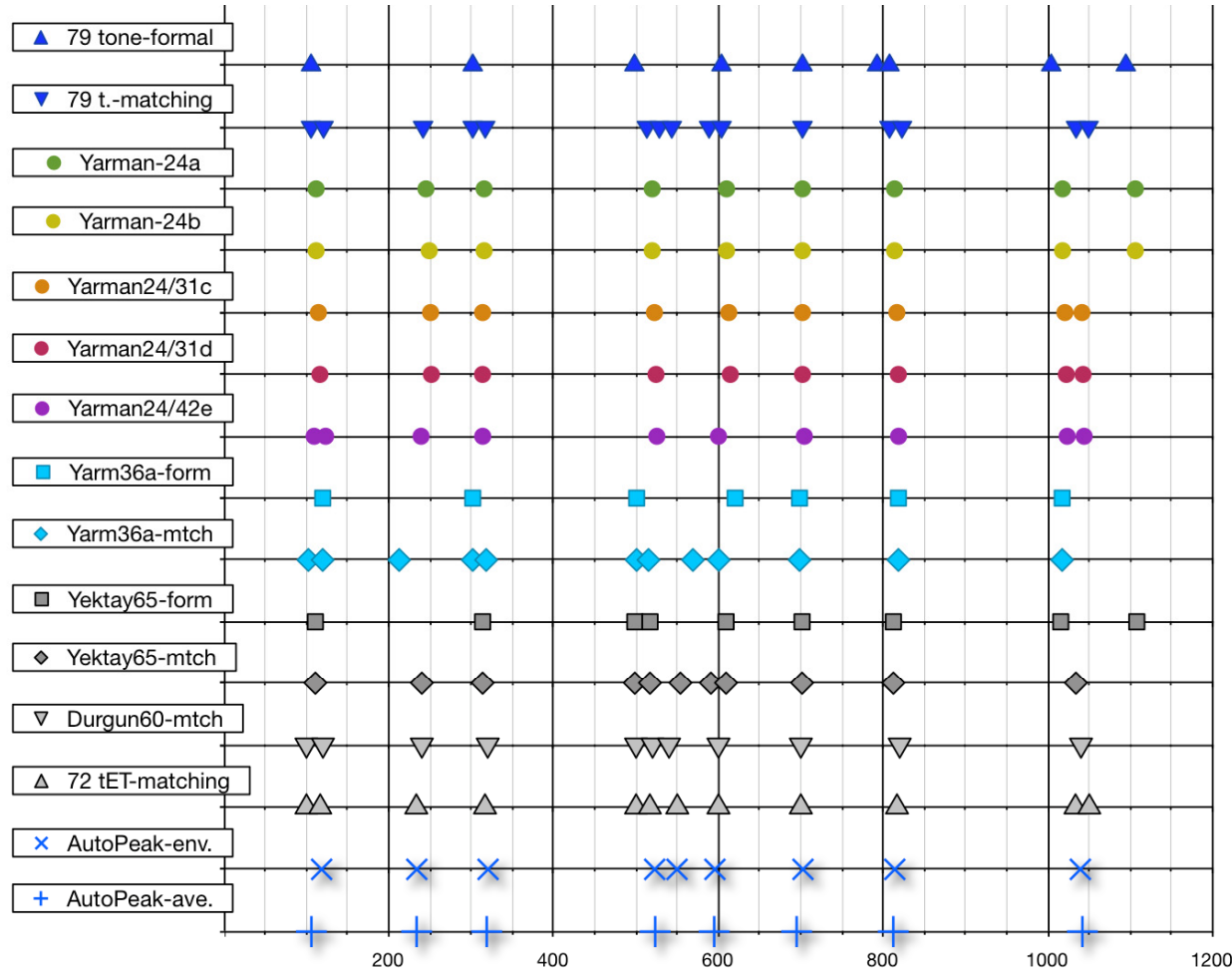


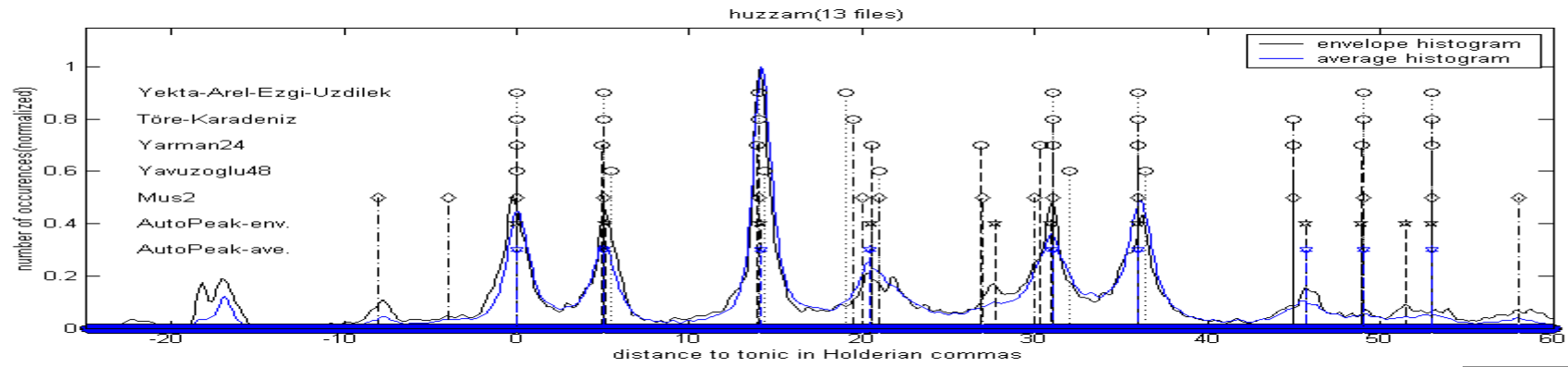
Figure 8: Plotting the data of Table 8 in comparison with the relevant histogram graphic in the precursor to this study [Bozkurt and Yarman et al. 2009, JNMR:38/1 pp.45-70]

Table 9: Mismatches in cents of the scale tones of various tunings with HÜZZAM auto-peaks (13 collated histograms) and the resultant *efficiency* (E) and *complexity* (C) percentages. “M” denotes the maximum difference and “D” denotes the mean of differences, with subscript “e” delineating values in reference to *Auto-Peak envelope* datapoints and subscript “a” delineating values in reference to *Auto-Peak average* datapoints, where best values are highlighted and in bold (while red, blue and purple text colors are cosmetic). Higher E and lower C are better.

HÜZZAM	Distance to tonic in cents														M _e	D _e	M _a	D _a	E	C		
79 tone-formal	120.7		316.9			483	498		702	822.7		1018.9		1109.4		19.5	7.91	20	7.8	87.5	91.1	
79 t.-matching	120.7	135.8	316.9	332.0		467.9	483	633.9	702	822.7	837.8	1018.9	1034	1109.4	1169.8	8.1	3.94	7.7	3.8	64.3	88.6	
Yarman-24 a	111.7		315.6			466.3		609.7	702	813.7		1017.6		1105.9	1173.2	18.6	6.79	18.6	6.32	100	82.3	
Yarman-24 b	111.7		315.6			468.6		609.8	702	813.7		1017.6		1105.9	1156.6	18.5	7.08	18.5	6.6	100	82.3	
Yarman24/31c	114.5		313.8			469.5		612.5	702	816.5		1020.4	1041.2	1108.9	1164.8	15.8	4.39	15.8	4.97	90	71	
Yarman24/31d	116.3		313.7			469.9		614.4	702	818.3		1022.2	1042.5	1110.1	1165.3	13.9	4.63	13.9	5.54	90	71	
Yarman24/42e	109.3	123.2	313.9			443.8	471.6	621.3	704.2	818.6		1023.2	1043.8	1117.1	1167	8.8	6.07	10	6.26	75	78.6	
Yarm36a-form	119.7		301.8			471.4			698.4	818.4		1017.1				18.5	8.92	19	9.37	100	83.3	
Yarm36a-mtch	119.7		301.8	318.1		471.4		620.2	698.4	818.4		1017.1	1068.9	1100.3	1170.7	18.5	6.54	16.7	7.09	81.8	75	
Yektay65-form	110.8		313.8	406.2	424.6	443.1	461.5		701.5	812.3		1015.4		1107.7		20.2	5.37	18.4	4.89	70	89.2	
Yektay65-mtch	110.8		313.8			443.1	461.5	627.7	701.5	812.3		1015.4	1033.8	1107.7	1163.1	5.9	2.42	7	2.05	81.8	86.2	
Durgun60-mtch	120		320			460		620	700	820		1020	1040	1100	1160	8.3	4.42	9	4.96	90	85	
72 tET-matching	116.7		316.7			466.7		633.3	700	816.7		1033.3		1116.7	1166.7	8.4	2.98	7.7	3.35	100	87.5	
41 tET-matching	117.1		322			468.3		614.6	702.4	819.5		1024.4		1112.2	1170.7	13.7	5.6	13.7	5.22	100	78	
34 tET-matching	105.9		317.6			458.8		635.3	705.9	811.8		1023.5	1058.8	1094.1	1164.7	14.2	6.58	14.9	6.92	90	73.5	
29 tET-matching		124.1		331		455.2		620.7	703.4		827.6	1034.5		1117.2	1158.6	13	7.63	11.8	7.45	100	69	
AutoPeak-env.	115.7		319.7			463.5		628.3	699.8	814.6		1035.6		1108.3	1165.1							
AutoPeak-ave.	113		320.8			463		628.3	701.2	815.8		1033.8		1109								

Table 9 continued: Complexity-weighted (WM, WD) and Efficiency-scaled (WEM, WED) means of M’s & D’s

41 tET-matching	WM: 15.83	WD: 6.25	WEM: 15.83	WED: 6.25
34 tET-matching	WM: 16.15	WD: 7.5	WEM: 17.95	WED: 8.33
29 tET-matching	WM: 13.2	WD: 8.03	WEM: 13.2	WED: 8.03



25.41	10.11	29.04	11.55
9.96	4.88	15.5	7.6
18.6	6.56	18.6	6.56
18.5	6.84	18.5	6.84
17.14	5.08	19.04	5.64
15.08	5.52	16.75	6.13
10.91	7.16	14.55	9.54
22.66	11.05	22.66	11.05
19.8	7.67	24.2	9.37
24.46	6.5	34.94	9.28
7.98	2.77	9.75	3.38
10.6	5.75	11.77	6.39
10.06	3.95	10.06	3.95
WM	WD	WEM	WED

Table 9 continued: Complexity and Efficiency scaled means of M's & D's

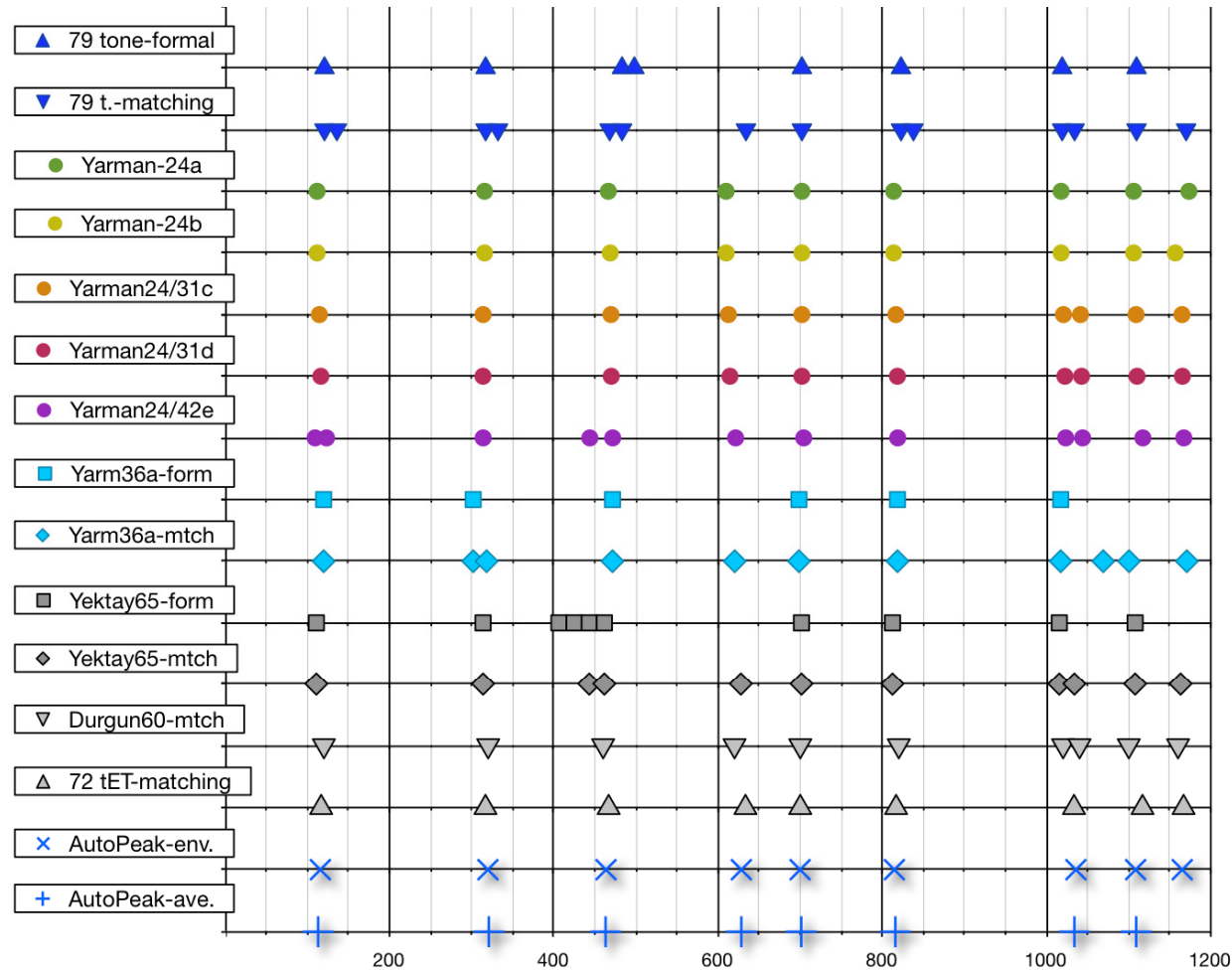


Figure 9: Plotting the data of Table 9 in comparison with the relevant histogram graphic in the precursor to this study [Bozkurt and Yarman et al 2009, JNMR:38/1 pp.45-70]

Table 10: Grand averages of all mismatches in cents of the scale tones of various tunings with auto-peaks, and the resultant mean *efficiency* (E) and mean *complexity* (C) percentages (constituting altogether PANORAMA A – with the bottom 5 rows drawn from Bozkurt and Yarman et al. [2009]). “M” denotes the maximum difference and “D” denotes the average of differences; with subscript “em” delineating mean values in reference to *Auto-Peak envelope* datapoints, subscript “am” delineating mean values in reference to *Auto-Peak average* datapoints, subscript “m” delineating the average of em’s and am’s as well as all preceding E’s and C’s, and subscript “c” delineating the complexity scaling (similar to for GWM: *Grand average of complexity-weighted maximums* and GWD: *Grand average of complexity-weighted average of differences* pulled out of continued Tables 1-9), where best values are highlighted and in bold (while red, blue, purple, green and turquoise text colors are cosmetic). As it so happens, 79 MOS 159-tET (the peak-matching version) outclasses its competition in this panorama even after complexity upscaling under the rightmost four columns. Higher E and lower C are better, while smaller deviations in all other measures are always better.

PANORAMA A	M _{em}	D _{em}	M _{am}	D _{am}	E _m	C _m	M _m	D _m	M _c	D _c	GWM	GWD
79 tone-formal (79 per 159 tET)	23.1	10	24.6	10.5	87.1	91.1	23.9	10.2	29.4	12.6	29.5	12.6
79 tone-matching	7.1	3.6	7.4	3.9	64.6	89.2	7.3	3.7	8.8	4.5	8.9	4.6
Yarman-24a	14.8	6.4	19.7	7.4	92.7	68.1	17.2	6.9	17.2	6.9	17.4	7
Yarman-24b	16.2	6.5	21.1	7.8	92.7	68.1	18.7	7.2	18.7	7.2	18.9	7.2
Yarman24/31c	15.7	6	20	6.8	85.8	75.3	17.9	6.4	19.1	6.9	19.3	7
Yarman24/31d	15.9	6.3	19.9	7	85.8	75.3	17.9	6.7	19.2	7.1	19.3	7.2
Yarman24/42e	11.3	6	12.7	6.2	79.2	81.5	12	6.1	13.7	6.9	13.8	7
Yarman36a-formal	19.6	10.4	20.3	10.3	92	82.4	19.9	10.4	22.8	11.8	23	11.9
Yarman36a-matching	18.2	7.7	18.9	7.9	77.6	75.9	18.5	7.8	20	8.4	20.2	8.5
Yektay65-formal (in 65 tET)	18.5	7.8	19.8	7.6	72.4	89.1	19.2	7.7	23.2	9.3	23.3	9.3
Yektay65-matching (in 65 tET)	9.1	4	9	4.7	79.4	86.5	9.1	4.3	10.7	5.1	10.8	5.2
Durgun60-matching (in 60 tET)	9.4	4.6	9.3	4.9	80.8	85.4	9.4	4.7	11	5.5	11.1	5.6
72 tET-matching	8.7	3.9	9.1	4.6	82.5	87.8	8.9	4.3	10.7	5.1	10.7	5.1
41 tET-matching	13.1	6.4	13	6.1	87.2	79.1	13	6.3	14.5	7	14.6	7
34 tET-matching	14.6	7	12.9	5.8	90	75.2	13.7	6.4	14.7	6.9	14.8	7
29 tET-matching	15.8	7.3	15.9	7.8	93.4	70.5	15.8	7.5	16.2	7.7	16.3	7.8
YAEU (24 per 53-tET)	22.5	8	23.3	9.1	98.4	74.1	22.9	8.6	24.3	9.1	24.4	9.1
Mus2 (53 tET-formal)	16.9	7.3	16.7	7.3	73.5	85.5	16.8	7.3	19.7	8.6	19.8	8.6
Töre-Karadeniz (41 per 106 tET)	23	8.7	28.8	11.6	95.8	83.5	25.9	10.2	29.9	11.7	29.9	11.7
Old Yarman-24a	18.4	7	19.4	7.2	92.7	68.1	18.9	7.1	18.9	7.1	18.9	7.1
Yavuzoğlu-48 (in 48 tET)	23.9	11.2	23.7	12.2	95.6	86.3	23.8	11.7	28.2	13.8	28.3	13.9

Table 11: Efficiency-upscaled M_c , D_c and GWM, GWD; designated as CEM, CED and GEM, GED respectively – with resultant ϕ values converted to percentages via taking as basis the smallest numbers each in the first four columns under the “Pre-normalized” heading. The operation uses the formula $\% = 100 \times [(\text{smallest among the list of } [\text{complexity-weighted } \phi / \text{corresponding efficiencies}]) / (\text{complexity-weighted } \phi / \text{current efficiency})]$. Rightmost two columns feature the average of CEM, GEM & the average of CED, GED correspondingly. In this “bulk vs. peak-matching performance” panorama that I dub PANORAMA B – with the bottom 5 rows drawn from Bozkurt and Yarman et al. [2009] – all inefficient players are aggressively taken down to the effect that 72-tET comes out on top, followed by 65-tET, 60-tET and 79 MOS 159-tET (e.g., the peak-matching version). Best values are highlighted and in bold, while worst values are striped in red.

PANORAMA B (Bulk vs. Peak-matching Performance)	Pre-normalized upscaled ϕ				Normalized to percentages				Average of performance maximums	Average of performance mean diffs.
	CEM ¹³ Perf.	CED ¹³ Perf.	GEM ¹⁴ Perf.	GED ¹⁴ Perf.	CEM Perf. %	CED Perf. %	GEM Perf. %	GED Perf. %		
79 tone-formal (79 per 159 tET)	33.75	14.44	33.92	14.50	38%	43%	38%	43%	38%	43%
79 tone-matching	13.61	7.02	13.7	7.07	95%	88%	95%	88%	95%	88%
Yarman-24a	18.61	7.43	18.78	7.5	70%	83%	69%	83%	69%	83%
Yarman-24b	20.17	7.71	20.36	7.78	64%	80%	64%	80%	64%	80%
Yarman24/31c	22.31	8.04	22.5	8.11	58%	77%	58%	77%	58%	77%
Yarman24/31d	22.36	8.32	22.55	8.4	58%	74%	58%	74%	58%	74%
Yarman24/42e	17.25	8.71	17.42	8.8	75%	71%	75%	71%	75%	71%
Yarman36a-formal	24.77	12.86	24.96	12.97	52%	48%	52%	48%	52%	48%
Yarman36a-matching	25.77	10.86	25.97	10.94	50%	57%	50%	57%	50%	57%
Yektay65-formal (in 65 tET)	31.99	12.79	32.11	12.84	40%	48%	41%	48%	40%	48%
Yektay65-matching (in 65 tET)	13.51	6.46	13.58	6.5	96%	96%	96%	96%	96%	96%
Durgun60-matching (in 60 tET)	13.61	6.86	13.69	6.92	95%	90%	95%	90%	95%	90%
72 tET-matching	12.94	6.18	13.02	6.22	100%	100%	100%	100%	100%	100%
41 tET-matching	16.6	8.01	16.7	8.08	78%	77%	78%	77%	78%	77%
34 tET-matching	16.35	7.66	16.5	7.73	79%	81%	79%	80%	79%	81%
29 tET-matching	17.38	8.26	17.48	8.34	74%	75%	74%	75%	74%	75%
YAEU (24 per 53-tET)	24.67	9.22	24.79	9.21	52%	67%	53%	68%	52%	67%
Mus2 (53 tET-formal)	26.81	11.65	26.88	11.67	48%	53%	48%	53%	48%	53%
Töre-Karadeniz (41 per 106 tET)	31.19	12.23	31.15	12.21	41%	51%	42%	51%	42%	51%
Old Yarman-24a	20.38	7.65	20.38	7.65	64%	81%	64%	81%	64%	81%
Yavuzoğlu-48 (in 48 tET)	29.45	14.45	29.58	14.51	44%	43%	44%	43%	44%	43%

¹³ Complexity-weighted AND Efficiency-upscaled Maximums (or the mean of the average of Differences). Smaller values are always better.

¹⁴ Grand-averaged version of complexity-weighted AND Efficiency-upscaled Maximums (or the mean of the average of Differences). Smaller values are always better.

Table 12: FINAL PANORAMA – with the bottom 5 rows drawn from Bozkurt and Yarman et al. [2009] – where the mean of M_c , GWM and the mean of CEM, GEM are averaged to yield *final average of maximums*, while the mean of D_c , GWD and the mean of CED, GED are averaged to yield *final average of mean differences*. Likewise to the procedure explained in the caption to Table 11, percentages are found according to the formula (*smallest value in column two or four*) / (*current value in column two or four*). This panorama highlights 7 tunings above the rest with 79 MOS 159-tET (peak-matching version) staying in the lead once more. Best values are highlighted and in bold, while worst values are striped in red. Smaller values corresponding to greater percentages are always better.

FINAL PANORAMA	Final Average of maximums		Final Average of mean diff.	
79 tone-formal (79 per 159 tET)	31.7	35%	13.5	42%
79 tone-matching (nr.1)	11.2	100%	5.8	98%
Yarman-24a (nr.7)	18	62%	7.2	79%
Yarman-24b	19.5	58%	7.5	76%
Yarman24/31c	20.8	54%	7.5	75%
Yarman24/31d	20.9	54%	7.8	73%
Yarman24/42e	15.5	72%	7.8	72%
Yarman36a-formal	23.9	47%	12.4	46%
Yarman36a-matching	23	49%	9.7	58%
Yektay65-formal (in 65 tET)	27.6	41%	11	51%
65 tET-matching (nr.3)	12.2	92%	5.8	97%
60 tET-matching (nr.4)	12.3	91%	6.2	91%
72 tET-matching (nr.2)	11.8	95%	5.7	100%
41 tET-matching	15.6	72%	7.5	75%
34 tET-matching (nr.5)	15.6	72%	7.3	77%
29 tET-matching (nr.6)	16.9	67%	8	70%
YAEU (24 per 53-tET)	24.5	46%	9.1	62%
Mus2 (53 tET-formal)	23.3	48%	10.1	56%
Töre-Karadeniz (41 per 106 tET)	30.5	37%	12	47%
Old Yarman-24a	19.6	57%	7.4	77%
Yavuzoğlu-48 (in 48 tET)	28.9	39%	14.2	40%

Cemil Bey 1925. *Rehber-i Musiki*. Transl.: H. Cevher, Ege Üniversitesi Basımevi (1993), Izmir.

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LINK: www.ozanyarman.com/files/searchfortheoptimaltonesystem.zip.

(Relevant MS Excel files; featuring two prepared with some essential help from Uğur Keçecioglu and Anthony Precht that greatly facilitated tedious calculations in this manuscript, and which can be freely used for any future study on assessing matches between tunings and histogram peaks.)

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CURRICULUM VITAE

Ozan Yarman is a Pianist-Composer-Music Theorist born in 1978 in İstanbul. He began his Piano education in Kadıköy Municipality Conservatory. Gained entrance to and studied Piano for one year in Moscow Gnessin Conservatory in 1992. Became a student of Ergican Saydam after succeeding in the entrance exam of Mimar Sinan Conservatory in 1993. Was accepted under special provisions to Brussels Royal Conservatory in 1994 and continued his Piano education as a student of Eugene Moguilevsky and Olga Roumshevitch. Graduated from this institution with the degree of “First Prize” in 1997. Entered the Postgraduate Composition Principal Art Department of İstanbul University State Conservatory in 1998. Acquired the degree of Master of Arts in 2001 with his thesis titled “Turkish Music and Polyphony”. Was accepted to the Doctorate Programme of Musicology Principal Science Division in İstanbul Technical University Turkish Music State Conservatory in 2002. Received his Ph.D. degree in Musicology with the unanimous decision of the jury for his dissertation “79-tone Tuning & Theory for Turkish Maqam Music” in 2008. Since early 2000, he fortified his Classical/Contemporary Western music background with research into microtonal music and makam theory, insofar as inclining towards producing some unorthodox Turkish and Turko-Western works. He additionally plays Qanun, bowed Tanbur and Ney as an amateur. He is a faculty member of İstanbul University State Conservatory – his childhood institution at Kadikoy – as a full professor under its Musicology Department since 2017.