THE RATIO BOOK

Proceedings of *The Ratio Symposium*
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EDITED BY
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THE RATIO BOOK
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Dedicated

to the memory of

Barbara Thornton (1950–1998)

and

Habib Touma (1934–1998)

Preface

This book is a documentation of *The Ratio Symposium*, organised by the Institute of Sonology at the Royal Conservatory The Hague and held there from 14 – 16 December 1992. The Symposium formed the first part of a project which was followed up and concluded by *The Ratio Festival*, held at the Conservatory from 3 – 8 April 1993. For more information on the project as a whole, see the brochure cover reproduced on page 71; the programme of the 1993 Festival is given in the appendix on page 321. The lectures held at the Symposium were videotaped, transcribed and sent to the authors for correction. The alterations in the returned texts ranged from slight additions and/or deletions to – in a few cases – completely rewritten papers: I would like to express my indebtedness to the fifteen other authors besides myself for the hard work involved in this and for their patience in (sometimes repeatedly) reviewing my edited results until total satisfaction was reached. My gratitude is also extended to Marijke Reuvers of the Royal Conservatory for her indefatigable assistance in organising the Ratio Project and for picking up the pieces afterwards. Also to be thanked are my colleagues of the Technical Department of the Conservatory for their permanent readiness to give help whenever it was required.

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On the Quantification of Harmony and Metre

1. On Metre

[Tape example]

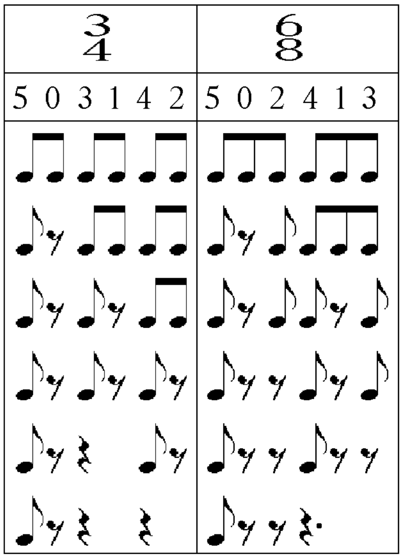
This piece is called “Otodeblu”. It was played on a Roboard, a pianola driven by a computer. It was composed in 1990 using my programme Autobusk here on this Atari computer; it runs on various parameters such as tonality (making the music more – or less tonal, as the case may be), metricity and such like. Let me give you an example of how the programme works; then I’ll explain why I needed a programme to compose the piece.

When I start the programme, you will hear some random music which is produced as a result of probability tables; let’s just start it and listen [starts computer programme]. The music is set to a very clear key and to a very clear metre. Let me now very slowly take down both the metricity and the tonality [operates programme].... Ok, we’ve finally reached a stage where there is no feeling of key or metre any more. There is of course a pulse feeling, but it isn’t graduated any more into the form of a really clear metre – where you could tell where the “one” would be.

Why does one need this? Suppose you want to write a music which is (as I’ve done here) very variable in both its key and its metre feeling. You need to know how to move to intermediate stages. What for example would be an adequate definition of metric music as opposed to non-metric music? For this I chose a very simple algorithm or definition: In the case of ametric music, all the pulses are equally probable.

So no matter what metre you have, suppose six or eight beats in the bar or whatever, they will in this case all have the same probability. Which means the bar doesn’t make any more metric sense. But if you want to make the music more and more metric, you have to then decide how probable or how important the individual pulses ought to be. This assumes there might be a correlation between their importance and their probability.

1 – Two metres compared



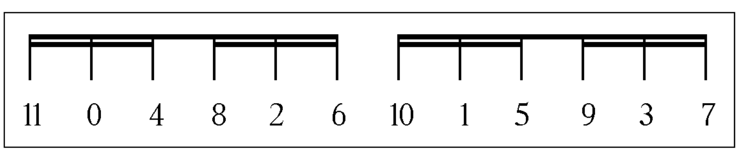
1 shows an example of two metres, $^3/4$ and $^6/8$. If we look at these rhythms you'll find them getting gradually thinner: in each case I've taken away one attack at a time. And I think you'll agree with me that the right column goes much more clearly together with a $^6/8$ feeling, and the left with a $^3/4$ feeling. This is reflected in a series of numbers at the top – [5,0,3,1,4,2] and [5,0,2,4,1,3], an ordering of the individual pulses according to their importance. I call this the *Indispensability of Attack*. The formula for it is somewhat threatening – this is only its main part (see **2**)[1] – but you can programme it into a computer and then forget it. According to this system, any metre can be expressed in terms of the relevance of its pulses.

2 – Indispensability formula

$$\psi_z(n) = \sum_{r=0}^{z} \left\{ \prod_{i=0}^{z-r-1} q_i \, \Psi_{q_{z-r}} \left(1 + \left[1 + \frac{(n-2) \bmod \prod_{j=1}^{z} q_j}{\prod_{k=0}^{r} q_{z+1-k}} \right] \bmod q_{z-r} \right) \right\}$$

Let me give you one more example. Take a $^{12}/16$ measure (see **3**): this system numbers the indispensability from 11 down to 0 in the given order.

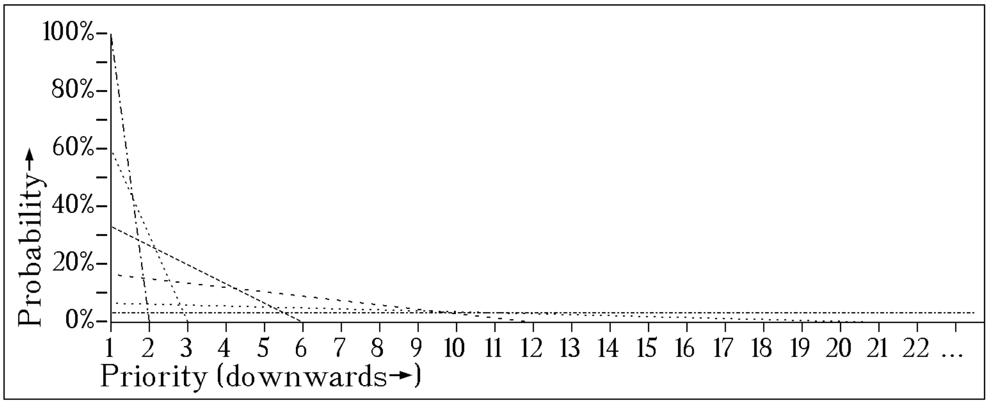
3 – $^{12}/16$ indispensabilities



2. On Priority and Probability

What do I do with these priorities? I set up a correlation between priority on the X-axis and probability on the Y-axis, as in **4**. In the case of an ametric music all pulses are equally probable, irrespective of priority – see the horizontal line. But the more metric the music gets, the steeper the line. This means that in this case the higher the priority (here 1 is higher than 2), the higher the probability. This very simple relation allows one to compose a music that can vary smoothly from metric to ametric.

4 – Probability as a function of Priority



Now I must say at this point that I am most decidedly not a musicologist, but a composer in search of techniques to realise certain pieces. Of course, the discoveries I make, the techniques I develop are very often close to things that seem to have some musicological significance. But I leave that to you. What I say here concerns finding a tool for making a piece of music.

The same correlation of priority and probability goes for the pitch domain. Using a pitch set (this could be e.g. a major or a chromatic scale), I allot to each pitch a certain unique priority, no two pitches the same way. And if the music is to be tonal, pitches of higher priority become more probable and thus more frequent.

There is also a correlation between the pitch and pulse domains (see **5**). Where the pulse is important, more indispensable, tonality rises, going down on the weaker pulses. This is because you can effect smooth motion in a music by passing notes on weak beats and structural notes (Schenker's term) on strong beats.

5 - Pitch-Pulse matrix for a Major Scale and a $^6/8$ Metre

MAJOR SCALE	Pitch:	SIX-EIGHT METRE					
		Pulse: 1	2	3	4	5	6
		Priority: 1	6	4	2	5	3
C'	2	30.4	12.5	12.6	15.3	12.5	13.1
B	7	0.0	12.5	12.4	9.7	12.5	11.9
A	6	0.0	12.5	12.4	10.8	12.5	12.1
G	3	19.6	12.5	12.6	14.2	12.5	12.9
F	8	0.0	12.5	12.3	8.5	12.4	11.7
E	5	0.0	12.5	12.5	11.9	12.5	12.4
D	4	8.8	12.5	12.5	13.1	12.5	12.6
C	1	41.2	12.5	12.7	16.5	12.6	13.3

So I raise the degree of tonality (reflected by the angle of the line in **4**) and decrease it wherever the pulse is weaker. Where do I get my pitch priorities? Now that's a different kettle of fish......

3. On Harmonicity

For several centuries people have been saying that musical intervals are of greater and lesser consonance. Another word used for that is *Harmonicity*. The word "consonance" I reserve for a totally different phenomenon: in the piano's middle range, a major second sounds generally more consonant than a minor second. But taking the same two intervals down to the bottom octave, you'll find the minor second the less dissonant of the two. Compare the perfect fourth and the tritone in the middle, then in the bottom range – the dissonance/consonance behaviour is reversed.

The sonic roughness caused by hairs on the basilar membrane and by other physiological matters is a phenomenon I call "consonance and dissonance", corresponding to general usage. It has to do with timbre and the basilar membrane, which I think Jim Tenney and Stan Tempelaars will tell us a lot more about, so I won't go into it any further. For me, "harmonicity" is the phenomenon which establishes whether intervals are more stable, like the octave and fifth, or less, like the tritone, which I call less harmonic.

It would seem logical to me that a music which is atonal uses all intervals equally probably or frequently. But if the music gets increasingly tonal, then more harmonic intervals, like octave and fifth, gain in probability against those of lesser harmonicity. The question now is: What is more and what is less harmonic?

Pythagoras was one of the first to say that the two numbers of an interval ratio are an indication of the (as I say) "harmonicity": the smaller the numbers, he said, the more harmonic the interval and vice versa. Hindemith, Schoenberg, Partch were to say the same thing several centuries later. But the concept of size alone is problematic – the intervals 1:2 (octave), 2:3 (fifth), 3:4 (fourth) etc. – are all nice and harmonic, and that's what we also learn at school. Going up to 5:6 that's fine, but the next interval 6:7 is generally not used in music of the West (or, by the way, of India). Nor is 7:8. But 8:9 is the well-known major tone, followed by the minor tone 9:10; another gap then ensues containing 10:11, 11:12, 12:13, 13:14, 14:15, none of which you'd normally find in classical music. 15:16, which comes after, is our minor second. One can see that all intervals in those gaps – 6:7, 7:8, 10:11, 11:12, 12:13, 13:14 and 14:15 – contain prime numbers larger than 5, the primes 7, 11 and 13 in this case. Thus the primeness of the factors plays a role as well: harmonic intervals are formed not only by <u>small</u> numbers but also by <u>divisible</u> numbers. Both are essential – smallness <u>and</u> divisibility.

In 1978 I came up with what I called the *Indigestibility of Numbers*, a concept combining smallness and divisibility. If a number is large but divisible, it is "digestible". **6** shows the formula: the integer "N" is the product of powers "n" of primes "p"; put "n" and "p" into this formula and you get the indigestibility value expressed by the Greek letter "ξ".

6 – Indigestibility formula

$$\xi(N) = 2\sum_{r=1}^{\infty}\left\{\frac{n_r(p_r-1)^2}{p_r}\right\}$$

Examples of this for 1-16 are to be found on the opposite page in **7**: the primes 7, 11 and 13 are very indigestible, their corresponding values (with that of 14) being the only ones over 10. The value 10 seems to be a kind of general cultural indigestibility barrier, since only less indigestible numbers are commonly used in classical music ratios. Note the power 2 in the formula; raising this makes higher primes much more indigestible, so this power is a key to the rate at which the indigestibility increases with the primes. I call it the "prime enmity factor", because the lower it is, the friendlier, i.e. more digestible each prime gets.

7 – Indigestibilities 1–16

N	ξ (N)
1	0. 0000000
2	1. 0000000
3	2. 6666667
4	2. 0000000
5	6. 4000000
6	3. 6666667
7	10. 2857143
8	3. 0000000
9	5. 3333333
10	7. 4000000
11	18. 1818182
12	4. 6666667
13	22. 1538462
14	11. 2857143
15	9. 0666667
16	4. 0000000

Using the above I now arrive at a formula for harmonicity (**8**) by adding the indigestibility values and inverting the sum.

8 – Harmonicity formula for an interval P:Q

$$H(P,Q) = \frac{\mathrm{sgn}\big(\xi(Q)-\xi(P)\big)}{\xi(P)+\xi(Q)}$$

The numerator tells you the direction of the interval's polarisation. For example, you might agree with me that the perfect fourth pulls upwards, that its upper note is the root. This is a matter of feeling; whether we agree or not is another matter. I here assume that e.g. the perfect fourth and the minor sixth have an upwards pull and that the fifth and the octave have a downwards one – the "sgn" sets a plus/minus sign for the polarity.

Here in **9** is a set of intervals in one octave, going from 0 to 1200 cents (100 cents form one semitone). Given its ratio, each interval's harmonicity is derivable according to the formula ; for example the perfect fifth 2:3 has a harmonicity of 0.2727, the perfect fourth 3:4 has a value of -0.2143 (upwards polarised) and so on. And so you can see that for various intervals you have varying degrees of harmonicity. All this is part of a composer's technique; you can get various harmonicity values which do seem to correspond pretty well to at least my feeling and to that of some colleagues of mine.

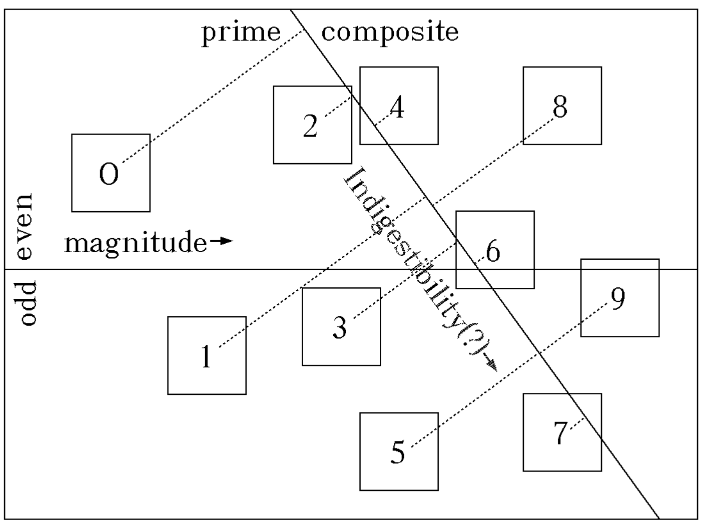
9 – Some Harmonicities

Cents	Ratio	Harmonicity
0. 000	1: 1	∞
111. 731	15: 16	–0. 076531
182. 404	9: 10	0. 078534
203. 910	8: 9	0. 120000
231. 174	7: 8	–0. 075269
266. 871	6: 7	0. 071672
294. 135	27: 32	–0. 076923
315. 641	5: 6	–0. 099338
386. 314	4: 5	0. 119048
407. 820	64: 81	0. 060000
435. 084	7: 9	–0. 064024
498. 045	3: 4	–0. 214286
519. 551	20: 27	–0. 060976
701. 955	2: 3	0. 272727
764. 916	9: 14	0. 060172
813. 686	5: 8	–0. 106383
884. 359	3: 5	0. 110294
905. 865	16: 27	0. 083333
933. 129	7: 12	–0. 066879
968. 826	4: 7	0. 081395
996. 090	9: 16	–0. 107143
1017. 596	5: 9	–0. 085227
1088. 269	8: 15	0. 082873
1200. 000	1: 2	1. 000000

Indigestibility is also to be found in interesting places. I asked friends of mine in a restaurant (which is a very nice place to ask friends) "if you had a round cake or a pizza, or something like that, to be cut into equal segments, what would be the easiest number of pieces to cut it into?" And they all said 2. And I said, well forget 2, now you have 3 to 10: what's your choice? And they all said 4. In this way the number order turned out to be: 2, 4, then 8, 3 and 6 lumped together (there was some dispute about their order). Then came 9 and 5 (some dispute here again), followed last of all by 7. Look at the indigestibility values: you'll find a very similar rating.

Another case was a Stanford University experiment of 1975, in which people subjectively evaluated similarities of the digits 0 to 9. They found that if a computer placed these digits on a sheet of paper, such that their distance would match the similarity ratings (a technique called multi-dimensional scaling), the digits increased in magnitude from left to right – see [10].. Now, the computer didn't know these were numbers, just took them as symbols!

[10 – Numerical Similarity Scaling (Stanford 1975)

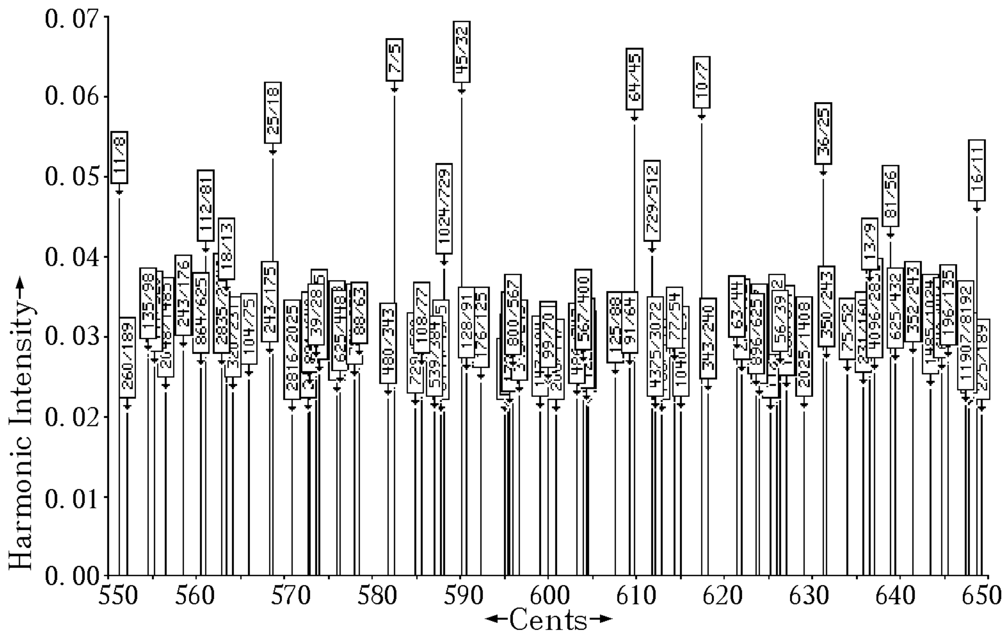


Note also that the even numbers are separated from the odd by a horizontal line. Another *slanting* line separates prime numbers from composites, a line I found to be practically my indigestibility axis: by plotting perpendiculars to that, I found it comes pretty close to the indigestibility formula – another case where I was gratified to find a parallel in nature. Well let's call it nature!

Using the harmonicity formula I then proceeded to rationalise scales. It's all very well to say, the more harmonic the interval the more probable it should be in a music, but how do I know that the perfect fifth (shall we say) is a harmonic interval? By listening to it maybe. I could evaluate each interval by listening. But there are cases where I wouldn't be very sure, for example in the case of micro-intervals. The piece we heard, "Otodeblu", had 17-tone tuning, with lots of intervals I'd never known before, never learnt about in school. How would I know their ratios? Because if you talk about a perfect fifth, for instance, you're talking of a scale degree, not a ratio. How do I know the perfect fifth could be a 2:3? How could I know the ratio for a neutral third of 350 cents?

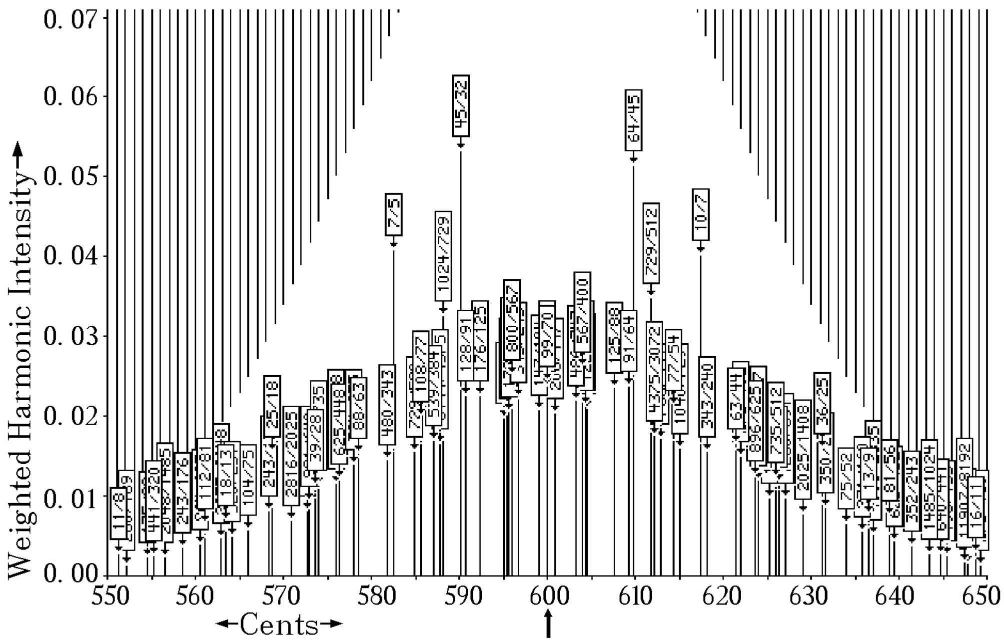
Some systematic method of rationalisation would have to be developed: I decided to go about it as follows. Let's look for instance at the region around the tritone, 600 cents (**11a**) within a range of plus or minus one quarter tone. I collect a large number of intervals in this range and plot them according to their pitch and their harmonicity. Here, for example, is a 45/32, a 64/45, a 10/7, a 7/5 and a whole lot of others very densely packed together[2]. Which one of these several ratios could be a given tritone?

11a – A list of several intervals between 550 and 650 cents



The procedure I used was to put a Gaussian bell-shape over the place that I want to tune, to rationally understand (see **11b**. – the bell-top is clipped). Now only a few candidates are left, those further away being pushed out of existence. The width of this bell is variable, depending on your own intervallic tolerance.

11b – The same intervals, harmonically weighted in favour of 600 cents

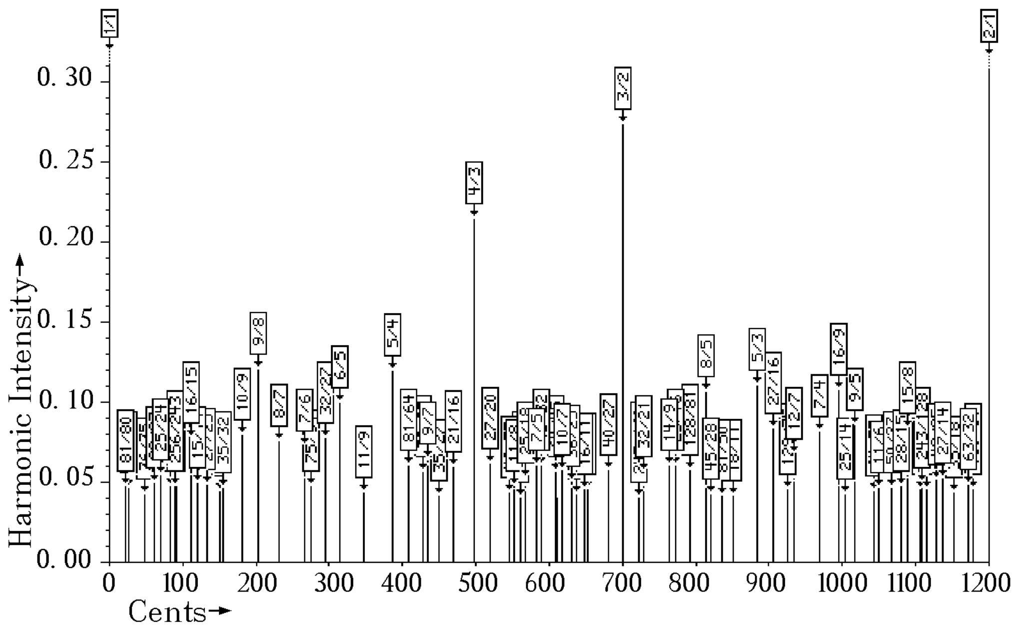


What do I do with these, shall we say two or three best candidates?

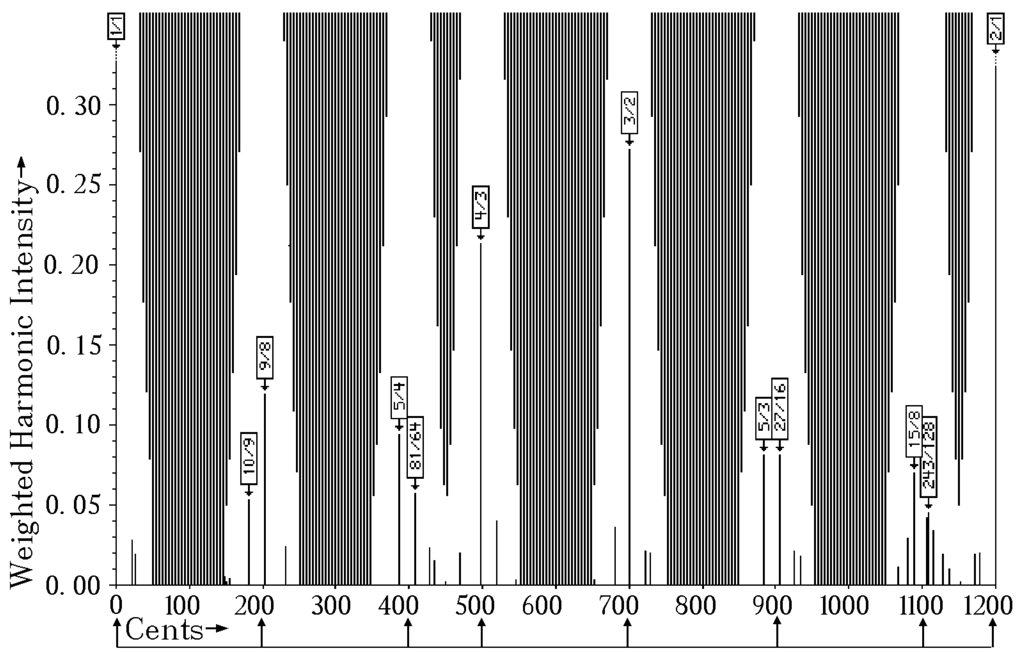
Let's repeat this for the major scale in **12a**.: here is an octave, with the perfect fifth 3/2 standing very high there in the middle, the perfect fourth 4/3 further left. Plus-minus signs are ignored.

We place bells over the places to be understood (see **12b**). In each tent-like enclosure, we see some candidates left over. Taking the two or three best candidates, we tune the whole scale by using candidate 1 of degree 1, candidate 1 of degree 2 and so on. Then candidate 2 of degree 1 against candidate 1 of degree 2 and so on. For every possible combination of a candidate per scale degree, we add all the intra-intervallic harmonicities – the sum indicates how harmonic the general tuning is. And as a matter of fact the result comes out very nicely.

⟦12a – A list of 77 intervals in an octave



⟦12b – Ditto, weighted for a tempered major scale (bell-tops clipped)



Doing this to a twelve-tone chromatic scale, the rationalised set

1:1, 15:16, 8:9, 5:6, 4:5, 3:4, 32:45, 2:3, 5:8, 3:5, 9:16, 8:15, 1:2.

is produced, which according to theory books, is the classical tuning of the harmonic chromatic scale.

Doing the same for a 13-tone tuning (0, 92, 185 cents etc.) we get

1:1, 128:135, 8:9, 6:7, 4:5, 16:21, 35:48, 56:81, 160:243, 5:8, 7:12, 5:9, 128:243, 1:2,

intervals we actually know quite well.

Finally, a 17-tone tuning (0, 71, 141 cents etc.) yields

1:1, 24:25, 25:27, 8:9, 27:32, 9:11, 25:32, 3:4, 18:25, 25:36,
2:3, 16:25, 11:18, 16:27, 9:16, 27:50, 25:48, 1:2

I've tried this on Indian and Arabian scales with plausible results.

J.Tenney: Clarence, how wide is your tolerance?

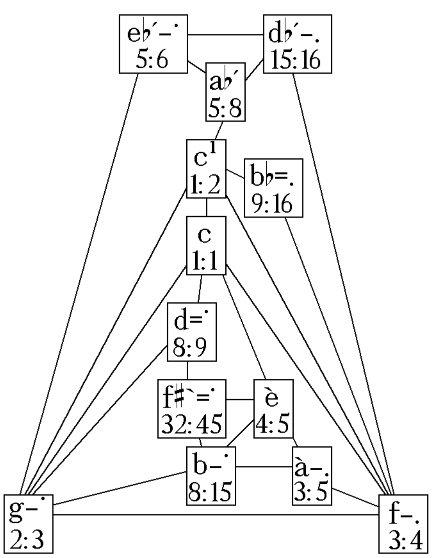
C.Barlow: Here 30 cents nominal tolerance – the place at which the Gaussian Bell arbitrarily reaches one 20th of its maximum. I usually use about half the smallest interval.

J.Tenney: So what is the cents value for which you arrived at 6:7?

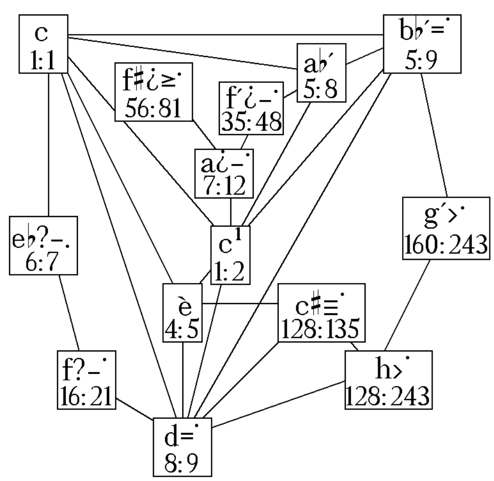
C.Barlow: 277 cents as input; the output is 10 cents lower.

J.Tenney: So you've filtered out 5:6 by your Gaussian.

13a – Rational 12-equal (h >0.115)



13b – Rational 13-equal (h >0.072):

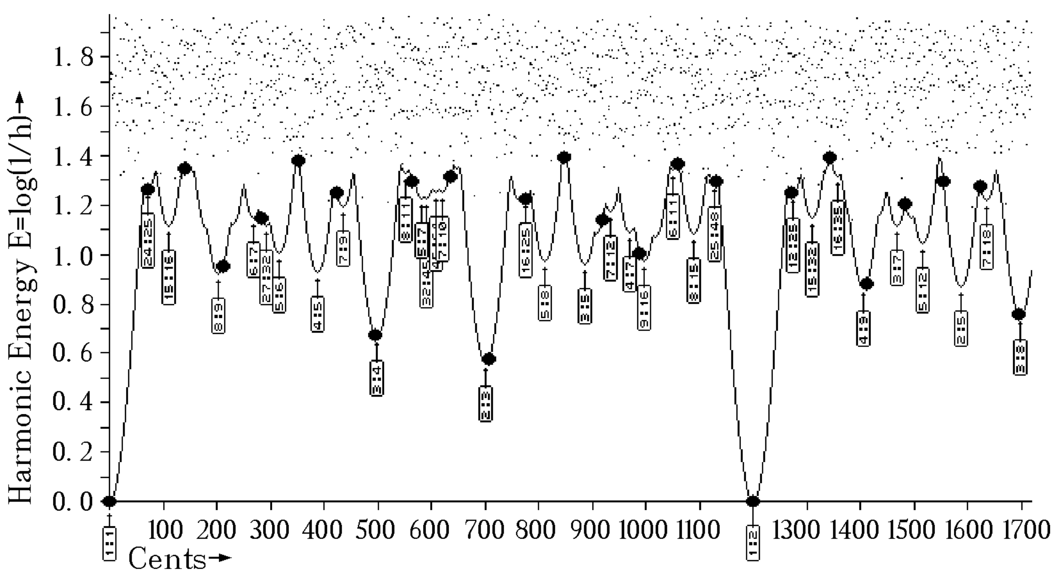


C.Barlow: Exactly – it all depends on your tolerance! The result here deviates from the input by less than 17 cents. 13a is a diagram showing the network for a twelve-tone tempered system of all intervals more harmonic than 0.115. You find the tonic [C] in the middle linked with [D] and [G] but not with [F♯]. But [F♯-B], [B-G], [B-A], [F-D♭], [D♭-E♭] are all linked. Below the note-names are the ratios of these intervals.

In 13b, the same is done for the thirteen-tone tempered system. I've given them names like these, derived from whether they're tertian or septimal intervals (based on the primes 5 or 7), but the ratios might mean more to you.

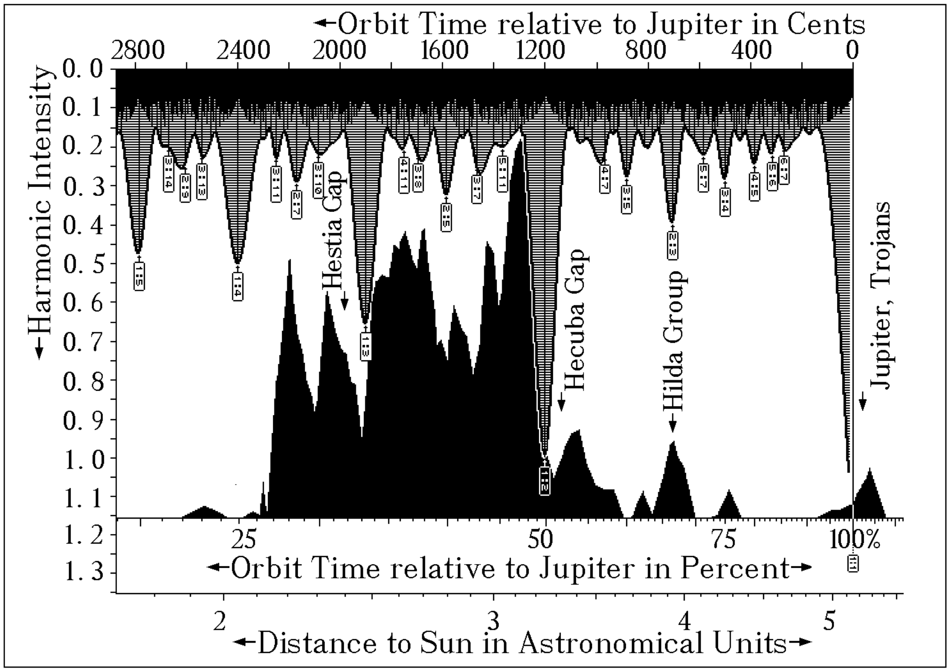
14 shows work of my friend and former student Georg Hajdu, now in Berkeley, California[3]. Based on my harmonicity formula, it concerns what he calls the "energy of a pitch space". You see downward bulges or dips at the more harmonic intervals. To rationalise a 17-tone tempered scale, he puts 17 equidistant balls into an octave of this pitch space and sees where they appear. In many cases they're on the flank of a dip. In such cases, he says, there is a strong pull on the ball causing a rationalisation of the scale degree into the dip. His method plots an energy curve and finds where the balls want to fall in. It's interesting to compare this rationalisation method to my own, candidate-based one.

14 – A 17-equal scale against a map of Harmonic Energy (after Hajdu)



Talking about curves and balls falling into things... Here's something completely different: a map of density of the asteroid belt between Mars and Jupiter (**15**)...

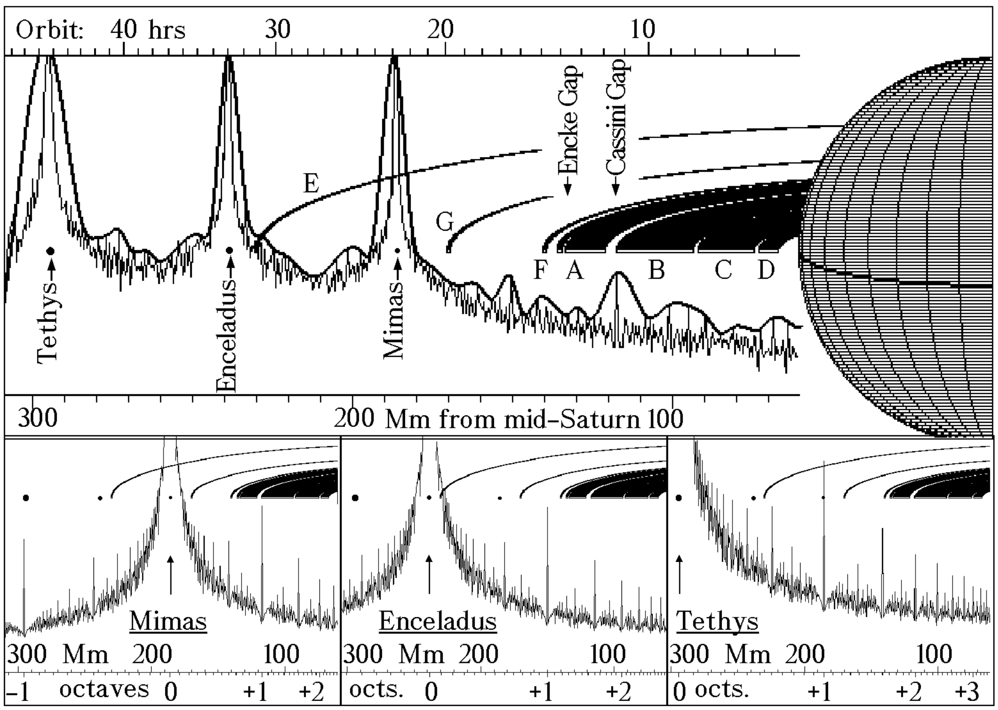
15 – Relative Density of Asteroid Belt vs. Harmonicity (Prime Enmity 1.2)



There are practically no asteroids around Mars, which is way over on the left outside the diagram. And on the right at Jupiter you have the Trojans, occuping the same orbit. The gaps you can see are caused, according to astronomers, by the "commensurability" (harmonic ratios) between the places in question and the planet Jupiter in relation to their orbiting time around the sun. The place marked 100% is at Jupiter's orbit. Look carefully at the 50% mark (1:2, a "distance octave" from Jupiter, so to speak) – you see a very deep cleft there called the Hecuba gap. Another one is at 33% (1:3). These gaps ought to and are indeed comparable to the harmonicity landscape running from left to right: the harmonicity increases practically everywhere there's a gap. These values are based here on a modified indigestibility formula which is prime friendlier: the power ("prime enmity factor") was experimentally lowered from 2 to 1.2, so it's the same formula, but with the power changed.

Here is an attempt to investigate the commensurability gaps in the rings of Saturn, based on harmonicities from the orbiting times of its satellites (16), of which the first three, Mimas, Enceladus and Tethys are individually shown in the lower half of the diagram; in all these curves, the harmonicity value is multiplied by the cube root of the mass and divided by the distance from a given satellite. The harmonicity curves generated by all three show peaks corresponding to the big Cassini gap between the A–and B–rings. The combined curves of the eight largest satellites is shown in the upper half.All this was done out of curiosity. And it matches rather nicely.

16 - Saturn rings A-G, harmonicity curves from satellites



So much about harmonicity. My measurement of intervallic harmonicity, the results of which I found very plausible, enabled me to compose a certain type of music: given a scale in cents, I was able to rationalise it and then to create fields of variable tonality by altering the probability of intervals according to their harmonicity. The question of scale has occupied me for a very long time. I'll make a couple more observations on this point in a minute. But now I'm going back to metre for a while.

5. On Metric Affinity

I spoke earlier about the indispensability of various pulses, i.e. of how relatively important pulses were. In 1981 I tried for the first time to use this method to find a measure of the *Affinity* of two metres, of how similar they might be felt to be. Suppose I match two metres in such a way that their pulses lie one against one. And if they don't match, I subdivide the pulses suitably and sufficiently so that their finest subdivisions do. And then I measure the indispensability of each pulse.

Here I have a 2x2x3 pulse system and a 3x5 pulse system (17); the indispensability values [11,0,4,8,2,6,10...] of the 2x2x3 metre are matched against the [14,0,9,3,6,12...] of the 3x5 metre.

17 – Pulse Indispensabilities for 2x2x3 against those of 3x5

Current Pulse:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2x2x3 Pulses:	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Indispensability:	*11*	*0*	*4*	*8*	*2*	*6*	*10*	*1*	*5*	*9*	*3*	*7*	*11*	*0*	*4*	*8*	*2*	*6*	*10*	*1*
3x5 Pulses:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	1	2	3	4	5
Indispensability:	*14*	*0*	*9*	*3*	*6*	*12*	*1*	*10*	*4*	*7*	*13*	*2*	*11*	*6*	*8*	*14*	*0*	*9*	*3*	*6*
Current Pulse:	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
2x2x3 Pulses:	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
Indispensability:	*5*	*9*	*3*	*7*	*11*	*0*	*4*	*8*	*2*	*6*	*10*	*1*	*5*	*9*	*3*	*7*	*11*	*0*	*4*	*8*
3x5 Pulses:	6	7	8	9	10	11	12	13	14	15	1	2	3	4	5	6	7	8	9	10
Indispensability:	*12*	*1*	*10*	*4*	*7*	*13*	*2*	*11*	*5*	*8*	*14*	*0*	*9*	*3*	*6*	*12*	*1*	*10*	*4*	*7*
Current Pulse:	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
2x2x3 Pulses:	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Indispensability:	*2*	*6*	*10*	*1*	*5*	*9*	*3*	*7*	*11*	*0*	*4*	*8*	*2*	*6*	*10*	*1*	*5*	*9*	*3*	*7*
3x5 Pulses:	11	12	13	14	15	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Indispensability:	*13*	*2*	*11*	*5*	*8*	*14*	*0*	*9*	*3*	*6*	*12*	*1*	*10*	*4*	*7*	*13*	*2*	*11*	*5*	*8*

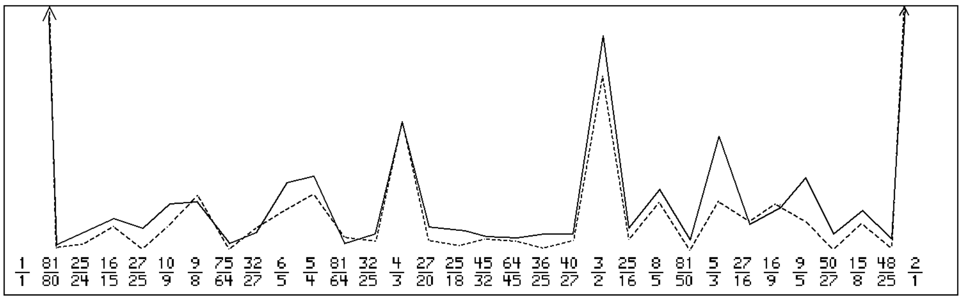
18 – Metric Affinity formula[1]

$$M = -\frac{1}{2\log_e\left(\dfrac{18\sum_{n=1}^{\Omega_o}\left[\prod_{i=1}^{2}\left\{\psi_{z_i}\left(1+(n-1) \bmod \Omega_{z_i}\right)\right\}\right]^2-2}{7\,\Omega_o\prod_{i=1}^{2}(\Omega_{z_i}-1)^2}\right)}$$

Multiplying the corresponding indispensabilities of the two metres, squaring the products and adding the squares, I arrived at a formula (**18**) for the metric affinity and found different affinity values for various pairs of metres.

I then took simple ratios like 1:2, 2:3 as if they were polymetres. For 2:3, imagine one bar with two pulses and one equally long in time with three, and measure their metric affinity. The joined line in **19** is the metric affinity curve, compared to the dotted line, the harmonicity curve for the ratios. I was flabbergasted to find two totally different methods yielding results so unexpectedly similar.

19 – Metric Affinity (joined line) vs Harmonicity (dotted) for simple ratios



6. On Ragas

I'll go back now to 1967, when I lived in Calcutta and began to learn about Indian music, about which I'd known nothing before except some names of instruments, like sitars, but which I'd not listened to consciously. My family was anxious to preserve its feeling of Angloid identity, and it really wasn't the done thing to listen to such music. The day I brought my first sitar, the hue and cry there was in the family! And the first time I wore Indian clothes! But I managed to get my parents and other relatives used to it – little by little.

I was nineteen when I began to actively listen to Indian music; and I discovered that there was quite a lot about it that I could learn quickly through my knowledge of European music. So I began to study the structure of various scales and ragas[4].

Soon after – this is already about twenty years ago – I combined standard Indian tetrachords to form a table of modes shown in **20** in Indian notation *Sa Re Ga Ma Pa Dha Ni Sa* (meaning exactly Do Re Mi Fa Sol La Ti Do) in abbreviated form: here the small letters "..rgm.." mean minor intervals plus perfect fourth, the capitals "..RGM.." major intervals plus augmented fourth. I enjoyed inventing Pseudo-Grecian names for the tetrachord combinations, names like Phrylyrian, Miphryxian, Iophrynigian, or Dolian, Lylian and so on. You also find here all the church modes Dorian, Phrygian, Lydian etc. (the Mixolydian is here termed "Mixian"). But this was also a precise nomenclative handle; e.g. the syllables "-phry-di-" imply a minor second with an augmented fourth and a major seventh, combining Phrygian and Lydian.

D.Lekkas: It also means an eyebrow.

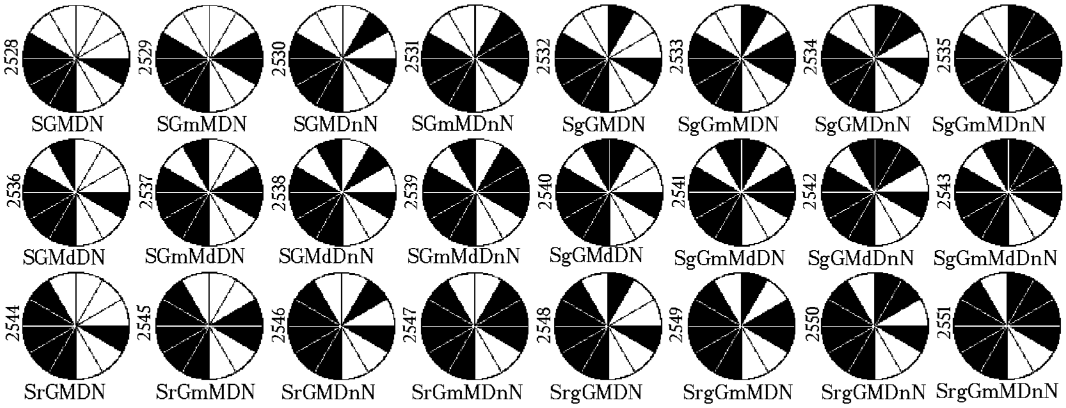
C.Barlow: Does it? Well one could raise that! ....

20 – The Barlopoulos Pseudogrecian Nomenclative System for the Forty-Eight Septagenous Heptatonic Scales[5]

	pdnS´	pdNS´	pDnS´	pDNS´	PdnS´	PdNS´	PDnS´	PDNS´
Sr gm	Locrian	Lonicrian	Locririan	Locrinian	Phrygian	Phrynigian	Phryrian	Phrynian
Sr gM	-------	-------	-------	-------	Phryligian	Phrylydigian	Phrylyrian	Phrylydian
SrGm	Milocrian	Iolonicrian	Milocrixian	Iolocrinian	Miphrygian	Iophrynigian	Miphryxian	Iophrynian
SrGM	-------	-------	-------	-------	Lyphrygian	Lyphrydigian	Lyphryxian	Lyphrydian
SRgm	Æocrian	Æonicrian	Docririan	Docrinian	Æolian	Æonilian	Dorian	Donian
SRgM	-------	-------	-------	-------	Æolylian	Æolydilian	Dolyrian	Dolydian
SRGm	Micrian	Ionicrian	Micrixian	Iocrinian	Milian	Ionilian	Mixian	Ionian
SRGM	-------	-------	-------	-------	Lylian	Lydilian	Lyxian	Lydian

Around the same time, I mapped possibilities of scale structures with a computer – see **21**. Each segmented circle here is a scale, the segments being not of a cake or a pizza, but adjacent notes in an enharmonic twelve-tone cycle[6] of fifths – filled segments mean notes present. Some scales have a whole bunch of adjacent notes; if there are e.g. five, they form a regular pentatonic scale, opposite to which there could also be one or two more adjacent notes. Suppose I take the five black piano keys and add a perfect fourth, say [A+D] to them as a drone: this is scale #2545 in the diagram; it confronts a tonic-subdominant drone with a foreign pentatonic scale. The harmonic potential can thus be predicted by looking at the diagram. And this kind of harmony is indeed used in ragas.

21 – Twenty-four scales depicted as 12-bit clockwise cycles-of-fifths: the tonic (coded as the most significant bit) is at 3-4 o'clock.



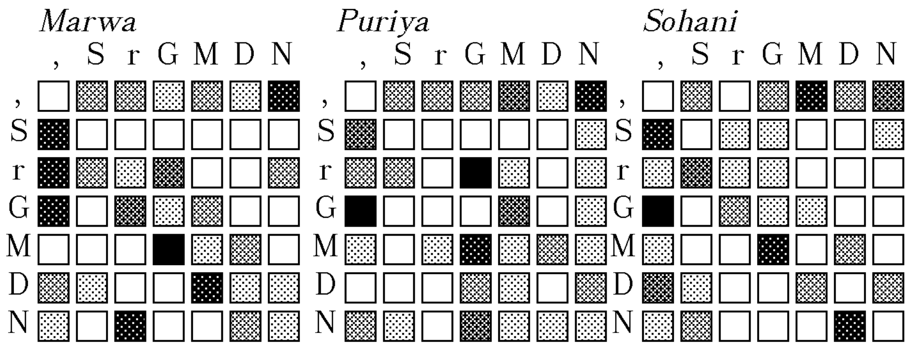
Two aspects of ragas fascinate me especially, which I've not found in any book. One I've just mentioned; the other's a set of "one-way streets". Here's a tape of ragas *Behag* and *Kedar* with three pieces each. Both ragas have the same notes (major scale plus augmented fourth); what differs is the typical melodic pattern, shown here on tonic [C] – *Behag*: C E F G B c B, (A) G F♯ G E F♮ E, (D) C
Kedar: C F, E G, F♯ A G c, A G F♯ A G F♮, D C

[Tape examples of musicians: Ragas *Behag* & *Kedar*]

This note-routing is one of the aspects that makes ragas special. One can draw diagrams of the probability that a note in a given raga will go to another note (a so-called Markov chain of order 2), as in **22** : three different ragas use the same scale (#2544). The diagrams show that the ragas are distinctly different.

22 – Statistical behaviour of three isoscalic ragas – density of shading indicates relative frequency of occurence

Scale #2544 [SrGMDN]



With this understanding I typed various raga patterns into the Cologne University main computer in 1976 and synthesized Markov chains, in other words new patterns in the same ragas. Then I played these syntheses to musicians in Calcutta. Now some ragas I believed would be recognizable only from Markov level 2 on – i.e. considering at least two-note patterns. But some would be already clear on level 1. And some, raga *Gaursarang* particularly, would need level 3. This suspicion was indeed completely borne out by my experiment. It's something I'll write about in detail some day.

Twenty years ago I started a catalogue of ragas by coding the presence or absence of a given note in the octave, a simple bit configuration. The presence of a *Sa* (the tonic) would yield 2048; you set the various bits for each scale degree as a member of an enharmonic cycle of twelve fifths, getting a binary code. I had this exercise book in which I used to, whenever I heard a raga new to me, enter it at its code number. There were of course lots of gaps, because not every combination is used. But there are some places where there were so many entries, I had to stick an extra page on. For example #4035 is the major scale with the added augmented fourth – there are no less than fifteen ragas listed here. It's one of the most popular scales in Indian music.

The one-way street system is the second aspect I mentioned. Let's go back to the first aspect, that of a raga's harmonic possibilities. A raga using the black keys added to [D] and [G] as drone would match #2297 in my catalogue ([SrGmMdN] – not shown in **[21]**) and could – and would – be played as raga *Lalit* by musicians.

[Tape example: Raga *Lalit*]

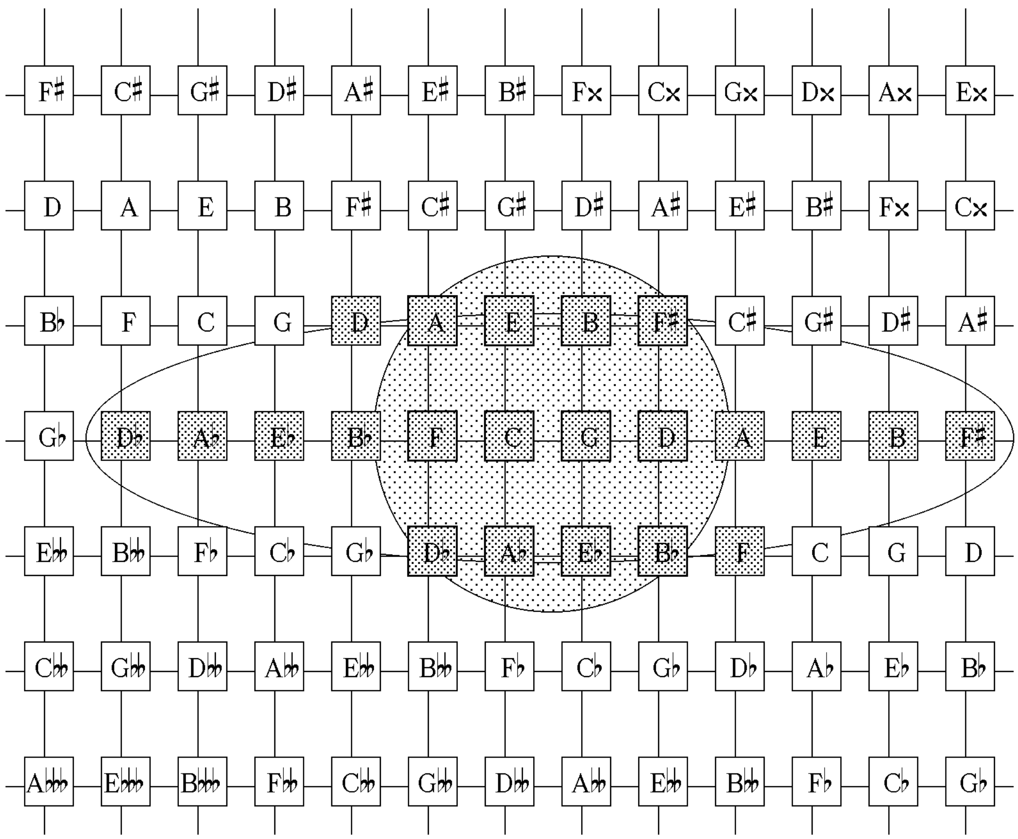
In fact if you take all combinations of five black keys placed on any perfect fifth, with either of the fifth's two notes as tonic (e.g. if you have [G] and [D], either could be the tonic), you would get 24 possible ragas. And this is borne out by practice.

7. On the Origin of Scales

Talking about scales always presumes you have a set of pitches to go by. But what makes these pitches arise? What if you want to devise a scale from a different set of prime factor ratios? If the prime number 7 is to help generate a scale, what do you do?

Take the familiar grid of fifths and thirds to be found in theory books (see **23**); those who use it know that the chromatic scale's twelve notes forms a kind of squat rectangle in the middle. The third being less harmonic than the fifth, I stretched the vertical axis to counterbalance this disadvantage[7]: now the chromatic scale is in a nice circle – which seems to make sense. The 22 srutis of Indian music are enclosed in an ellipse –they're in shaded boxes:

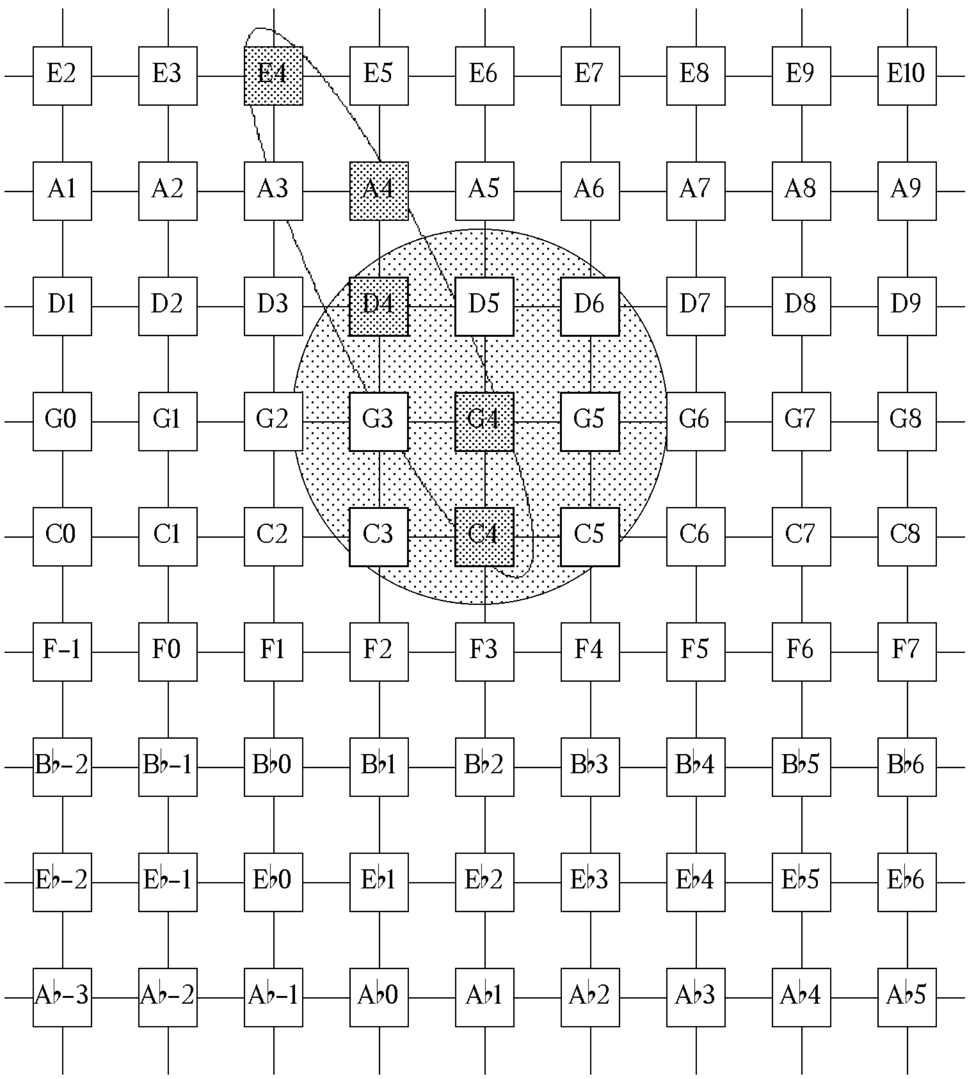
23 — Network of 2:3 fifths (horizontal) and 4:5 thirds (vertical)



Is this how scales are generated? If you throw an oil film on a pitch grid, stretched or not, and it forms a nice round shape, would this contain a prospective scale? I think not!...

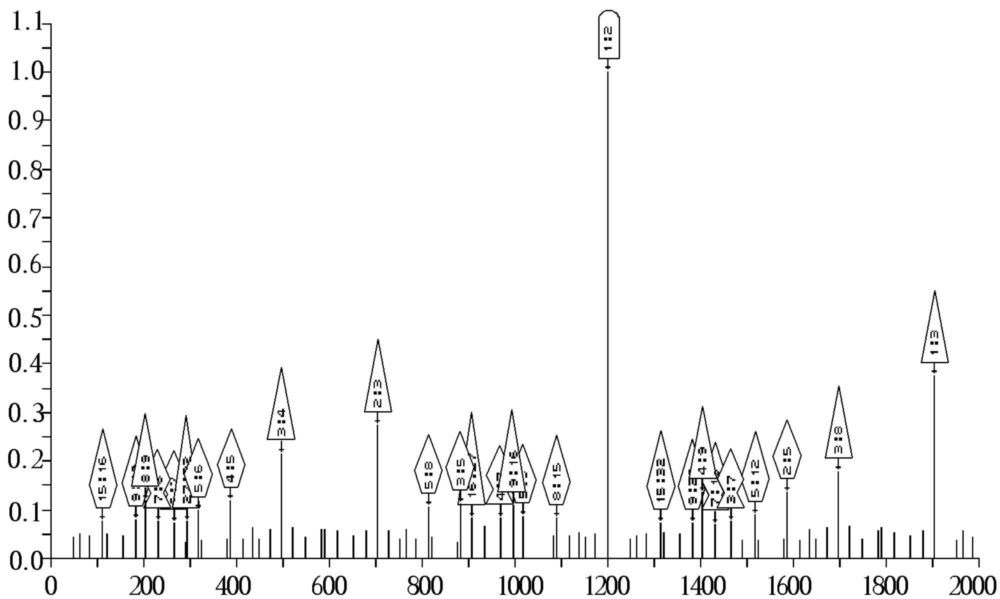
Look at the grid of octaves and fifths **in [24** – normally, the poor old octave is always discriminated against, always taken for granted. But it's an interval in its own right. A scale like the encircled one – [C3 G3 C4 D4 G4 C5 D5 G5 D6] – would hardly be useful. It would seem that the nearness of the notes will have to play a role as well and that this grid is nothing more than just a representation, a diagrammatic interval catalogue because as you see it doesn't yield a usable scale. The pentatonic scale, commonly supposed to consist of octaves and fifths, is enclosed by an implausibly longish cigar-like shape imaginable on the upper left, written in shaded boxes (interesting, though, all these ellipses!):

[24 — Network of 1:2 octaves (horizontal) and 2:3 fifths (vertical)



I'm beginning to move in the following direction (but haven't got far yet). Imagine, for example, a 3-limit system of harmonicity, (i.e. based on the prime numbers 2 and 3) and limit this to 2000 cents (nine intervals in triangular boxes in **25**), but of course you can go much beyond this. And cast a kind of filtering Gaussian curve somewhere in the centre of gravity of all the pitches you've got. That might yield a scale. In the diagram, all intervals more harmonic than an arbitrary threshold of 0.07 are shown as ratios; twelve 5-limit (primes upto 5 in pentagonal boxes) and five 7-limit intervals (in heptagonal boxes) are also shown. These intervals all commonly occur in scales of numerous world cultures. Raising the harmonicity threshold to 0.107 would cause sixteen of the intervals to be filtered out, leaving a pure Mixolydian scale.

25 – List of intervals≤2000 cents marked according to prime-limit



I could therefore imagine trying to develop scales out of prime number material – not by drawing circles or ellipses on a grid, but by setting a harmonicity threshold and selecting intervals of all possible configurations within a certain prime limit, for example 7. And by possibly drawing a Gaussian curve somewhere in there and seeing what gets filtered out. That might be a usable scale.

1 See *Computer Music Journal* Vol 11 № 1 (1987) for more detail.

2 In this text, a ratio notated with a slash (/) indicates the direction of the corresponding interval, e.g. 4/5 is a falling third, 5/4 a rising one. A colon (:) ignores the direction, as in 4:5.

3 Georg Hajdu now lives in Münster, Westphalia.

4 The word is pronounced "ra:g"; I used to write it "raag" to counteract common mispronunciation, but you can't always swim upstream!

5 The term "septagenous" pertains to seven classes of pitches (*sa*, *re*, *ga*, *ma*, *pa*, *dha*, *ni*), each – with the exception of *sa* – manifest in two forms, the lower *komal* (rgmpdn) and the higher *tivra* (RGMPDN). The complete range of pitch names S/rR/gG/mM/pP/dD/nN is exactly equivalent to theWestern nomenclature C/D♭D/E♭E/FF♯/G♭G/A♭A/B♭B (here arbitrarily C-based). Though it is theoretically known, *komal pa* ("G♭") is never referred to in practice, since it does not coexist with the preferred *tivra ma* ("F♯") in scales of Indian music.

6 These 4095 possible scale-circles (2048 of them containing a tonic) can be reduced to 351oscale-cycles in all, 66 of which are heptatonic – of which one is the cycle of seven church modes (Ionian, Dorian, Phrygian, Lydian, Mixolydian, Aeolian and Locrian).

7 The stretch is effected here by the factor $Z_\gamma(P)/Z_\gamma(Q)$, where P/Q represents the interval of the Y-axis,, $Z_\gamma(n) = 1 + \log(256)/\log(27)$ when n=2, else = $2(n-1)^\gamma/n + \log(n)/\log(2)$.. γ is the "prime enmity factor", set here at 1.2 for ⟦**23** (interval 5/3, stretch 1.422) and ⟦**24** (3/2, stretch 1.162).

Demetrios E. Lekkas

The Rationale of Ratios and the Greek Experience

I am here on behalf of Professor Amargianakis; he was very distressed that he couldn't make it. He was suddenly notified of an engagement on these very dates. So he regrets he cannot be here. He asked me to extend his greetings. He sent me in his place, asking me to come here to talk about Byzantine music.

That's not a subject which I have a very clear idea on yet. I didn't really know what I was to do, but then I didn't write anything – I came here, I looked at what everybody else was speaking about and thought “Oh yeah – we're fine!”; because my domain is really that of ratios and the mathematical theory of music. Actually I am in the process of completing a whole book on an organized mathematical way of looking at the theory of music.

Byzantine theory is in a state of chaos. I promised Mr Amargianakis that I would help settle things: look into Byzantine music again and try to come up with some answers. We'll talk about that later. He was very encouraging in telling me that whatever I was writing could be turned into a doctoral dissertation. So by chance, as I happened to study mathematics, I also accidentally happened to get into the University of Athens. So there we are now. A week ago Professor Amargianakis told me I had been a doctoral candidate officially since April. I hadn't been aware. That's the way things work in Greece sometimes. Anyhow, I was very happy to come here, because I have found a lot of people working along similar lines. When you think you're alone!

Well, this research into the domain of the mathematics of music began a long time ago, after I happened to go to a mathematics school. I was terrified because my parents had sent me to study physics, so scared that in the first semester I wanted to blindly run away; the first thing that was next door was mathematics. So I just went in there, and not until much later did I realize how lucky I had been to have studied mathematics: it helped me sort out several basic problems of music, until later, when that whole process got me into geometry – the back door again.

My methodology is purely mathematical. I have mentioned in the programme note something about Pythagoras noting ratios first. There is a dispute about that. I want to straighten the matter a bit. Pythagoras probably heard things regarding his theory in Egypt. Conceivably Mesopotamians knew beforehand. There is always an admiration that comes to us, saying Greece is the place where Western civilization as we know it was born. And again there is a dispute, which says: “What did Greece do? It was just a knowledge transferring station and nothing more than that”. The question has arisen in my mind and around me too many times, and I think that I have come to an answer which covers both sides.

Yes, most probably the greatest part of this old knowledge had been around before. And Pythagoras learned it in Egypt. And it went there from Mesopotamia, and India was in the game too. What came about in Greece for the first time was nothing other than direct democracy. Knowledge became available to whoever wanted it and whoever was capable for it. So it left closed circles, to become a generalized and available phenomenon. In order to accomplish that, Greece had to develop dialectics and theoretical science. Because you could no longer force upon somebody what you thought, you couldn′t indoctrinate them, you couldn′t mystify them into beliefs; you had to convince them.

That′s what the focal turning point was in the transition away from Asia towards Europe. And naturally this bridge theory about Greece being “between East and West, with one foot here and the other one there”, is not exactly accurate. Actually Greece is, figuratively speaking, the narrow point of an hourglass. Flux tends to happen in one direction, and not in the other.

What happened in the meantime, leading to the present state of Modern Greece? You know that after this direct democracy era, there came conquests by empires. After long imperial centuries there came representative democracies; nothing has been the same since. Modern Greece has been turned into a by-product of the West. Having lost the direction of our flux, and having a rather low profile as a European country besides, we do have serious problems in facing the new realities; yet we have always been a country of individuals. Some people, on their own, might still be continuing ancient ways which are not practised in the West.

I would now like to describe the mathematical method in brief. Mathematics, a typical and unique product of Greek thought, is a theoretical science which deals in abstraction and structure, by effecting analysis and synthesis. Now these are two related pairs of words; they do not exactly coincide, but, roughly speaking, they correspond to the way you think about something and what you do with it. I will try to explain these terms – maybe very briefly?....

Abstraction is a discipline whereby you try to isolate constituent features and to form categories. You look at different objects and you try to come up mentally with their common qualities, common identities and fit them into a category. So it leads to categorisation. But in order to attain that, you need to use analysis, because you have to isolate features, break things up. Moving further along, synthesis and structure are related, because the road taken goes back to look at the products of this isolation process, to finish by rebuilding them in new combinations. Of course there is a little bit of analysis in structure and synthesis in abstraction.

But the paramount feature of mathematics (and that's where it sharply contrasts with physics) is this: the supreme and only basic laws are the basic axioms of logic. And elementary logic is what we call "statement calculus". These axioms formulate ideas like self–identity, identity to entities other than the self, freedom from contradiction and the rules of derivation. Now these can be extended up through generalization and specification towards logics of different levels in nested layers. After statement calculus you have logic of order 1, of order 2 etc. like the shells of an onion.

This was not completely settled in people's minds until fairly recently. Objections, contradictions and paradoxes kept coming till Goedel, in 1936, showed the nestedness of generalizations and isolations of one case from a general situation. That is what literally saved mathematics as a science. Because with the paradoxes of Russell and Whitehead things had started going down the drain. Something very strong had to come. The pity about twentieth century thought is that it has tried to stifle and suffocate mathematics. One established way of attempting that is to group it with positive sciences in the same University Schools. You have physics, mathematics and chemistry taught together. And this makes no sense for a discipline as purely theoretical as that.

The result is that now mathematicians are stuck with the role of providing mathematical methods to physicists doing work in theoretical physics. And I think it will make very much sense to you to that is a violation of the very nature of things. Mathematics is a science of the mind. You may indeed start from a stimulus. You get your stimulus no matter how; it doesn´t matter. That fertilizes your brain. You forget about your stimulus and all it boils down to is an abstract principle in your mind. Then you may start trying to build a theory. And, if you want, you can even set axioms.

Now axioms are not an imposition of anything upon anything; instead, they are the quintescence of the guarantee of free will. No one is forced to accept them. People accept them if they want; if they don´t want them, they can drop them or change them. There is an additional fact about axioms, which makes them free–will tools: They apply to nothing, to nothing tangible that is. Nobody has anything to gain or profit by them, except maybe power.

Well, generally that doesn´t seem to be very threatening, so people usually get away with putting down whatever axioms they wish. Or, if they don´t want to set any axioms, they just start out from an already known set of axioms or a proven fundamental theorem. Making assumptions is the only thing ruled out.

But then you might ask, as we are always asked in this century (that question would never be asked in the nineteenth century): "How does this apply to the real world?" In the nineteenth century they knew that a mathematician was someone up in the clouds. Well it can apply in the following sense: If some thinking entity, which might be your brain, or somebody else´s, or of a group of people, takes your basis – the axioms or the theorems – and somehow comes to the belief that they are applicable to a real–world phenomenon, they will have to take up your already finished product, go from beginning to end, adopt your fully developed and proven theory – the complete structure – apply it and see what happens.

Following that, experience through the ages has shown the mathematical models to work just fine in the real world, although they were not made for the real world. For example, Pythagoras laid down the small numbers law, which is a predecessor of

Fourier's theorem. Of course Fourier's theorem is proved in a much fancier way. How did he come to that? He observed the sonic behaviour of good musicians of his time, free from any pre-conceived fixed ideas – or the Egyptians told him about it. In mathematics the real world comes in at the very last stage, if at all. And to do that is a task of applied science.

Summing up, what the science of mathematics does not do is start from the real world. That is the wrong direction. It does not try to reach a theoretical model from facts, driving its way towards principles. Of course this is the methodology of experimental and observational exact sciences, like physics, chemistry and astronomy and, to a lesser extent biological and behavioural sciences – like biology, psychology, sociology, economics. So mathematics just goes the opposite direction of all those.

In these cases, chances are that mathematicians have somewhere, sometime, put down an axiomatic theory that fits the case better than any model built by empirical or behavioural scientists themselves in the other direction.

Of course there are theoretical physics and chemistry. The difference between experimental and theoretical physics is related to mathematics. Experimental physics will recognize similarities to extant mathematical models from the symptoms – real world situations and how they agree with the finished product in mathematical theory. On the other hand, theoretical physics will tackle observations by attempting to construct mathematical models, formulating principles that resemble axioms and fundamental theorems of a mathematical theory.

The twentieth century, as I have said, has witnessed a retreating tendency in mathematics as regards new theories. That is a fact that, if applied to historical experience, will show that positive science is on the verge of collapse. What's funnier is that it is a self-inflicted collapse. Physics has tried to push mathamatics aside. Mathematicians don't produce any more new theories. Physicists have no new theories to work with. They make their own concoctions of older theorems, aiming at corrections of formulae, building their own way so to speak. Naturally that will lead theoretical science nowhere.

The general conclusion of this outlook is that there are two approaches: “theory precedes fact” versus “theory follows fact”. And mathematics is “theory precedes fact”. If anybody, during the question period, wants to know why, I´ll be happy to respond.

Departing from that, I shall now go into the field aspect of music, the real-world aspect of music. Let´s try to see how musicologists work; and show once again how the mathematical model would go the other way.

We have an auditory experience – we hear things. We decide what we like. We take into account cultural tendency and things like that. That is a mental process possibly not too well-defined. But, when ethnomusicologists go out to collect and formulate theories, they of course feel they have to be more exact in their methodology. What they do is: They take samples – they go round the country asking who is a musician, who is not? They record. They put sonometry to effect. They write down models, theories, hypotheses and so on. If the sampling were done on a randon sample of the population, you would get your probably average musical talent. And your average musical talent from the general population is not what we usually call a musical talent.

If you have to choose a more specialized sample – and that´s bordering on an area of statistics called “sampling”, you ought to have a criterion of how to pick your sample – how to pick the musicians that will record for you for example. And what enters into selecting from the general sample? Tastes, points of view (of yourself, of the cultural milieu where you are operating etc.). In statistics that will invariably bring about a skewed or prejudiced distribution. If you don´t go that way, then you have your average citizen and his musical talent, which is of no importance.

So, anyway, whatever you do, you employ criteria, you set priorities. You choose your target population, when you don´t know what variations or what changes through time there are or have been. But you have to come up with theories for that. You may revert to old recordings, yet you don´t really know who had had access to the recording process, who collected or arranged for those old recordings, why and so on.

So really your “scientific” process is subjective from the first stage to the last – no matter if an ethnomusicologist will then write a paper in which the views expressed will exhibit a mathematical methodology or whatever, appearing systematic and objective. It's subjective from A to Z.

It also depends on what professor does it, in what academy he does it, what tendency there is in that place, what mathematics are used to place samples on an arithmetical model, how you look at pre-existent documents and why. Suppose your example is good enough. What do you do about intervals that are very close? Do you take a mean and variance? Do you express your interval in cents, Hertz and so on? With what margins of error tolerance? How do you go about error theory? How can you define a variance on the general population, as your variance comes from a specific skewed sample? And how about a value that is quite outside your normal distribution? Is it an error or is it a stroke of creative genius?

So that is why some of us are now trying over again to do it the other way, through mathematics. That is the way our ancestors did it. And I sense that in Greece our effort to build a new approach will soon lead us successfully to some sort of national specialty. Like moussaka!

Our first shot is to try to come up with a definition for music. And then see what might apply to it from the extant theories. It might well be number theory and rational numbers. We do think that's a good starting point. Then one goes into fundamental questions as to: what are rational numbers? What are natural numbers? Are there any irrational numbers? What are the laws governing numbers? And so on.

But that is all from a number-theoretical point if view. If later we were to find out that it fits music, that would be good enough. Yet if it didn't, it would still be ok : we'd have got a lovely theory.

Periodicity comes in, and the question is why we prefer periodic sounds. Why notes are predominantly periodic, why rhythms are of a periodic nature. There are arguments on this. There is an ontological argument, which says we prefer periodicity because we are products of periodicity. I was going to talk about these stellar magnitudes, about these asteroid belts and these rings of Saturn, but to my amazement my predecessor went through the whole thing very adequately. So I'll skip that. But there is this periodic aspect governing stellar bodies, and then ourselves, our molecules and our atoms and our chemical bonds. They are all products of periodicities. So maybe by looking for periodicity we are looking towards that fundamental law of shaping the universe which has shaped us. That's an ontological argument; it sounds like an argument for the existence of God.

Then there is an aesthetic argument, which touches upon linearity and logarithms; I don't want to go into that. And then there is a perceptual argument, saying that the ear's setup is logarithmic, basillar membrane and the rest. Mathematicians would leave that for the end. They would develop the whole model, then see how it applies to the ear and adjust or modify the model at the far end.

If we have a closer look, the ear is a biological tool. To tell us what? To tell us who the predator is, what the prey is. What the direction of the sound coming from the predator or the prey. And what kind of space we are in and how we can get there, or how we can get away from there. That's the biological side of things, focused on spatial resonance.

But then again, when we come to the question of order, we have to ask the following: Fourier's theorem implies linear algebraic compositions. On the other hand there is the logarithmic scale, typical of methods of fitting more information in a limited space. It's as if the designer of the inner ear knew his mathematics very well. The perceptive organ is logarithmic. But simultaneous sounding of logarithmically connected sonic data clashes with the linearity of their algebraic composition. You have an interval here (high) and the same interval down there (low) which is perceived as the same; however the rate of beats is different. So they're not really perceived as identical. This cognitive clash is a disagreement detected, and the ear is very sensitive to that. Futhermore it's probably very sensitive because at one time it had to tell you whether there was one wolf or three wolves coming against you. Or whether it wasn't a wolf, but a rock rolling down the cliff. Or whether it was a rabbit you could go kill and eat.

The ear is very sensitive to the clashing of linearity and logarithmicity. And that is where order is broken. So, in order to restore order, you have to pick out one of these things; to make one predominate. And actually that's another very probable reason why we're attracted to periodic sounds; because there disorder recedes. While if we follow the logarithmic path, we just get beats all over the place. It can be no coincidence that besides being capable of creating all kinds of noises by their motion, animals – amongst which human beings – have developed specialized means of emanating sound, of a linear spectrum this time: their voices. This spells order and, beyond that, it spells identity.

Identification comes through the specifics of order, and that leads us to the harmonic series and her ratios. Once the musicologist utters – articulates – the word "ratios", he is in the domain of mathematics. And if he indeed is in the domain of mathematics (I'm sorry to have to say that), he ought to develop his mathematical structure now starting over again in the right direction from axioms. If he does not, then he may be lost, erratic, intuitive and so on and so forth; but not systematic at any rate. If he does, he ends up having done the work twice: he has gone from the real world to axioms, then back to the real world. Whereas doing it mathematically saves you one way, it saves you half your time – it's much more economical.

There is a general question about why do it mathematically. Nobody is obliged to go at that; one just chooses to. All I'm saying that is if you are a mathematician, you do it that way – that's it!

The set of rational intervals is the same as the set of rational numbers, which is a countably infinite set. That leads to the inductive method of analysis, which was put down theoretically by Aristotle. It was further developed by others in mathematical logic and it gave the frame Goedel worked in. The inductive method constitutes a general shape of sweeping through several distinct elements of a set, one after the other. You need a first element and a general inductive method of going from an element to the one next. Then as an illustration you might want to put down the first elements, look closely and conceive the feeling of a valid set of results – as many as you wish.

You have your inductive method, so you know what happens ad infinitum, without actually having to go to infinity to find out. In mathematics there is a set of axioms called "Peano's number theory axioms", yielding the natural number set. Of course natural numbers go 1,2,3,4,5,6,7, and so on. What about rational numbers? Can you write them all down? Which would be a complete enumeration of all rational intervals in music? Well, certainly you can do it, and this is the method (draws on board) – You start with <u>1/1</u>. There you have a numerator and denominator. You increase your numerator by one, and then go through all denominators from 1 up to your numerator. If you come to a fraction which you can simplify, you drop it, because you already have it written down. Here's how you go: Write
<u>2/1</u>. (Drop 2/2 which is the same as 1/1). Then you write
<u>3/1</u>, <u>3/2</u> (3/3 you have again as 1/1). And then
<u>4/1</u>; (4/2 you have as 2/1); Then
<u>4/3</u>, <u>5/1</u>, <u>5/2</u>, <u>5/3</u>, <u>5/4</u>, <u>6/1</u>, (going on a bit further)
<u>6/5</u>, <u>7/1</u>, <u>7/2</u>, <u>7/3</u>, <u>7/4</u>, <u>7/5</u>, <u>7/6</u> and so on. In this way you can write down all rational intervals – all rational numbers.

At this pont we come to the question of primes. What do you do about primes? Prime-friendliness, and what's the other one prime-hostility? In number theory you don't have the right to do that. You have no right to discriminate against certain natural numbers, because it's an inductive set and anything is as good as anything else. We have a very strong feeling in mathematics as to the equality of natural numbers. So we cannot play certain tricks mathematically, we are not allowed, whether it is fascinating or not. But we can define sub-structures relating to prime numbers.

I'm going to give you an example of how you can classify elements of a set in a number of ways. Each classification will give you a different method of looking at them. There are varied criteria. One criterion is the "class" of an interval, namely the difference between numerator and denominator. 2/1 is superparticular: the difference is 1. 3/2 is superparticular and so are 4/3, 5/4, 6/5. But 3/1 will be of order 2 – right! 3-1 is 2. If you want to get musical besides all that, you can look at what octave each ratio is. Which means what powers of 2 it lies between. For another criterion yet, you reverse this super-particularity; you look towards the difference between the numerator and the next octave. That is what we would call "leading tendency". There are all kinds of numerical tendencies definable within number theory. Still another one is whether the interval is "erect" or not, resting upon what power of 2 factors out in the numerator or denominator. It was something you mentioned (to Clarence Barlow); you didn´t say it in so many words but it was there. And another really big one is "prime number system".

Now here is an interesting way of layering ratios. Your largest prime factor suggests a concept called "intervallic systems":

S1 is the "Tautophonous System", having only the unison.
S2 would be the "Cyclic System", comprising the octaves.
S3 would be the "Pythagorean System".
S5 would be the "Natural System".
S7 would be the "Septimal System".
S11 would be the "Ptolemaic System".
S13, S17 and so on.

Now what gives us the right to do that? Because you have to have a right to do anything. What happens inside these systems? Well that´s a very good and interesting question.

It leads to intonation. Fine, we know that – different systems of intonation; which, I must warn you, if built mathematically, may come out quite different from those we are used to getting from experience. They may come out much more complete, because they are built from the top.

Suppose you want to set up an intonation. If you start out with a set of intervals which are in a certain system, and you start fusing them, tearing them apart, taking ratios of ratios and so on, you will come to the realization of the closedness of this set with respect to multiplication and division. No matter what you do, you are always in the same system. That is exactly the mechanism giving you a mathematical right to create sub-structures, which are very mathematically organized. And there you will undoubtedly perceive a correlation with the real world´s intonations. But ultimately why do we create intonations?

The answer to that question might be related to the aversion of human beings to infinity, and the marked tendency to concentrate on, learn and use concrete tangible mental objects. Which is equivalent to the search of mechanisms of disciplined self-limitation.

A second question might be asked as to the benefits of ideas that follow the other route, namely the logarithmic one.

That is basically a method approaching intervals not by way of their numerical features, but by their size. And, mind you, the two methods are not equivalent, complementary, interchangeable or anything of the sort; they are the opposites of each other. The former belongs to theory, while the latter falls under applied science and intuitive perception.

The most important function of logarithmicity is indeed to compare sizes of intervals; and that would be where approximations come in. Why does practice favour approximative intonations? Reasons of economy are usually mentioned. Suppose we have a a standing polychord. Then a lattice of relations of its elements to one another is formed. And you know that the greater the number of notes the more the number of relations in the Gestalt booms. And so sometimes in order to deal with periodicity we go to ratios, while in order to deal with logarithmicity we go to affinities of intervals. These are two sides that are not mathematically related.

But if you want to deal with both of them, you just have to come up with your own intuitive formula of how you can compensate between the two, deciding which is more important and which less important. I heard something like that mentioned in the previous lecture again. That would not be mathematical. Mind you, it's non-mathematical, but not wrong; it's one of the choices left open by mathematics.

Now we can proceed to approximative intonations. They are usually expressed by temperaments, and a lot has been said about those. That's something that can go on for ever. I've written a paper on the matter, which hasn't been published; it's part of my dissertation – and then I wrote another paper on the same subject through different methods with people from the University of Thessaloniki. The essence is that we are advocating the division of the octave by 612. Everybody asks why. I have a whole paper here on why 612. We believe that 612 is a very good division of the octave. Much much much better than 1200, which is a larger number. It may sound like a lot with respect to 53, but with respect to 1200 cents it's much cheaper to produce.

Now, may I please go into the real world. Covering successive prime number systems, by following the ascending order of prime numbers, we have observed that this specific approach to the development of practical intervallics, beyond other things, traces the history of music quite faithfully. We think. Not that it matters. But it is satisfactory. And if you follow that method very rigorously, it will lead you to interpretations and rationales as to the development of musical civilisations, musical cultures, differentiations within them – and traceable styles; whether they do come from theoretical considerations or whether they can be correlated to auditory perception; it is theoretically indifferent.

Another observation is that certain, if not most, if not all cultures exhibit a theoretical and auditory conservatism. That is usually and generally a barrier to the transcension to an upper system. You have your set of intervals, and then you feel you want more intervals. If you attempt it within a certain system, creating nested layered sub-structures of interior intervallic multitudes within a system, at some time you go so complicated that you have to break through your system. It would be done spontaneously, were it not for the conservatism of musicians and academies; they are capable of trying any means to hold you back.

When the pressure becomes very strong in that direction, maybe the situation will forcibly open up for a breakthrough to higher systems. But going to higher systems inflicts having to start from scratch. You have to throw away everything else you had your hands on before, and start building your intervallics from the very beginning again: a transition from Pythagorean to Just Intonation will compel you to rebuild your construction forgetting about the major tone. This tone will crop up in the new structure – if it does – through totally new mechanisms and for totally fresh reasons.

Notes in scales serve both melodic and harmonic purposes. If a scale is built by harmonic criteria, then the relations among notes will be coincidental; they will be secondary. But you don't want them to be just any old shoe, you want them to be rather nice, something you can work with. So you may add melodic criteria to building scales, running the risk of throwing harmony down the drain. There, again, one must decide for oneself: what is more important? These shades of choices will undoubtedly account for differences in styles. But if you do not realize what system you are in, also being a conservative on top of all that, then you might get into terrible deadlocks.

For example you hear all over the place that Asian music is monophonic. Well, my foot it is! Take a melody and a drone. What is that? In a certain sense it is one-voice writing, in another sense it's two-voice writing. This drone (on board) is either a trivial melody or a trivial chord. Tackling it from different angles you come to different realizations and hence to different practical results. Yet these different ways of looking at it are theoretically interchangeable. For example if you move the drone very slowly, it may be serving a harmonic function as in Byzantine music (which is thus clearly not homophonic, but harmonized). Or, if you go to the West, its melodic nature may be more prevalent. It may well be a cantus firmus.

Then in one case you could be talking about melody and accompaniment, in the other case you might be talking of counterpoint.

These alternative views have a lot to do with instruments, but I don't have the time to go into how we classify instruments. I'll come to a slightly different point immediately.

The West has chosen for herself a rather gross temperament – by 12 –, which I understand was a demand of instrument makers in Germany of the 1700's. That's not applicable any more – we're not Germans of the 1700's and our technology is not that technology; it's way past that stage. But a feeling has been built that the tempered semitone is the rule of everything. So if anything is less or more than a number of tempered semitones, then we call it a “micro-interval”. We've got to get rid of that terminology. Because what we call “micro-intervals” are real intervals; intervals that make sense. And we don't call “micro-intervals” exactly what doesn't make sense.

The result of this semitonal temperament is that a set of crucial intervals has been disregarded. And those intervals I shall write down as (on board) sigma (σ), zeta (ζ), kappa (ϰ), capital pi kappa (Πϰ) and capital zeta (Z). The schisma, the diaschisma, the comma, the Pythagorean comma and the great diaschisma. Other writers have other terms for them. These are reduced to zilch! Then you have this set of intervals: The diesis, the limma, the great diesis, the semitone, the apotome and the great limma. If anybody wants, I can give you the ratios, but I don't think I have time[1].

Now these are assimilated to something somewhere in between a limma and an apotome. Then the double diesis, the grave tone and the diminished third are swallowed by the tone. Furthermore the augmented tone and minor third are absorbed by the trisemitone, 32/27. Here's really what we have in the tempered scale: it's not the just minor third, its the trisemitone. And then the just major third vanishes within the ditone.

The differences in functionality can be preserved throughout, (bearing certain approaches in mind – and those approaches are of course very inaccurate), but grouping together so many intervals and functions in the same pot will unilaterally lead to the downfall of their differentiation.

There is another interesting fact underlining the Pythagoricity of this 12-tone temperament. It is not only limited to the quality of approximations, but it is brought to a conclusion by the assimilation of the two tones to each other. In which case, natural diatonic scales are approached via two sizes of intervals rather than three: 5 tempered tones and 2 semitones. And this formation is a purely Pythagoric specialty, I must add here. The same Pythagoric deviation had previously struck Western music even at a time of manic tendency towards natural/just systems. In Renaissance and in the Baroque, people wanted perfect thirds. They even deformed fifths terribly, in order to get just thirds.

Then, all of a sudden, having got a just major third, they cut it down into two equal "mean" tones, which would give them again two sizes of intervals in the scale. They went through so much trouble to create something that was closer to just intonation, and immediately they ruined it by making it ideologically Pythagoric – because they thought they wanted two sizes of intervals. That blew the whole thing apart and created so many problems.

If you go now to Byzantium, and to Islam, you'll find they don't suffer from such confusions; because they learn to hear better and don't disregard anything but the very small intervals not even audible. That might sound OK – well it ain't! Try the diaschisma, which is a just step. The diaschisma is something between the augmented fourth and the diminished fifth. It's about 19.5 cents. Now that is nominally a step, because it goes from F♯, which is a fourth degree, to G♭, which is a fifth degree. You can't confuse that with the comma, being a just lever of acuteness or graveness without changing step. You stay on the same degree of the scale if you move by a comma. As far as the Pythagorean comma is concerned: you move a Pythagorean comma up, you go one degree down. It's an inverse step. Differences of size are minute, but theoretically they are worlds apart. Were we to confuse these three, we would get our dynamics all wrong.

The next confusion comes up around the limma (on board). The limma and the great diesis appear interchangeable in these cultures. And then you have the apotome – which is, as far as I'm concerned, a very stupid limmatic interval, because it's a left-over of a left-over of a left-over. They confuse it with the semitone. In which case you find Byzantine and many Islamic cultures splitting a tone by an apotome and a limma, when the whole milieu is just intonation; when they have perfect thirds and so on. That is mathematically deplorable.

But when you apply to the real world, do you know what happens? A structure like that will not allow you any step in the size-area of 4 commas within a just environment. That demonstrates the major differences stemming from the use of a mathematical perspective on elements that are not audibly differentiated. There is no such thing, in a natural environment, as a limma step. There is no such thing, in a Pythagoric environment, as an apotome step.

So, really, when you go down to your modes, it starts making a difference. What you have to do is: either go back Pythagoric and have your tones and limmas, or you go to a just environment, which is different – built differently from the ground. It's a building next door! And there you are not allowed limmas or apotomes; because the whole logic of your present material gives you much better solutions than that, through tones, grave tones and semitones. Now that is an indication of what your mathematics does for you. I think I ought to mention that we in Greece have been trying to develop our thinking and take it from beginning to end, relying on a good solid mathematical base. And we have also tried to compose music on it. So we have actually started composing septimal music.

As far as we are concerned, it comes out quite ok. I have here, if anybody wants to look at them, amazing lists of tetrachords. Just any number of tetrachords. If you look at them like this you might get lost. If you follow their ordering and rationale, they make sense. Each tetrachord goes in its right place according to the functions it is called upon to fulfill.

Beside all else, we are also trying to check up on the theory of our traditional music. That is a task that will be completed soon. What we have to face regarding ancient Greek music is a dispute about how the language was pronounced, how the meter went and what the intervals were. The last is largely due to the intervallic war of antiquity: between the Pythagorean and Aristoxenic schools. They could never get the two things together. That is probably why Pythagorean – being stronger socially and as a doctrine – attained a general acceptance in the modern world, distorting everything in its way. Even to modern European and Arabic music. It's just done terrible damage. There we are then, still thinking Pythagorean, still thinking apotomes and so on.

We want to clarify all that. We want to set our structures straight. I'm going to stop in one minute, after saying that the Byzantine side is also a mess, because that is where many different theories have been and still are tried, coming from various sides: from the East, from the West and so on. If you read up on what writers have been writing about Byzantine intervallics, you'll go crazy.

You will be confronted by five, ten different points of view. Five or ten incongruous intervallic setups. Chrysanthus himself gives two of them. He postulates a numerical aspect and then he divides his octave into 68. However 68 does not fit his own numerical intervallic structures. It turns out that what fits his diatonic structure – alone – is 72. Then the Patriachal Commission, in 1881, comes in and says: “OK, we′ll give you not 68, or 64 (which was the number he had given for chromatic modes); we′ll give you 72”. In the meantime they themselves give another set of intervallic ratios, for which 72 is no longer good. Their set now needed 53, because the Patriachal Commission′s numbers were in unadulterated Just Intonation.

On the other hand, the way they came up with intervals was acoustical: they gathered several cantors and made them listen to proposed intervals, until sometime the Cantors would say: “About there sounds ok”. That was done in the last century, and it proves that the ratios they gave were arbitrarily selected and imposed, indeed in application of Rameau′s method. They may sound as close to anything as desired, but where structural considerations depending on theoretical importances of inaudible differences are concerned, we are stuck with worthless speculation. As I said, I′m going to be working on that soon, and that is one of the reasons why Prof. Amargianakis eagerly accepted me as his doctoral student.

Our folk music is also very varied. We have been collecting, listening and sometimes trying to come up with mathematical renditions. I have personally re-done folk material for the public. And I must say that there the response was unanimously fantastic. Whenever I played songs, mathematically restituted, in concerts to their natural public, often to simple people, the responses we got were of the type: “My God, how did all this emotion and feeling come back to these songs? It had been lost for six years.”

Wouter Swets: Where did you get the musicians to perform that according to your....

DEL : In Athens.

WS : But how can they do that?

DEL: I don't know how they can do it. But the thing is I wrote the scores out in four different notations. I got people who didn't rehearse together. I get them together to play in a concert and they all play the same thing – and the public goes crazy! Old people who had lost track of these songs and their emotion since the twenties. Which was rewarding – and fun of course. The other thing that was fun was when people gave us versions of songs – remembering them in haphazard ways – not knowing what the songs were exactly like. I'd sit down, do a mathematical reconstruction of the song – and finally it would be played back to the people who had taught it to us. And they'd say "Yes, you are right, that's what it sounds like. I didn't remember it correctly, but now that I'm hearing it, that's it!"

WS: Could you give an example of a folk song which used to have certain intervals you have replaced here?

DEL : We never occupied ourselves with what it was or what it was thought to be. What we did is we got an approximate idea of the intervals, given a wide tolerance of error, and we tried to come up with a mathematical structure that fits that certain melodic behaviour. That certain wide margin of error of the intervals and the behaviour of the melody.

WS : But how, for example, you can be so against an apotome (which is 2187:2048) and like so much 16:15 when the difference is only 2 cents? And now you say there is room for tolerance. What is 2 cents in God's name?

DEL: 2 cents is a schisma.

WS: If we speak about tolerance in performance. What does your system mean? I believe you if there was a beautiful performance. But what I want to know is what exactly – what kind of intervals they used – which made it so beautiful. Or was it just a kind of psychosis of people who heard something about the new system, and now this must be wonderful?

DEL: Oh no no, as I said, it was the general public that attended, not musicologists. It was a concert given in a concert hall. They didn't have any psychosis about whatever stupid thing I was doing, they couldn't care less. It would take me much time to answer that.

1 Editor´s Note: here is a ratio list of the more basic of these intervals arranged in order of size –

schisma	32768 : 32805	1.95 cents
comma	80 : 81	21.5 cents
Pythagorean comma	524288 : 531441	23.5 cents
dieses	125 : 128	41.1 cents
limma	243 : 256	90.2 cents
great dieses	625 : 648	62.6 cents
apotome	2048 : 2187	113.7 cents
tone	8 : 9	203.9 cents
diminished third	225 : 256	223.5 cents
augmented tone	64 : 75	274.6 cents
trisemitone	27 : 32	294.1 cents
minor third	5 : 6	315.6 cents

Ann La Berge

Mongrel Tuning: The Temperamental Flute

I´m going to speak about a collaboration between flutist/composer John Fonville[1] and I which was started in the mid 1980´s. Both of us are tuning buffs and we enjoyed experimenting with tuning even before we met each other. During my stay in San Diego at UCSD, we played together a lot, mostly improvising at first, and then working towards hearing and playing in extended just intonation. We also worked out sets of fingerings for different non-just temperaments, including the 19 tone per octave scale, a tuning that people have been experimenting with for a long time[2]. This scale is specifically not intended to be in extended just intonation. And when we played in this tuning by using this "unnatural" scale we tried make the beating (that was appropriate for some of the intervals) predictable and obvious.

One aim of our project was to make a clear distinction between playing in just intonation and playing in another type of tuning (or temperament). After a year or so of improvising together, a music using a temperamental system of intonation (or de-intonation) was developed. It now consists of three pieces; one written by me (*unengraced*), one written by John (the *Mong Songs*), and one written by David Dramm (*by*).

To find non-standard fingerings on the flute which would work for a temperament other than the conventional 12-tones per octave is relatively simple. The concept is similar to that used in baroque flute or recorder, where cross fingerings or half-hole coverings to raise or lower pitches are used. By using a set of fingerings to produce the pitches, rather than depending on the flexibility of our lips, we could actually, and relatively confidently, play this 19 tone scale. But, of course, because it is manifested on an acoustic instrument built for conventional 12-tone temperaments, each note had a slightly (and sometimes extremely) different timbre.

This collection of timbres which spans the three octaves of the flute offers much more complex sounds than the same collection played on most synthesizers. The flute is actually a very elegant instrument. It's just a cylindrical tube, although it has a little bit of a conical shape in the bore of the headjoint to make the third octave somewhat smoother. I like to think of it as a compact pipe organ – basically: the shorter the tube the higher the pitch, and thus the longer the tube, the lower the pitch. Because the conventional flute tone has been analysed to be very close to a sine wave (especially from performers who play with a boring sound; no pun intended!), it is usually very easy to hear the fundamental of whatever pitch is being played.

A trend which has gained popularity in the last ten years is a flute tone which has the possibility to include more of the higher partials than just the simple sine-wave tone that we all read about in acoustic books. In fact, for tone colour variations and for certain kinds of intonation inflections it's necessary to emphasize different partials at different times. A flute which can handle this kind of timbral flexibility has specific measurements in the cutting of the head joint, and specific relationships between the tone holes in the body of the flute, making intonation much better than the flutes from before 1975 or so.

For example: I'll play a chromatic 12-tone scale (plays). As you can see, I just lift up my fingers to shorten the tube and the pitches get higher. The second octave is overblown to get the second partials of each note. Now, the third octave combines two harmonic series. Once we get beyond 1) simply "fingering up the tube", 2) blowing the second partial and fingering up the tube, we have to use a more complicated combination of harmonics and fingerings.

So, the third octave is not just overblowing (demonstrates overblowing to play the first two partials simultaneously; plays multiphonics using third octave fingerings). In some ways the multiphonics and double octaves which I have just played are much more interesting to me as a flute player. It opens up a harmonic world that supposedly we flutists never had, although in some non-western cultures we have always had.

Now, as you can see, the flute tone (in my mind) is a sonority. It's not just a single, isolated tone. If I want to play loudly or softly, or change the color of a timbre (plays) I'm also adding and subtracting harmonics. By combining two flute players at once that enjoy this kind sound production the sonorities that are produced in duo playing sound very well tuned or in some cases, powerfully out of tune. Except for a couple of fingerings the 19-tone scale, that John Fonville and I used, is made up of non-standard fingerings, and thus non-conventional timbres. In essence, we refingered the traditional classical twentieth century flute. Due to the nature of the acoustics on the flute, it was necessary fingered each octave differently, although there are a few notes which are the same in the first two octaves. We were both playing with the same brand of flute (almost), so that we knew the timbres of individual notes would be somewhat similar. It may seem unlikely, but its true that every flute is different.

If it's a hand made flute, or if it's a factory assembly line flute, there are certain subtleties which give a flute an individual character. Plus, everyone produces a sound differently. So the 19 tone scale that appeared, mostly through John's intense experimentation and my commentary, starts on F with a standard F fingering (plays). Maybe it starts on F because Fonville helped develop it... And this is what it sounds like (plays). This is F in the first octave. You see I can't overblow the second octave because I've cross-fingered everything so peculiarly in the first that the overblown notes for each pitch are not necessarily an octave. Thus the same fingerings in the second octave don't work. As a result, the second octave is another set of fingerings for the most part (plays). There's the second octave F again – going on (plays).

I hear these three octaves as a collection of timbres and through that sort of orientation to the pitch material, we started make a music for our duo. John and I were at that time very active as improvisers. So what came out of our collaboration was a style of making music from an intuitive in addition to a more objective structural process. I would like to add that the F-19 is an octave divided into 19 equal intervals of 63 cents each. Of course, on the flute, the intervals were not always exact, but because the tuning offers some nice 3rds and a really nice 5th we would sometimes gravitate towards just 5ths and 3rds, although we made a point of trying to replicate the F-19 tempered intervals as precisely as possible. Another way we used the sonorous depth of the scale was to overblow or underblow the notes and obtain even more unusual timbres or, in extreme cases, multiphonics (demonstrates).

I will play you an example of a synthesizer playing (19-tone) retuned versions of cadences from the chorales in J. S. Bach's St. Mathew Passion (plays recording).

I wrote a piece for flute and synthesizers using this as basic material for the harmonic language. The piece didn't work out as I wished, mainly because the complex timbral interplay that I was used to was lost by using the synthesizers. But, I must say, as a flautist its really no fun to play with an FM synthesizer. Through various experiences, I've decided that I need to play with instruments that can replicate the multiplicity of timbres and noise that are possible with the flute, especially with this kind of extended tuning. And, for a synthesizer that is very expensive sound, and I don't have that kind of money right now.

I'll play a little bit of our music. The first piece is entitled *by* composed by David Dramm. David used the F-19 material less harmonically than John or I did. His more limited selection of notes forms a sort of quasi minimal, repetive music (plays recording). Later in this section more and more notes in the scale are added which breaks down the "groove" of the repeated pattern.

The next piece is mine. It's entitled *unengraced*. I took mostly scale passages and extended blowing to create multiphonics. I structured it by semi-serially organizing material that John and I would play in our improvisations. (plays recording). As you can hear, our unisons weren't bad for having to play so many weird fingerings! As time went on, we developed an ability to hear and reproduce the subtleties of our tuning. Our rehearsals lasted about 3 hours, and we played together twice a week for a couple of years, and then once a week in the third year. We also learned that this music needs to be performed amplified, because the sound projects much less evenly than the traditional, conventional flute (plays another section of *unengraced*).

The next piece is John Fonville's *Mong Songs*. It has three movements and only one is in F-19 (plays recording).

And the last musical example is the third movement of the *Mong Songs* called *.5*; it's not in F-19, but it uses all of the musical ideas I have spoken of, only it is in another tuning (or rather, collection of timbres).

I have to add that as far as future projects in this extended tuning world for flute are concerned, I now strongly prefer working with acoustic instruments. The difficulty in this kind of work is to find a player like John Fonville who invested so many hours to recreate the flute and then collaborate with me to develop a repertoire for that new instrument. Not many people will go that far out on a limb on a new project. I'm ready for questions.

(Audience question): Why F-19, presumably you could take any note?

ALB: You could. I never asked John specifically why F was his chosen note. I guess it was a handy choice to use a conventionally fingered note which we could function as a sort of anchor.

Q: Is the flute rebuilt or is it a normal flute?

ALB: No it's this flute that I am holding. Let me play a section from John's *.5* so you can see how it would sound live (plays).

Postscript

The flute duos (*by*, *Mong Songs*, *unengraced*) composed by David Dramm, John Fonville, and Ann La Berge, which emerged from a period of intense collaboration between flutists John Fonville and Ann La Berge in the late 1980's, build a repertoire that may never have a commonly known performance practice attached to it. When played on the western 20th century flute (built in the 80's), the idiosyncratic timbral, articulatory, and dynamic mannerisms of each note of the entire two and a half octaves of this scale makes each of these works untransposable. By crossbreeding (the intentions of) mathematical purity of the 19-tone scale with the sounds which come from such a quirky tuning and timbral world, the composers impose upon the flutists a necessity to blow and finger their instruments in a manner which emphasizes the acoustic differences between each note/fingering in the scale. This practice of highlighting differences rather than striving for a homogeneous timbre and resonance throughout the range of their flutes is one of the distinguishing features of these three pieces.

1 John Fonville is a professor at the University of California, San Diego.

2 John worked out the original fingerings and I adapted them to my flute with consideration for the nuances necessary for my own instrument.

Wim van der Meer

Theory and Practice of Intonation in Hindusthani Music

The other day I was present at a concert of Hariprasad Chaurasia. As is common in Indian music he started out by tuning the tanpura, which takes quite a long time – like twenty minutes or so. He wants it really perfect. And then he says, as he picks up his bamboo flute, "thank God I don't have to tune this instrument". Now, that is indeed a very nice joke, because the bamboo flute has seven holes that are more or less equidistant, so you can imagine how much trouble it is to play that instrument in tune. And I assure you he is one of the most well attuned musicians in India. Just to give you an idea of what it sounds like I'll play a small piece of a relatively unknown but excellent young singer. This raga is in the Western major scale.

[Music example: Raga *Tilak Kamod* by Ashwini Bhide]

Indeed, it is often striking that Indian musicians achieve an uncanny exactness in intonation. We will come back to that in the course of this talk.

In this small piece you hear the drone. You don't hear it very clearly. It's supposed to be soft. You also hear the voice and the drum, and on top of that you might have heard a small harmonium that is actually tuned in more or less equal temperament. But that doesn't really disturb the Indian musicians so much. It's also played softly, and they refer to the tanpura, and in particular of course the major third is different in one instrument and the other.

Now, before I really go into this subject of how this intonation came about I want to say one thing which is that people think that a culture like India's has undergone very little change over the ages; that the music is transmitted orally from teacher to student and that very often the student spends twenty-five years with his teacher and I mean not just spending in the sense of coming to him once a week but living with him and assimilating the whole music.

But you know there are at present approximately fifty ragas that are really very well known, big ragas, important ragas. There are surely another two hundred ragas that are reasonably well-known. Not to everyone, but at least some people know them. There is one book in which about seven hundred and fifty ragas are discussed. But in fact ragas are invented everyday and ragas are changed everyday.

Musicians try all sorts of things all the time, so if you would start counting the number of ragas that might have been in existence at any particular moment you are talking about thousands, many thousands. And there's really a Darwinian process of selection that goes on.

It's in the first place the musician himself who may say, "Well, I tried this". He may have tried it for a few days, he may have tried it for a few months, or even for a few years, but he may conclude in the end that it didn't really work. And in the second place of course it's the audience; and I'm not talking about once or twice, but it's going to take a process of ten years or twenty years that a certain raga came into being, was played for some time, and then disappeared again. And how it disappears is not because there is some committee, or some musicologists who say, "this raga's wrong". They have no influence on that. It just didn't work. And some other ragas have existed already perhaps for the past fifteen hundred years or so, because the whole raga principle got its main shape in about the Vth or VIth century AD. Even then ragas that are that old might have changed in the course of time. So the whole history of Indian music is very much an evolutionary process of trial and error. Most probably, various aspects of intonation also have been subject to this evolutionary process – trying and finding the best tuned solutions.

Towards the end of this talk I'll come back to that. I'll go first to the ancient theory of intonation in Indian music.

The man who is always cited on this is Bharata, a great scholar of two thousand years ago, who wrote a treatise on theatre in which there is an important part devoted to music. He explains different intervals of music and people have tried to understand his theory. I think by now there is a kind of general consensus on how it works.

Take his division of the octave in a tuning called *Sa grama*. He divided an octave of seven tones into a total of twenty-two *shrutis*, which one nowadays knows were not equal in size. He saw that you can tune perfect fifths (2:3) and perfect fourths (3:4) and if you tune an instrument (they used harps in those days), you get a problem with your fifths. Most probably he got that problem because he was aware of the existence also of the harmonic major third 4:5.

Put simply, he knew the octave, the perfect fifth, the harmonic major third as primary intervals, derived the fourth as an inverted fifth, then getting the *chatushruti* (meaning "four *shrutis*") which is the major whole tone 8:9 (204 cents), the difference between the fifth and the fourth. Then he recognized another slightly smaller interval called the *trishruti* ("three *shrutis*"), i.e. the minor whole tone 9:10 (182 cents), the difference between a harmonic major third and a major tone. Then came the *dvishruti* ("two *shrutis*"), the major semitone 15:16 (112 cents) or the fourth minus the harmonic major third. He was also aware of the syntonic comma 80:81 (22 cents, the difference between the major and the minor whole tones), which he called the *pramanashruti*. Now, by variously chaining together the *dvishruti* ([2] below), the *trishruti* ([3]) and the *chatushruti* ([4]), he arrived at the following seven-tone scale[1] (European note-names and cent equivalents are given below):

Sa	[3]	*Re*	[2]	*ga*	[4]	*Ma*	[4]	*Pa*	[3]	*Dha*	[2]	*ni*	[4]	*Sa'*
do	182	re	112	mi♭	204	fa	204	sol	182	la	112	si♭	204	do1

Just add up the *shrutis* and you'll see they total twenty-two (the cents add up to 1200). Note that the perfect fifth is thirteen *shrutis*, the fourth is nine. You can also see that the interval *Re–Pa* (re-sol) is not a perfect fourth, something he was obviously aware of. What we are saying is that he somehow understood that the harmonic major third actually makes a mess of the beautiful system of fifths: when you tune an instrument you meet that problem naturally.

Let me go back a step here. This will be very much a repetition of what we saw this morning. I will first state a

> *General law of consonance:*
> *Consonance decreases as the fractional relation between base frequency and the frequency of the related pitch becomes more complex.*

Look now at the following figures:

1:1	1:2	2:3	3:4	3:5	4:5	4:7
I	VIII	V	IV	VI	III	--

You see the octave (VIII), fifth (V) and fourth (IV), followed by the sixth (VI) and third (III). Then you see 4:7 and here comes my first comment, which is just what Clarence Barlow said this morning:

> *Comment 1 :*
> *Prime numbers above 5 aren't part of a fraction.*

Then you can go on and you come here to other known intervals:

5:6	5:8	5:9	8:9	9:10	8:15	9:16	15:16	16:25
iii	vi	vii	II	II-	VII	vii	ii	--

Having eliminated the numbers Clarence eliminated – 7, 11, 13 and so on, you arrive at 25/16, the next one in line. The 25 also poses a problem. [To C. Barlow] I don't know if you would know by heart the indigestibility factor of 25.

C.Barlow: I think about twelve.

W.v.d.Meer: Right, above ten. I'm sure we could easily apply the formula of Clarence's lecture this morning. As soon as you have a 25 you're putting thirds together, and that's difficult tuning. If you're singing, that's really out of the question. This leads to my

> *Comment 2:*
> *The number 5 doesn't occur more than once in a fraction.*

Thus no compound thirds.

D.Wolf: Question: are you making a distinction between 25 in relationship to the tonic? For example if you go from 5:6 over the tonic to 4:5, you're going 24:25 and that's quite common.

W.v.d.Meer: I would say in Indian music it's not. And I'm not eliminating these on the basis of some theory. I'm just going through all the possible intervals and already indicating which ones are not used in Indian music.

C.Barlow: I think you're are talking about the relationship between a certain tone and the tonic, if I'm not mistaken. But, as Daniel Wolf says if you have both major and minor thirds you can indeed find the difference between them forming 24:25, particularly the tonic.

W.v.d.Meer: In that case I agree absolutely.

J.Tenney: The tuning you showed us looks like our minor scale.

W.v.d.Meer: Yes. That's a minor scale basically, the *Sa grama*. That's what they used as their basic scale. There was another one called *Ma grama*, in which the fifth (*Pa*) was lowered a bit to make it consonant with the second (*Re*); if I have time I'll come back to that. This is a fundamental scale from which, by transposition, all sorts of other scales were derived with basically seven tones of course, although later two more tones were added – the major third and the major seventh, on which basis again new scales were derived. You finally get quite a complex set of musical scales.

Going on with our intervals we get

16:27	20:27	27:32
VI+	IV♯	iii–

which I'll come back to.

Here I'll make another general observation:

Comment 3:
Inverted intervals are more difficult to tune and perform

I mean the fifth above the tonic is very easy to produce. A fifth below the octave is very difficult to produce – it would mean the fourth. The perfect fourth is really far more difficult than the perfect fifth. Similarly, the minor sixth is also much more difficult than the major third. It's very easy to understand why, because what really happens in this kind of natural tunings is that you're matching harmonics – the harmonics of the voice with those of the drone. And, if the harmonics of the drone are kept steady, you match the harmonics of the voice to them. It's much easier to do that above the drone than to do the inverted thing. It's like cutting your hair in a mirror, something like that.

H.Radulescu: Is it because your fourth is nearly your forty-third harmonic? It's very difficult to control. It's a prime number.

W.v.d.Meer: I wouldn't say that.

H.Radulescu: But why are primes bigger than 5 forbidden?

W.v.d.Meer: They're just not used in Indian music.

H.Radulescu: But they could come. Between the seventh and sixth is fantastic. A minor minor seventh, no?

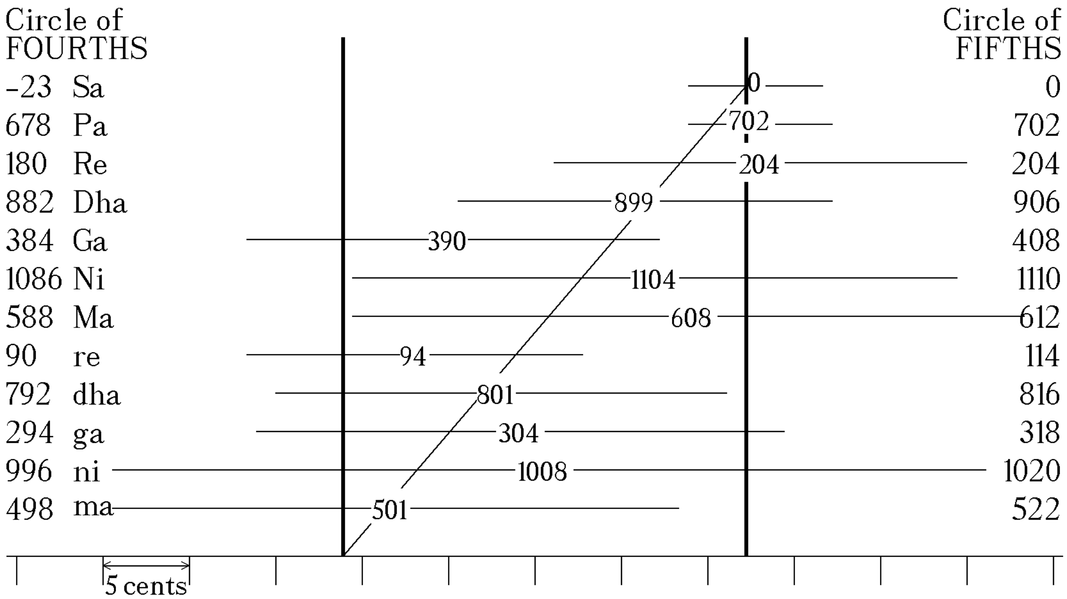
W.v.d.Meer: Oh yes, they could, but they don't!

Now these are some general outlines that we find in the interpretation of a natural scale in Indian music. Now here's my last comment – I'll have to come back to that in much more detail.

Comment 4: The semitone is an independent interval

The semitone is really an independent interval produced by some kind of acoustics of the instrument or the voice generating the melody and the drone. There is something funny going on there that is not explained in this theory of simple harmonic relations because we are talking about a strictly complex ratio. I will show you that the semitones used in Indian music are with great accuracy and dependability about ninety-five cents. They are certainly not the 15:16 we commonly find in books. What ratio the ninety-five cents is, you can figure out for yourself, of course – extremely complex.

Ex.1 – Average intonation measured for the twelve scale-degrees shown in circles of fourths and fifths; all values in cents – note names in *sargam*



Ex.1 shows an ascending cycle of fourths (with Indian note names) along the left vertical line opposite a descending cycle of fifths on the right, 23.46 cents (a Pythagorean comma) apart. The diagonal shows equal temperament, the horizontal lines the pitch spread (with the mean value centred) of the twelve chromatic notes found in about two hundred 5- to 15-minute compositions we computer-processed in the past twelve years. The fifth (*Pa*) averages at 702 cents, the major second (*Re*) at 204, beautifully. The major third (*Ga*) is a bit high at 390 cents instead of at 386, hardly noticeably. The major sixth (*Dha*) is tempered: the major third and the major whole tone pull on it about equally. The major seventh (*Ni*) 96 cents below the octave (*Sa'*), the augmented fourth (*Ma*) 94 below the fifth (*Pa*), the minor second (*re*) 94 above the tonic (*Sa*) all more or less follow the rule I mentioned that drone centres, here always tonic and fifth, tend to be flanked by semitones at about 95 cents. The minor sixth (*dha*) is interesting, a bit higher than expected (99 cents above *Pa*) and practically tempered. The minor third (*ga*) is relatively well spread; especially the minor seventh (*ni*) goes really wild. The perfect fourth (*ma*) is at 501 cents a bit high, known to Indian musicians who say this is because musicians are too greedy.

Ex.2 – Tabulation and evaluation of the findings in Ex.1

Scale-degree Name	Semitones	Theoretical alternatives in cents with ratio (and derivation)			Measured average in cents (range and position* in % of a syntonic comma)
Sa (do)	0	0 1:1			0 (37/103)
re (re♭)	1	90 243:256(IVx5)	112 --schisma-- 15:16(IV-III)	114 2048:2187(Vx7)	94 (90/16)
Re (re♮)	2	180 --schisma-- 59049:65536(IVx10)	182 9:10(IV+III-V)	204 8:9(Vx2)	204 (110/102)
ga (mi♭)	3	294 27:32(IVx3)	316 --schisma-- 5:6(V-III)	318 16384:19683(Vx9)	304 (140/46)
Ga (mi♮)	4	384--schisma-- 6561:8192(IVx8)	386 4:5(III)	408 64:81(Vx4)	390 (110/20)
ma (fa♮)	5	498 3:4(IV)	520--schisma-- 20:27(Vx2-IV-III)	522 131072:177147(Vx11)	501 (150/13)
Ma (fa♯)	6	588 729:1024(IVx6)	612 512:729(Vx6)		608 (180/84)
Pa (sol)	7	678 177147:262144(IVx11)	702 2:3(V)		702 (40/100)
dha (la♭)	8	792 81:128(IVx4)	814 --schisma-- 5:8(VIII-III)	816 4096:6561(Vx8)	801 (120/43)
Dha (la♮)	9	882--schisma-- 19683:32678(IVx9)	884 3:5(IV+III)	906 16:27(Vx3)	899 (100/69)
ni (si♭)	10	996 9:16(IVx2)	1018--schisma-- 5:9(Vx2-III)	1020 32768:59049(Vx10)	1008 (230/56)
Ni (si♮)	11	1086--schisma-- 2187:4096(IVx7)	1088 8:15(V+III)	1110 128:243(Vx5)	1104 (160/71)

* distance from (where schismatically paired next to) lowest shown theoretical value

General observations:
Pa, *Re* clear preference for high, *Ga*, *ma* clear preference for low position
Dha almost tempered, *ga*, *dha* and *ni* also near-tempered
re, *Ma*, *Ni* approximately 95 cents from drone centres *Sa*, *Pa* and *Sa´*

Note by note:

Sa	although properly zero, often corrected in view of the other notes
re	easiest place in theory IV-III not used due to absence of IV in drone
Re	absolute and stable preference of 8:9 over 9:10 due to *Pa* tuning
ga	tempered between the two theoretical positions, not very stable
Ga	clearly naturally harmonic
ma	a bit above the inverted fifth, not so stable due to lack of *Pa*-support
Ma	high position
Pa	more stable than *Sa* because *Pa* is stronger in the tanpura - s. Ex.5
dha	tempered between the high VIII-III and its 95ct adjacency to *Pa*
Dha	tempered between the low III+IV and the high Vx3
ni	tempered between the low IVx2 and the high Vx2-III
Ni	clearly high in spite of the apparently simple low V+III choice

Ex.2 – continued

Further observations It could be expected that notes with an easy choice for low or high would a) follow that choice and b) be quite stable. This is so for *Re*, *Ga* and *Pa*
It could therefore be expected that notes with two accessible positions are tempered and unstable – this is the case with *ga* and *ni*
The instability of *ma*, is spite of an easy choice, is due to its lack of support by the tanpura – inverted harmonic matching is more difficult
The semitones adjacent to *Sa* and *Pa* are at a distance of 94-96 cents, but for *dha* at 99 cents above *Pa*, seeming to indicate a phenomenon unknown in literature
The temperament of *Dha* indicates balanced consonance with *Re* and *Ga*

J.Tenney: So if there were for example in your sample two different versions of the major sixth, you would lose that distinction by averaging them out.

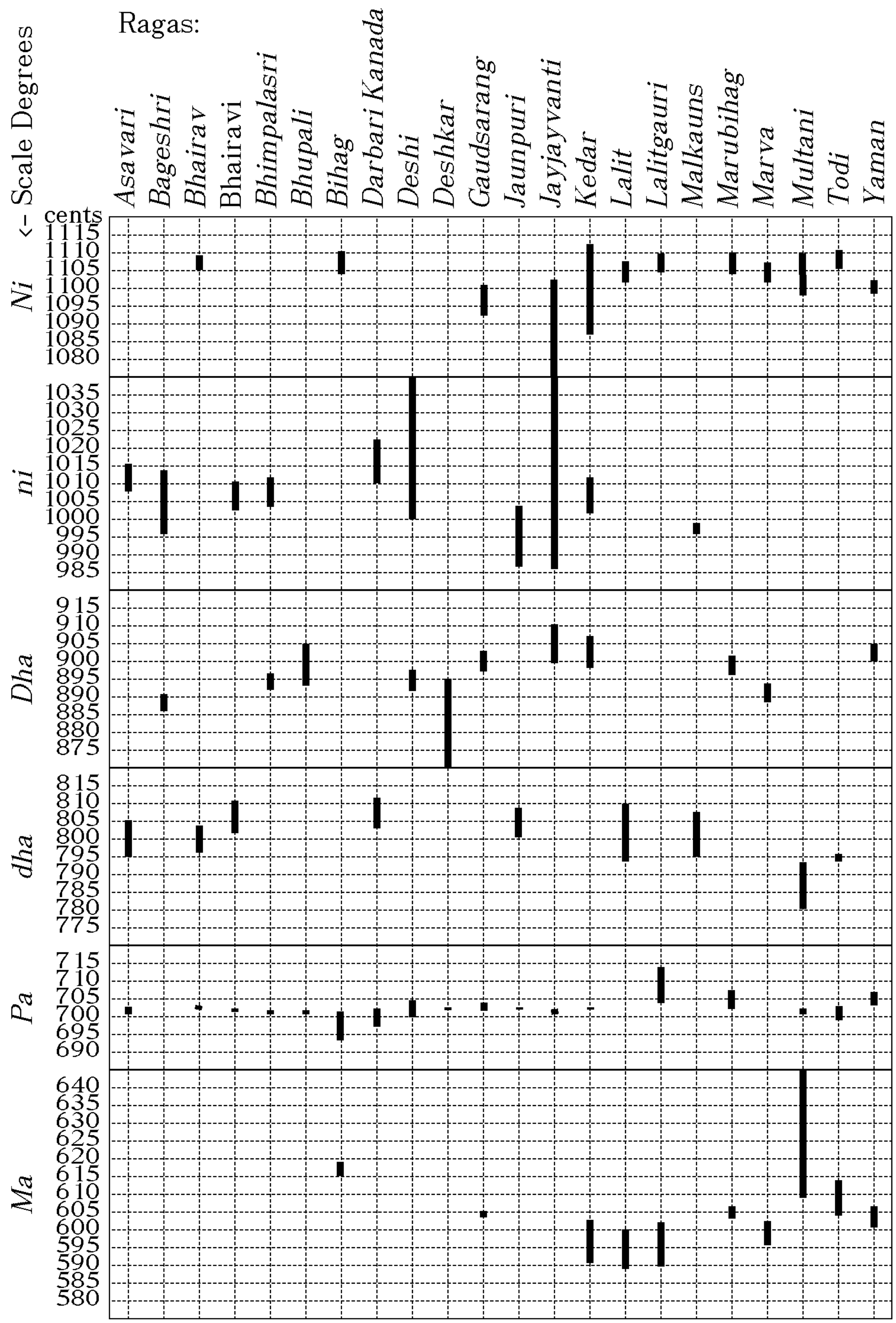
W.v.d.Meer: Absolutely. Of course. That is the next question that has to be raised.

Differentiation of intonation by raga

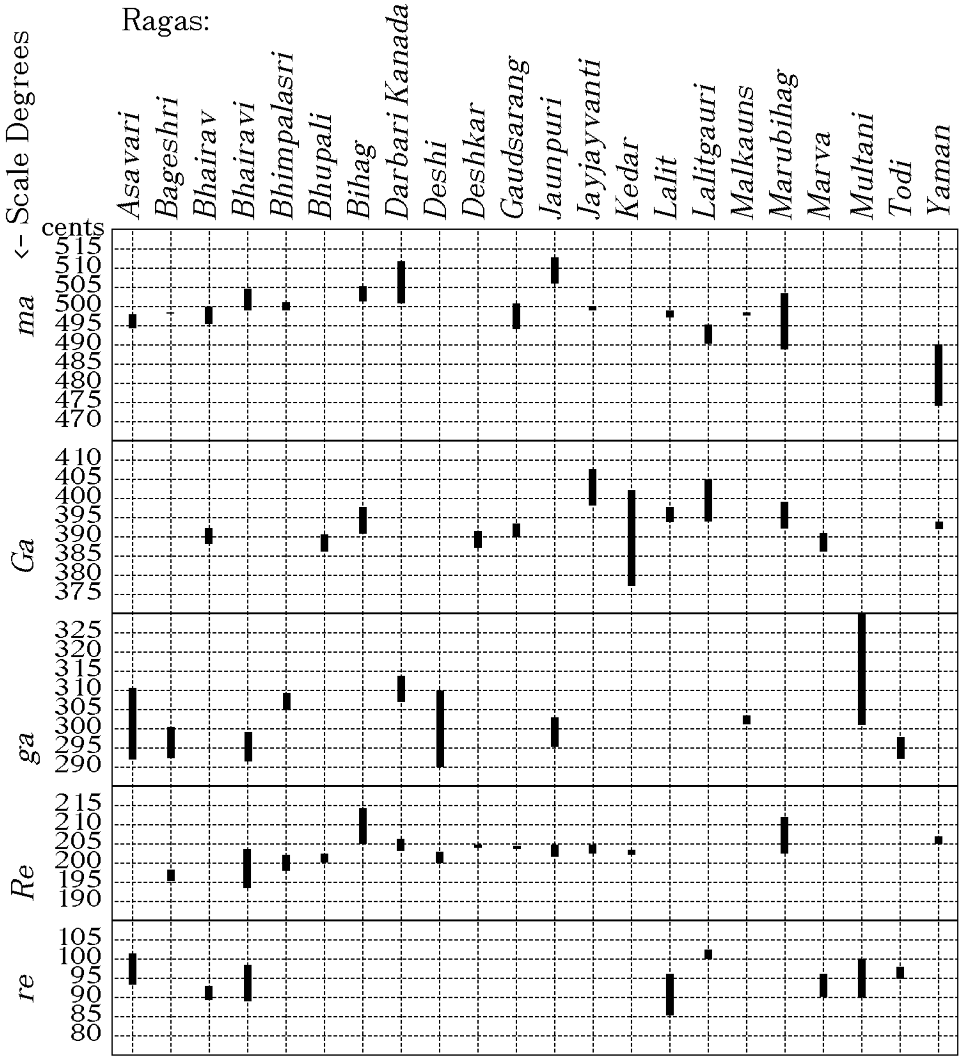
I must tell you that after studying the history of Indian music and discussing with many people this scheme of Bharata in which you make this distinction between the higher position and the lower position, a distinction which is discussed very often among Indian musicologists, (not so much among musicians, as you value), I find that musicologists like to talk about the high position which is the bright position of the notes that relates to the day time, and the low position which is the dark position and relates to the night. You know; day ragas, night ragas. I must say, about ten or fifteen years ago, I staunchly believed that somehow some scheme like this was being followed by Indian musicians. So naturally, when you take this kind of general average of course it happens that sometimes musicians take the higher position, and sometimes they will get a lower position, you will get an average.

So naturally the next thing we did was to see, raga by raga, if one can find some ragas that really take the high position and some which take the lower position, because that would be the theory, originally.

Ex.3 - Intonation of eleven scale degrees measured for twenty-two ragas



Ex.3 continued



Watch these measurements, raga by raga, note by note. The minor second (*re*), for example, is found here in eight different ragas. The measurements speak for themselves – there is hardly anything significant here. The minor second is generally at 85 to 103 cents, always lower than the 112-cent 15:16. Now in Raga *Bhairav* it's supposed to be low. Nice. But you can't say this is significant.

C.Barlow: I remember hearing that the minor second in Raga *Marva* ought to be especially high. Isn't this a general belief?

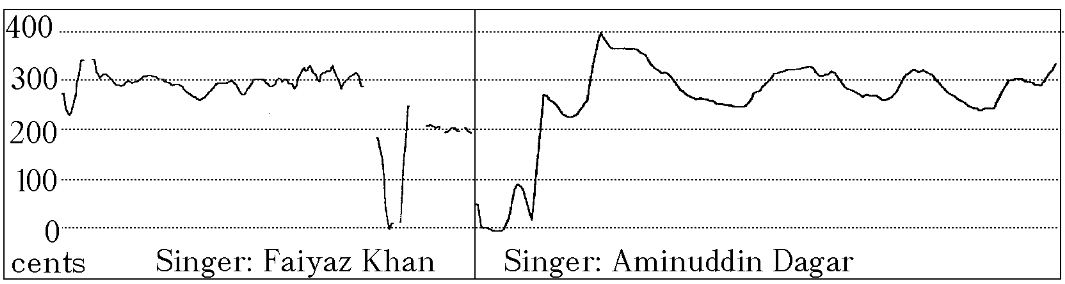
W.v.d.Meer: Exactly. But it's not true.

J.Tenney: How did you measure these intervals?

W.v.d.Meer: In a minute. Let's run through a few. An interesting case to attend to is the major second (*Re*) ranging in *Bhairavi* from 194 to 204 cents because both the minor and the major second are used. There tends to be a little play there; in measuring you're going to get some variability. For instance, here is one really on the low side: in *Bagesri*, a raga in which the drone tuning is not done with the tonic and the fifth, but the tonic and the fourth. You would indeed expect it to be a bit low, but again it's certainly not the 182 cents (9:10, the minor whole tone) you would theoretically expect. You see that most of the major seconds are around 204 cents, though, certainly in the general average. Quite clear cut.

The minor third (*ga*) is all over the place. Sometimes it doesn't even fit on this diagram: it goes from 300 to beyond 325 cents in Raga *Multani*. Interesting that in Raga *Darbari Kanada*, the minor third is supposed to be very low, and it is significantly higher here than what we would actually expect – see also **Ex.4**.

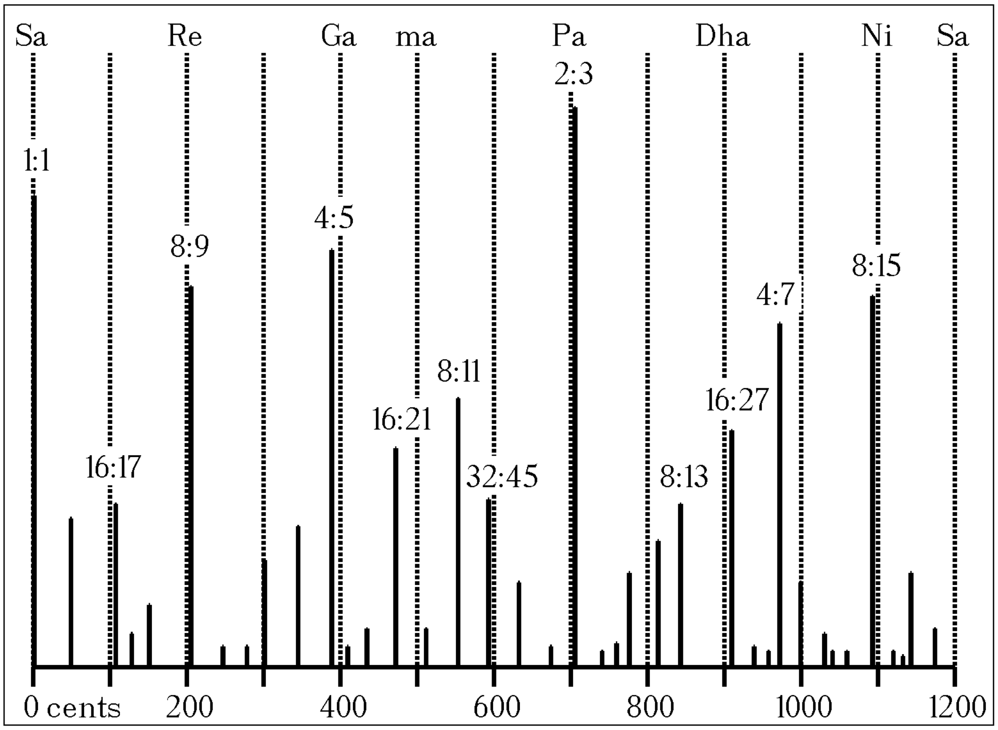
Ex.4 - Measured intonation of the *Darbari Kanada* minor third as sung by two prominent singers (about five seconds each)



The major third (*Ga*) is also extremely spread out – a problem of measurement. In Raga *Kedar*, for instance, the major third is used very little and therefore isn't very dependable: measurements get more dependable if you have really steady notes used regularly in a performance. You will find large spreads either when the note is seldom used or if it oscillates strongly which happens in some cases. Or if both major and minor forms of one note are used. Yet this is hardly significant. A quick look at some of the others, e.g. the sixths (*dha*, *Dha*) and sevenths (*ni*, *Ni*), shows the same story. You hardly get any significant differences from one raga to another in intonation. I don't find it interesting to assess each case separately.

Here's a picture that's of some interest – **Ex.5**:

Ex.5 - The cumulative spectrum of a lady's tanpura in *Pa*-tuning; Indian note-names at twelve-tone equal tempered positions



This is a tanpura spectrum. You see very clearly the fifth (2:3) even stronger than the tonic. The major third (4:5) is also very clear, as is the major second (8:9). Very clear, too, the major seventh (8:15 or 1088 cents) a third above the fifth. But this is not the one preferred in practice which at 1104 cents is above the dotted line of equal temperament.

The 4:7 interval at 969 cents is very interesting. Very audible. Clear in the tanpura sound . But ask any Indian musician: "Do you hear that?". – "No…". You sing it. It's very clear. You soften your voice to hear the tanpura better. "No. It doesn't exist. What are you singing? It's out of tune!"

D.E.Lekkas: Excuse me, do you mean they have been trained away from hearing that harmonic, or how do you account for that?

W.v.d.Meer: I suppose so. I suppose the ear is so much trained to hear those set intervals that an interval that's out of …

C.Barlow: Yes, but look at Western music: if you play a low note on the piano you hear the seventh harmonic very clearly. And none of our harmony has a natural seventh in it.

D.E.Lekkas: Well that's different from not being able to hear it. You might not use it but you should be able to hear it.

C.Barlow: I think it's a matter of openness, actually. It's probably lacking there in a certain respects.

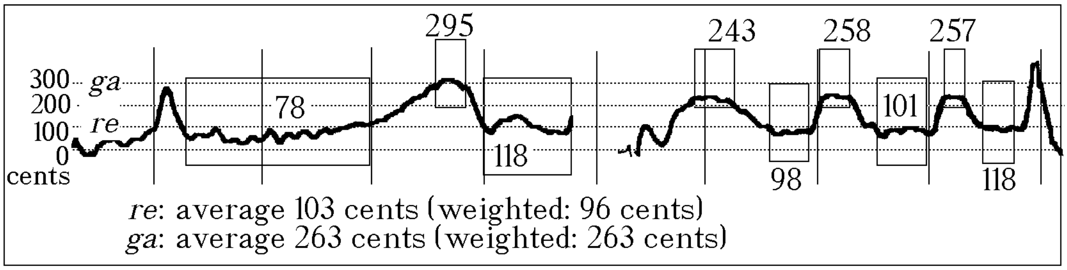
The problem of measurement

W.v.d.Meer: Now let us listen to just one small musical fragment.

(Tape example)

In **Ex.6** (next page) you see a line representing what you just heard, the minor second and the minor third in the Raga *Todi* sung by the great Mallikarjun Mansur, who died a few months ago. This picture is obtained by pitch extraction. A lot of the research we did was based on fundamental pitch extraction. It was done by a machine designed by Bernard Bel in Bombay, on which a large amount of material was processed. Of course I later used the techniques that were developed here in Holland for pitch extraction, a programme that's called LVS that's quite satisfactory to people nowadays. And I also developed a pitch extractor myself to be able to do this work at home and on a normal computer, because all those things work on special computers. Bernard's machines are in Bombay and the LVS machines are only available at phonetic labs and institutions of that kind. Whereas the one that I built works on a relatively simple Apple Macintosh.

Ex.6 – A short fragment of Raga *Todi* sung by Mallikarjun Mansur



Now pitch extraction by itself is a complex matter. I don't think I should talk about that here. But here you see the problem of how to decide what really is the intonation of the minor second and third: see here the various windows in which they were measured. You get an average here of 103 cents for the minor second, and an average of 263 for the minor third. In one case, at 295 cents, the minor third's a bit higher, but it's otherwise at 243, 258 and 257; the minor second's at 78, 118, 98, 101 and 118 cents. This happens a lot in Indian music, this moving between notes from one to another. The crazy thing is you can never really measure these notes. Already making a window makes your measurement appear lower than what maybe it should be. At the present state of the art we cannot really measure a point with great certainty because even in producing this graph there was a certain amount of smoothing going on; actually very often these graphs look like lots of tiny steps. Which point are you exactly measuring? It's very difficult to say. Moreover, looking at such a narrow point in time, the question also arises as to what note is suggested, because notes are often much more suggested than actually produced, as is clear in Ex4. **Ex.7** shows the overall spread of *re* and *ga* in *Todi*.

Questioner from the audience: I have one question about this problem, a question I came especially for. According to Daniélou, the minor third in *Todi* is a low 64:75, about 274 cents. What do you think? Did you find this interval?

W.v.d.Meer: Not really. Unless you say, "well let me find one here." If you see the variability in this kind of movement you could say "yes, well here look, he's using a 243 you know." But it makes no sense also because the pitch moves too much. And soon as the minor third is held steadily in *Todi* (which a number of musicians do, but some say you never should), it's very close to 310 cents.

C.Barlow: You have 263 as an average in that fragment.

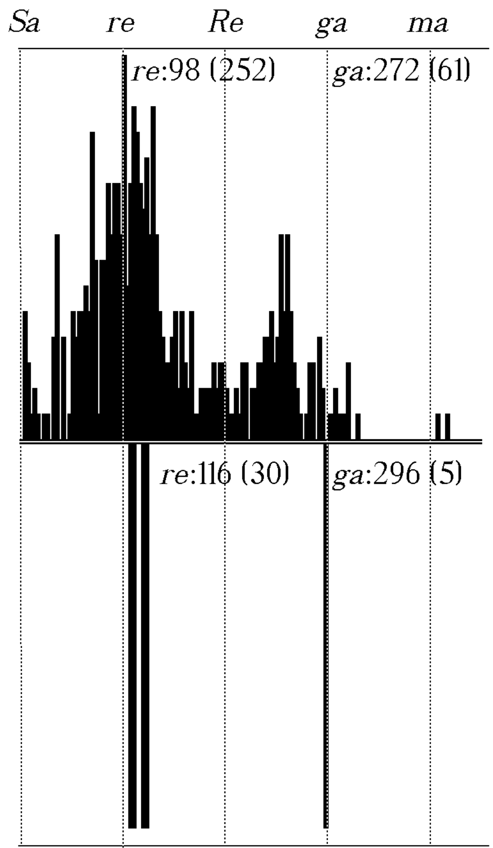
W.v.d.Meer: Yes, 263 here. But as I said, what does this really mean?

D.E.Lekkas: May I make a point of this? This 64:75 really shows up in a lot of Asian music decidedly not as a third, but always as an augmented second. So, if you don't have an augmented second with a tonic, I think it would be hardly probable that you would find it in practice. You might find it between *shrutis* further up, but not down there.

C.Barlow: Yes. Chromatically it would have the function of an augmented second, with two major thirds in it.

D.E.Lekkas: It's conscious culture that counts whether it's a second or a third.

Ex.7 – Pitch spread for the lower tetrachord of *Todi* as performed by Mallikarjun Mansur with position and weight of *re* and *ga* indicated



W.v.d.Meer: Now, if you listen to Indian music you'll in fact hear mostly that when notes are held steadily, they are very close to the twelve-tone system. With some adjustments you'll hear that the third is really harmonic. But for the rest it's a twelve-tone system.

However there is to my knowledge one clear exception:

(Tape example)

I was intending to play more of this example because it's really fantastic – this is Kishori Amonkar singing Raga *Vibhas*. And, as you've heard, there is a beautiful major sixth really way below the regular major sixth. You can see here in **Ex.8** how low it is.

Ex.8 – Two examples (about three seconds each) of the *Vibhas* major sixth as sung by Kishori Amonkar

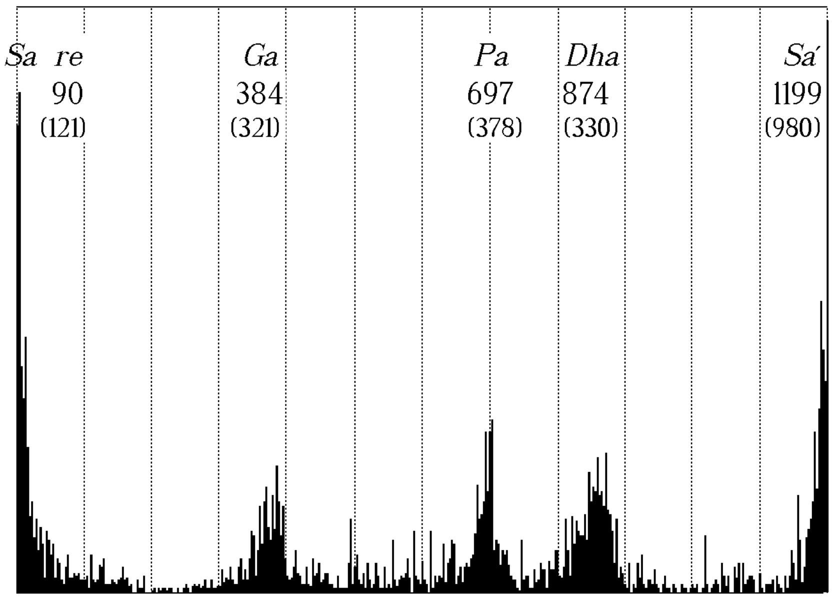
And it's interesting also to to tell you that when I discussed it with her she said, "I spent many years practising this," because it's really not easy. It's particularly difficult to get your perfect fifth in order after you've made this major sixth so much lower. The intention behind it is obvious – you see a certain consistency in the *Dha* averages measured on a number of different occasions (**Ex.9**; see also **Ex.10**).

Ex.9 – Ten cases of measured averages for the five scale degrees of *Vibhas*

	a	b	c	d	e	f	g	h	i	j
Sa	2	0	-2	-1	0	0	0	0	0	-1
re	75	90	77	90	87	92	65	145	71	86
Ga	380	388	385	384	389	375	378	360	377	386
Pa	692	696	696	697	698	698	695	690	698	696
Dha	865	875	876	874	880	878	883	875	868	877

This table also includes data from Mallikarjun Mansur (case ‘h’), the singer from whom we heard the *Todi*. Both Amonkar and Mansur are extremely reliable artists. Absolute top of the Indian tradition. And you see here a clear and blunt deviation from the general model of our system of twelve semitones.

Ex.10 – Pitch spread for Raga *Vibhas* (positions in cents, weights bracketed)



J.Tenney: It’s very close to a 3:5. It’s almost right on it.

W.v.d.Meer: No. There is a very audible difference.

J.Tenney: Yes. A 3:5 is only a few cents down.

H.Radulescu: It’s a thirteenth harmonic.

J.Tenney: You’re within ten cents of a 3:5 in all cases.

W.v.d.Meer: I would say more like twenty cents.

A.LaBerge: Well, what did she say?

W.v.d.Meer: Oh, this is absolutely of interest, because if you are talking about the 3:5, which is found quite commonly (and quite steady) in Indian music if you have the tanpura tuning in *ma*, the perfect fourth. If the tanpura is tuned to the perfect fourth, then the major sixth will have that 886 cents position (see **Ex.11**), but the one in *Vibhas* is definitely lower than that and she knows it very well, having to work hard to make it that low. It's so much more out of tune, in the Indian conception of intonation.

J.Tenney: Can we hear it again? I didn't hear it out of tune.

H.Radulescu: You're not an Indian!

(Repeat of the last tape example)

J.Tenney: That's a real good 3:5 I hear.

W.v.d.Meer: Very clearly not I'm afraid. I would never sing that *Dha* of *Vibhas*, not even try to, whereas the 3:5 is a piece of cake.

Ex.11 - Tabulation and evaluation of raga tunings with a *ma*-tuned tanpura (Pa-tuning supplied for comparison)

Scale-degree Name	Semitones	Theoretical syntonically alternatives in cents with ratio (and derivation)		Measured average in cents (range and position in % of a syntonic comma)	
				ma-tuning	*Pa*-tuning
Sa (do)	0	0 1:1			0 (37/103)
re (re♭)	1	90 243:256(IVx5)	112 15:16(IV-III)	91 (100/2)	94 (90/16)
Re (re♮)	2	182 9:10(IV+III-V)	204 8:9(Vx2)	197 (30/67)	204 (110/102)
ga (mi♭)	3	294 27:32(IVx3)	316 5:6(V-III)	299 (60/23)	304 (140/46)
Ga (mi♮)	4	386 4:5(III)	408 64:81(Vx4)	396 (50/43)	390 (110/20)
ma (fa♮)	5	498 3:4(IV)	520 20:27(Vx2-IV-III)	498 (10/0)	501 (150/13)
Ma (fa♯)	6	588 729:1024(IVx6)	612 512:729(Vx6)	595 (140/27)	608 (180/84)
Pa (sol)	7	678 177147:262144(IVx11)	702 2:3(V)	690 (--/50)	702 (40/100)
dha (la♭)	8	792 81:128(IVx4)	814 5:8(VIII-III)	802 (170/43)	801 (120/43)
Dha (la♮)	9	884 3:5(IV+III)	906 16:27(Vx3)	889 (40/21)	899 (100/69)
ni (si♭)	10	996 9:16(IVx2)	1018 5:9(Vx2-III)	1001 (100/24)	1008 (230/56)
Ni (si♮)	11	1088 8:15(V+III)	1110 128:243(Vx5)	1105 (70/76)	1104 (160/71)

Ex.11 continued

The few cases of *ma*-tuned ragas are interesting:	
re	remains, as with *Ma* and *Ni*, at about 95±4 cents from drone centres
Re	stable and surprisingly quite high
ga	slightly lower than with *Pa*-tuning
Ga	higher than in *Pa*-tuning, probably due to the 95ct proximity to *ma*
ma	very stable, exactly at the low position
Ma	see *re*
Pa	only one case was measured, not surprisingly low
dha	here the least stable, at the same pitch as with *Pa*-tuning
Dha	stable and low as expected
ni	slightly lower than with *Pa*-tuning (as with *ga*)
Ni	see *re*

Historical background of the *Vibhas* tuning

I will finish my talk here. You should still know in this particular case that there are three varieties of Raga *Vibhas*. One is just like the Raga *Bhup*, *Sa Re Ga Pa Dha* (do re mi sol la). Then there is *Sa re Ga Pa Dha* (do re♭ mi sol la), which you just heard with the minor second. The third is *Sa re Ga Pa dha* (do re♭ mi sol la♭) in which both the second and the sixth are lowered. Now it could be the case that this raga was imported from another culture where quarter-tones are used. I don't know for sure, because I don't know any other than Indian music. Perhaps this *Dha* (la) has been slowly trying in the process to find a place either in the higher or in the lower position. It could also be that what's happening is a transition from one to the other, a kind of transition seen very often in Indian music, of notes one by one slowly shifting by a semitone: that would be particularly probable in this case because there are already four ragas using these tones and it's really very confusing.

It has been shown to be a general principle, that when there are many ragas using the same tones, some modification starts taking place in one of them to differentiate it from the others. So it could be simply a process in which *Re* (re) and *Dha* (la) are slowly being lowered. One point that is perhaps in that direction is that Mallikarjun takes the second at 145 cents, higher than the normal minor second.

W.Swets: It sounds to me like the Turkish makam *Hicaz*. There you have the same thing. The high minor second and the third a little bit lower, and the sixth has about that pitch. But then of course *Hicaz* is heptatonic, not like *Vibhas*.

Some final conclusions:

> *Natural intonation is based on harmonic matching, the coincidence of the n–th harmonic of the drone with the m–th harmonic of the instrument.*
>
> *Whenever harmonic matching offers two possibilities, temperament occurs.*
>
> *Inverted matching is more difficult – you have to listen to whether the drone is in tune with the note you produce.*
>
> *The combined spectrum of the drone with its adjacent semitones has a unique quality that defies the laws of consonance.*

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1. Editor's Note: The note-names of North Indian music are based on the seven degrees of the major diatonic scale, named as follows (commonly used abbreviations in brackets): *Shadj* (*Sa*), *Rshabh* (*Re*), *Gándhár* (*Ga*), *Madhyam* (*Ma* or *ma*), *Pancham* (*Pa*), *Dhaivat* (*Dha*) and *Nishád* (*Ni*). Through the addition of the lowered (*komal*) second, third, sixth and seventh (notated <u>*Re*</u>, <u>*Ga*</u>, <u>*Dha*</u>, <u>*Ni*</u> or alternatively *re*, *ga*, *dha* and *ni*) and the raised (*tivra*) fourth (notated *Ma♯* or *Ma* [against *ma* for the perfect fourth]), one gets the complete twelve-tone chromatic scale as generally used in North Indian music. The notation system used here is *Sa - re - Re - ga - Ga - ma - Ma - Pa - dha - Dha - ni - Ni - Sa´.*

Bernard Bel

Rationalizing Musical Time: Syntactic And Symbolic-Numeric Approaches

> Music, like mathematics but unlike language, is not intelligible unless it is grammatical: its form is its content. As a product of "the unchanging human mind" and body in the context of different cultures, music reflects both man's biological structure and the patterns of interaction that have been institutionalized as systems of relationships in culture. (Blacking 1974)

This paper deals with various problems in quantifying musical time encountered both in the analysis of traditional drumming and in computer-generated musical pieces based on "sound-objects", meaning code sequences controlling a real-time sound processor.

In section 1 it is suggested that syntactic approaches may be closer to the intuitions of musicians and musicologists than commonly advocated numeric approaches. Furthermore, symbolic-numeric approaches lead to efficient and elegant solutions of problems of constraint-satisfaction relative to symbolic and physical durations, as illustrated in sections 2 and 3 respectively.

1. A syntactic representation of musical accentuation

Many players of the tabla, a North Indian two-piece drum set, claim to follow a "rational" system of improvisation, the rules of which are generally not explicit and are conveyed informally to students – much like a natural language. Therefore, a strong initial motivation of our formal study of the Lucknow tabla tradition was the challenge of modelling a knowledge relying exclusively on oral transmission (Kippen & Bel 1989a). Indian musicians represent elementary sounds or finger movements by onomatopeic syllables ("bols", from the verb *bolna*, to speak), precisely transcribable on a computer (Kippen 1988:xvi–xxiii). The very first version of the Bol Processor (BP1) of 1982 was a customized word-processor allowing real-time transcription of drumming sequences thanks to a mapping of keyboard strokes to the vocabulary of tabla bols.

Analytical work was then undertaken with the aim of (1) making rules explicit for some compositional types, and (2) checking the consistency of musicians' assessments of correctness in both teaching and performance situations.

Here is an example of a compositional type named *qa'ida*, a theme and variations form par excellence (Kippen 1988:xi) from the Ajrara tradition. Read linearly from left to right, each group represents a beat comprising six units – note the variable lines in italics.

Theme:

dhin-dhagena	dha-dhagena	dhatigegenaka	dheenedheenagena
tagetirakita	dhin-dhagena	dhatigegenaka	teeneteenakena
tin-takena	ta-takena	tatikekenaka	teeneteenakena
tagetirakita	dhin-dhagena	dhatigegenaka	dheenedheenagena

A few variations:

dhin--dhagena	dha--dhagena	dhatigegenaka	dheenedheenagena
tagetirakita	dhin--dhagena	dhatigegenaka	teeneteenakena
dheenedheenagena	*teeneteenakena*	*tirakitatira*	*kitatirakita*
tagetirakita	dhin-dhagena	dhatigegenaka	teeneteenakena
tin--takena	ta--takena	tatikekenaka	teeneteenakena
taketirakita	tin--takena	tatikekenaka	teeneteenakena
dheenedheenagena	*teeneteenakena*	*tirakitatira*	*kitatirakita*
tagetirakita	dhin-dhagena	dhatigegenaka	dheenedheenagena

dhin--dhagena	dha--dhagena	dhatigegenaka	dheenedheenagena
tagetirakita	dhin--dhagena	dhatigegenaka	teeneteenakena
dhin--dhagena	*dha-dha-dha-*	*dhagenadheen--*	*dhagenadha--*
tagetirakita	dhin-dhagena	dhatigegenaka	teeneteenakena
tin--takena	ta--takena	tatikekenaka	teeneteenakena
taketirakita	tin-takena	tatikekenaka	teeneteenakena
dhin--dhagena	*dha-dha-dha-*	*dhagenadheen--*	*dhagenadha--*
tagetirakita	dhin--dhagena	dhatigegenaka	dheenedheenagena

dhin--dhagena	dha--dhagena	dhatigegenaka	dheenedheenagena
tagetirakita	dhin--dhagena	dhatigegenaka	teeneteenakena
dheenedheenagena	*dheenedha-dheene*	*dhatigegenaka*	*teeneteenakena*
tagetirakita	dhin-dhagena	dhatigegenaka	teeneteenakena
tin--takena	ta--takena	tatikekenaka	teeneteenakena
taketirakita	tin--takena	tatikekenaka	teeneteenakena
dheenedheenagena	*dheenedha-dheene*	*dhatigegenaka*	*teeneteenakena*
tagetirakita	dhin--dhagena	dhatigegenaka	dheenedheenagena

Observations of several samples of variations (from performances and demonstrations by the late Ustad Afaq Husain Khan of Lucknow) suggested to us that the variable lines were made with "words", bol-chunks of lengths three, four and six in permutations we presumed context-free: no technical (fingering) difficulties were encountered with words arranged in arbitrary order.

The most frequent words are listed in the following lexical rules:

A3	→	dhin--
A3	→	dha--
A3	→	dhagena
A4	→	tirakita
A3 A3	→	dhagenadhin--
A3 A3	→	dhagenadha--
A6	→	dha-dha-dha-
A6	→	dha-ta-dha-
A6	→	dheenedheenedheene
A6	→	dheenedha-dheene
A6	→	tagetirakita
A6	→	dheenedheenagena
A6	→	teeneteenakena
A6	→	dhatigegenaka

In view of their frequent occurrence in examples, the words "dhagenadhin--" and "dhagenadha--" have been listed specifically. A grammar for defining all possible sequences in variable lines of six, twelve or twenty-four units is easy to construct (Kippen & Bel 1992). However, some pieces generated by the grammar display irregularities in their accentuation. For instance,

dhin--tiraki tadhagenadhati gegenakatira kitatirakita

imposes a rhythm counter to the natural stresses of the beat and half-beat and is therefore virtually impossible to recite or perform at speeds normally employed by musicians (MM 108-120, i.e. up to twelve bols per second). In a four-beat string comprising twenty-four units, primary accents fall on beats and half-beats: 1, 4, 7, 10, 13, 16, 19 and 22. A cursory analysis of variations created by musicians showed that in addition to these divisions they employed hemiolic rhythmic patterns beginning on units 1, 7 and 13. This produces a series of secondary stresses on units 5, 9, 11, 15, 17, 21. Here is a list of possible starting positions for the blocks defined above:

A3:	1, 4, 7, 10, 13, 16, 19, 22
A4:	1, 5, 7, 9, 11, 13, 15, 17, 21
A6:	1, 4, 7, 10, 13, 16, 19
tagetirakita:	1, 4, 5, 7, 9, 10, 11, 13, 15, 16, 17, 19

The exceptional status of "tagetirakita" is due to the fact that it is accentuated in two different ways. Therefore it is labelled with a new variable: C6.

We developed a way to systematically define derivations of B24, B12, and B6 by taking into account acceptable starting positions:

```
B24 → A3 B21   ...(A3 in starting position: 24 – (3+21) +1 = 1)
B24 → A4 B20
B24 → C6 B18
B24 → A6 B18
B21 → A3 B18   ...(A3 in starting position: 24 – (3+18) +1 = 4)
B21 → A4 B17   ...(cancelled: A4 in starting position 4)
B21 → A6 B15
B21 → C6 B15
B20 → A3 B17   ...(cancelled: A3 in starting position 5)
B20 → A4 B16
B20 → A6 B14   ...(cancelled: A6 in starting position 5)
B20 → C6 B14
etc...
```

This grammar may produce a string "A4 A4 A4 A4 A4 A4", the only derivation of which is an unbroken series of *tirakitas* musicians would certainly assess as incorrect. More than two consecutive A4s were found to be unacceptable. The solution to this problem lies in introducing left contexts in all rules producing A4. Rather then listing all acceptable left contexts (as standard Chomsky grammars require), we found it practical to introduce negative contexts.

The resulting grammar is

```
B24          → A3   B21
#A4 #A4 B24  → #A4 #A4 A4 B20
B24          → C6   B18
B24          → A6   B18
B21          → A3   B18
B21          → A6   B15
B21          → C6   B15
#A4 #A4 B20  → #A4 #A4 A4 B16
B20          → C6   B14
...
etc...
```

Here, for instance, rule "#A4 #A4 B24 → #A4 #A4 A4 B20" means
"B24" may be rewritten "A4 B20" if not preceded by "A4 A4".

A full description of the grammar of this *qa'ida* is discussed in (Kippen & Bel 1992, appendix 3); a variant of it is available in the Bol Processor BP2 shareware package.

A detailed comment of syntactic extensions of the formal language model applied to musical sequences we call BP grammars may be found in (Bel & Kippen 1992). Readers may also refer to (Bel 1992) in order to understand the parsing algorithm used for assessing the compatibility of arbitrary sentences with a given BP grammar.

The *qa'ida* example makes it clear that quantization of rhythm and metre, although generally described as a typical numeric problem (e.g. Vuza 1988), may also yield syntactic descriptions with the advantage of reflecting productive and analytical processes based on *permutations* and *substitutions*. Learning these processes from examples is an important part of the basic training in traditional drum improvisation/composition (Kippen & Bel 1989b).

2. Symbolic representation of discrete sound-object structures

2.1 Bol Processor BP2: the environment

"BP2" is a new version of the Bol Processor operating in both MIDI and Csound environments for design-based (stipulatory) or improvisational *rule-based composition* (Laske 1989:51,53). It is available as a shareware package for Macintosh computers distributed on Info-Mac mirror sites[1].

Several operational modes are available in BP2, from one that leaves all decisions to the machine (stochastic improvisation) to one that allows a composer to take stepwise decisions. The interaction of modules in the MIDI environment is summarized in **Ex.1**.

Three fields are used for storing a grammar, items generated by the grammar (on the basis of decisions taken by the inference engine) and sound-object prototypes (arbitrary message sequences loaded from a MIDI musical instrument and edited manually). Terminal symbols in the grammar are the labels of sound-objects replacing the onomatopeic syllables (bols) used by BP1.

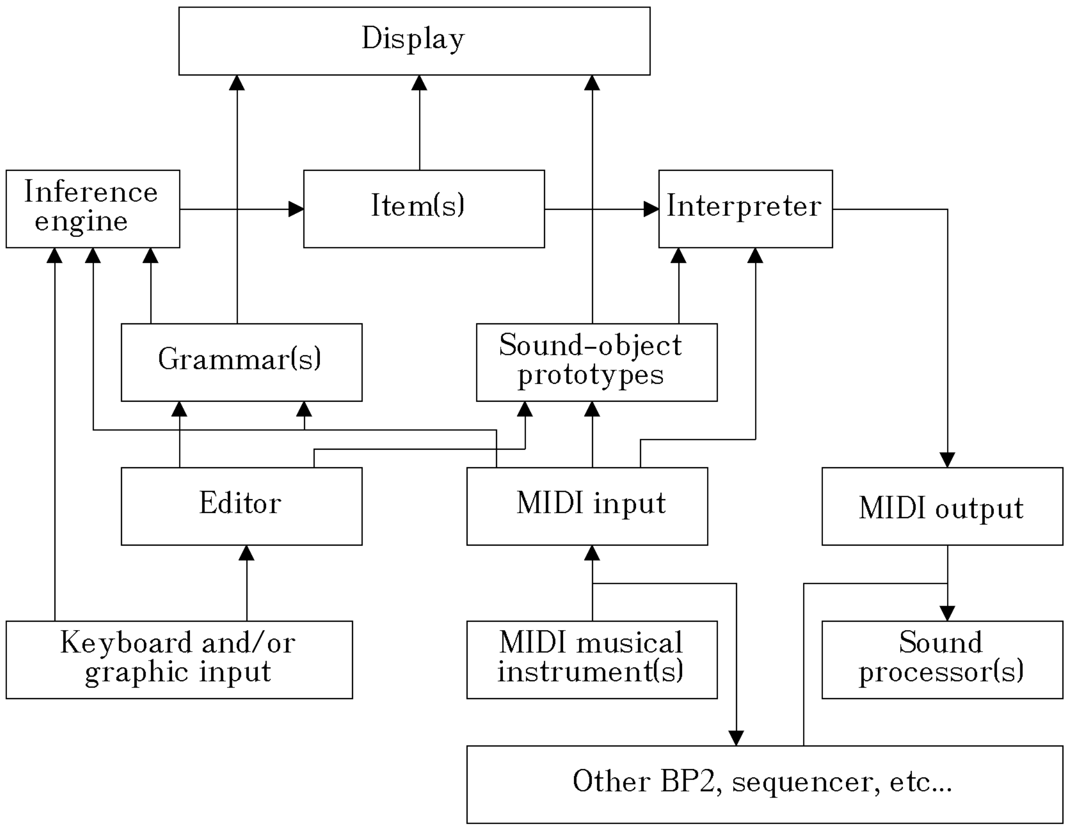
The interpreter works in three stages:

1) The item generated by the grammar is interpreted as a polymetric expression (see §2.7 infra). The output is a complete polymetric expression yielding a bidimensional array of terminal symbols called the phase diagram (see §2.3).

2) The expression is interpreted as a sound-object structure, using information about the structure of time (see §2.2) and object prototype definitions. The main output is an extension of the phase table containing the performance parameters of objects in the structure: their start/clip dates, time-scale ratios, etc.

3) MIDI messages contained in sound-objects are dispatched in real time to control the sound processor. Optionally, a Csound score is produced.

Ex.1 - A block diagram of Bol Processor BP2



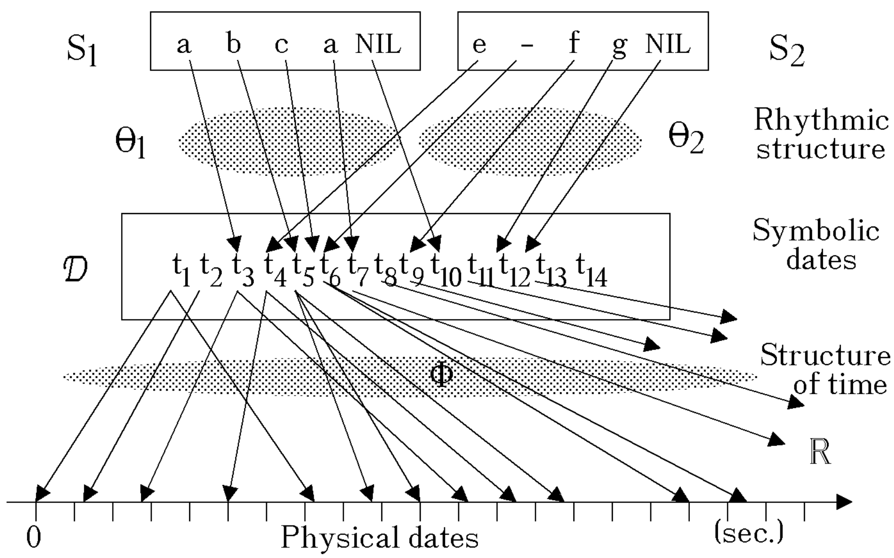
The diagram indicates that external control can be exerted on the inference engine, grammars and the interpretation module. Specific MIDI messages may be assigned to changes of rule weights, tempo, the nature of time (striated/smooth) and many other parameters. Messages may also be used for synchronizing events during the performance, or even assigning computation time limits. These features are used in improvisational rule-based composition.

Several BP2s may be linked together and with other devices such as MIDI sequencers. Messages on the different MIDI channels may be used to make machines communicate or control several sound processors. Thus it must be kept in mind that "sound-objects" do not necessarily produce sounds; depending on the implementation, they may contain any kind of control/synchronization message as well.

2.2 Symbolic time

Assume that "a", "b", "c", "e", "f", "g" and "-" are labels of arbitrary sound-objects (similar to "dhin", "dha", etc. in §1). Label "-" is reserved for silences which are viewed as particular objects. **Ex.2** represents a structure of two sequences which, as a first approximation, might be notated S_1 = "a b c a" and S_2 = "e - f g".

Ex.2 - A representation of sequences S_1 and S_2.



Here a set of strictly ordered *symbolic dates* $\mathcal{D}$ = $(t_1,t_2,...)$ is introduced along with Θ_i, an injective mapping of each S_i into $\mathcal{D}$. By convention, each Θ_i is a monotone increasing function: sequentiality implies that all objects appearing in a sequence are ordered in increasing symbolic dates. Each mapping Θ_i may in turn be viewed as a restriction to S_i of a general mapping Θ which we call the *rhythmic structure* of the sound-object structure. "NIL" symbols are used to mark the ends of sequences.

The mapping of sequences to the set of symbolic dates is mainly information about the ordering of any pair of events belonging to either sequence. Here, for instance, S_1 and S_2 will partly overlap.

The set of symbolic dates $\mathcal{D}$ is then mapped to physical time, i.e. the set of real numbers $\mathbb{R}$. We call this mapping Φ the *structure of time* (the same was called *structure temporelle* in Xenakis 1963:190-191,200). In the above example, Φ is a multivocal mapping, which means, for instance, that each sound-object "a" and "e" at symbolic date t_3 would be performed twice. In general only strictly increasing (univocal) mappings are envisaged, so that

$$\forall i,j \in \mathbb{N},\ t_i < t_j <=> \Phi(t_i) < \Phi(t_j).$$

In this case, if we consider $\mathrm{Dist}(t_i,t_j) = |\Phi(t_j)-\Phi(t_i)|$ (the absolute difference value), Dist is a distance on $\mathcal{D}$.

Besides, since

$$\forall i,j,k \in \mathbb{N},\ \mathrm{Dist}(t_i,t_j) + \mathrm{Dist}(t_j,t_k) \geq \mathrm{Dist}(t_i,t_k)$$

$(\mathcal{D},\mathrm{Dist})$ is also a *metric* space. $(\mathcal{D},\mathrm{Dist})$ is also *Euclidian (metronomic time)* if this additional property holds:

$$\forall i,j,k,l \in \mathbb{N},\ j-i = l-k => \Phi(t_j) - \Phi(t_i) = \Phi(t_l) - \Phi(t_k)$$

The composition of the two mappings (Φ,Θ) is the in-time structure of the musical item, i.e. the mapping that permits its actual performance.

As suggested by the terminology, structure of time and in-time structures are two concepts borrowed from Xenakis (1963). We find these concepts essential as they deal with sets of physical dates not necessarily structured as a Euclidian space.

2.3 Phase diagram

Both sequences of the last example may be represented together in a single array (the *phase diagram*), the columns of which are labelled and ordered on symbolic dates (see **Ex.3** – the *empty sound-objects* "_" indicate the prolongation of the preceding sound-object, if any, and should not be confused with silences "-").

Ex.3 - A phase diagram

t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}	t_{11}	t_{12}	t_{13}	t_{14}
_	_	a	_	b	c	a	_	_	NIL	_	_	_	_
_	_	_	e	_	-	_	_	f	_	g	NIL	_	_

Using this information, S_1 and S_2 are properly notated as

S_1 = a _ b c a _ _ $\quad\quad$ S_2 = e _ - _ _ f _ g .

Here the relative position of the next non-empty sound-object or "NIL" marker shows the *symbolic duration* of a sound-object. In S_2, "e", "-", "f", "g" have symbolic durations 2, 3, 2, 1, respectively. S_1 contains "a" twice with respective durations 2 and 3. If "a", "b" etc. express conventional note-lengths, taking "b" as a quarter-note would make "e" a half-note and "-" a dotted half-note rest.

2.4 Smooth vs striated time

Pierre Boulez (1963:107) introduced the notions *smooth time* ("*temps lisse*") and *striated time* ("*temps strié*") to characterize two typical music performance situations. Striated time is *filled with pulse* (regular or irregular), whereas smooth time *does not imply any counting*: a particular case of striated time is of course the pulse of a metronome. Examples of smooth time are common outside Baroque music, e.g. melodic introductions in Indian raga music.

In computer-generated music, these notions are bound to the structure of time (the Φ mapping): in striated time, Φ is known in advance, whereas in smooth time it is determined at the time of performance. Therefore, a *striated structure of time* is a set of physical dates defining *reference streaks* on which sound-objects should be positioned (see §3) whereas a *smooth structure of time* is a set of dates determined by the sound-objects themselves.

2.5 Out-time objects

Sound-objects have strictly positive symbolic durations. In some cases it is useful to have "flat" objects with null durations called *out-time objects*, i.e. sound-objects executed "simultaneously" or in very quick succession. A typical application of out-time objects in BP2 is the exchange of parameters or synchronization messages. For a sound-object "a", the corresponding out-time object is notated "«a»". In this convention, a string like "«a» b" represents a structure in which out-time object "«a»" starts at the same symbolic date as sound-object "b".

2.6 Tempo markers

Sound-object sequence "a b c d e f" may be notated "/1 a b c d e f", where "/1" is an *explicit tempo marker*. To play the same sequence five times faster we write "/5 a b c d e f", a notation already used in BP1 to indicate *bol density*. North Indian drummers and dancers say *dogun*, *tigun* etc. for bol densities of two, three etc. *bols per matra* (beat).

Explicit tempo markers make it possible to modify tempo within a single sequence. For instance, in the sequence

/2 a b c d e f /3 g h i j k l m n o

"a"..."f" are played at bol density 2 (two sound-objects per beat), then "g"..."o" at bol density 3, a tempo acceleration of $^3/2$, also notatable as /6 a_ _ b_ _ c_ _ d_ _ e_ _ f_ _ g_ h_ i_ j_ k_ l_ m_ n_ o_ .

Silences may be notated with hyphens or integers. These notations are strictly equivalent:

/2 a b - - c d /5 e - - - - f g h
/2 a b - _ c d /5 e - _ _ _ f g h
/2 a b 2 c d /5 e 4 f g h

Rational numbers may also indicate fractional silences, e.g.

/1 a b /2 c d e f 4/3 g h

where "a" and "b" are at bol density 1, "c", "d", "e", "f", "g" and "h" at bol density 2, while sequences "cdef" and "gh" are separated by a silence of duration $^4/3$. Since this silence has bol density 2, its actual symbolic duration is $^4/3 \times {}^1/2 = {}^2/3$. Here, BP2 expands the representation to /6 a _ _ _ _ _ b _ _ _ _ _ c _ _ d _ _ e _ _ f _ _ - - - - g _ _ h _ _, where the "4/3" silence appears as "- - - -" (or equivalently as "- _ _ _" or "4").

Suppose we wish to superimpose two sequences A and B defined by rules A → a b c A → d e f g B → h i
in which "a", "b", ... "i" are labels of sound-objects. Alternative definitions of "A" indicate that it may contain either three or four objects. To start with, we do not know how to interpret the exact superimposition of two sequences: combining "abc" and "hi" may for example yield the following four alternative phase diagrams:

(1)	(2)	(3)	(4)	
a b c	a b c	a _ b _ c _	a _ b c	etc...
h i _	_ h i	h _ _ i _ _	h i _ _	

The prolongation symbols "_" could be replaced by silences ("-"). However, since silences do not explicitly appear in the grammar, we may postulate that creating them is not a valid choice. We also discard interpretations (1) and (4) wherein equal symbolic durations are not maintained within the string "hi". Finally it is reasonable to expect a synchronization of both the start and clip points of the synchronized sequences, there thus being no reason to start "a" before "h" as suggested by (2). As a result, the most intuitively appealing interpretation (failing any additional information) is (3).

Now we introduce a notation of superimpositions:
{A,B} (or its equal, {B,A}) is the superimposition of sequences "A" and "B". We call "{A,B}" a *polymetric expression* with *arguments* "A" and "B". Using this notation, a grammar yielding all acceptable superimpositions of "A" and "B" would be:

S → /1{A1,B1}	A1 → a _ b _ c _	B1 → h _ _ i _ _
S → /1{A2,B2}	A2 → d e f g	B2 → h _ i _

We need to check that a string like "/1{d e f g, h _ i _}" contains an equal number of terminal symbols in both arguments, failing which the phase diagram cannot be constructed. It is evidently cumbersome to have two versions of "B" – they point to identical ratios of symbolic durations: "B2" resembles "B1" in every respect. Ideally, the grammar that should be used is

S → /1{A,B} A → a b c A → d e f g B → h i

expecting that there will be a method for interpreting an *incomplete polymetric expression* like /1 {a b c, h i} as

/2 {a _ b _ c _, h _ _ i _ _}

i.e. a *complete polymetric expression.*

Note that the tempo marker now indicates bol density 2 because of stretched durations. Thus, for instance, the symbolic duration of "b" remains one beat. A compact representation of this complete expression uses explicit tempo markers in each argument, i.e.:

{/3 a b c , /2 h i}

showing the classical "three-in-two" polyrhythm, along with the information that tempo should be divided by a *time scale factor* of three so that actual durations will be the ones we expect.

Interpreting polymetric expressions is the task of a fast algorithm implemented in BP2 (Bel 1991-1992). Since the algorithm makes use of arithmetic operators such as LCM (lowest common multiple) together with rewrite procedures it may be classified as a *symbolic-numeric* method. Thanks to recursivity it is possible to interpret nested expressions such as {i{a b, c d e}, j k} yielding {/6 i{/6 a b, /9 c d e}, /4 j k} (in which the time scale factor is six).

If some arguments contain explicit tempo markers indicating a compulsory bol density, the algorithm will try to satisfy all constraints so that arguments of polymetric expressions finally have identical symbolic durations. In some cases there is no solution; therefore it is preferable (and always possible) to avoid writing explicit tempo markers in sequences or in polymetric structures, as we will now show.

2.8 Polymetric representation of a sequence

Introducing a string of silences as the first argument of a polymetric expression is a good method for suppressing explicit tempo markers in a sequence. For instance,

	a b c _ /3 d _ e
may be notated	a b c _ /3 {- - -, d _ e}
which is equivalent to	a b c _ /3 {3, d _ e}
	a b c _ {3/3, d _ e}
	a b c _ {1, d _ e}

The advantage of the last notation is that the same expression may be used at different tempos. For instance, when it needs to be performed four times faster we just write

	/4 a b c _ {1, d _ e}
rather than	/4 a b c _ /12 d _ e

which forces us to recalculate the second tempo marker.

Polymetric representation, therefore, makes it possible to build very complex musical structures by way of simply rewriting rules (formal grammars), given that the computation of symbolic durations and the matching of superimposed sequences is ultimately taken care of by a unique and efficient polymetric interpretation algorithm.

Other features relative to polymetric expressions (along with typical examples in conventional music notation) may be found in (Bel 1991-1992).

3. The time setting of sound-objects

Informally, *instantiating* a sound-object means dispatching to the sound processor all messages defined in its prototype. A naive interpretation of sequences of sound-objects would be to arrange all corresponding time intervals strictly sequentially. Duthen and Stroppa (1990) have suggested a more general approach starting from the assumption that any sound-object may possess one or more time points playing a particular role, e.g. a climax. These points they call *time pivots*. They further suggest the construction of sound structures using a set of synchronization rules. Their approach is attractive but hard to implement if the formalism of synchronization rules remains too general. We therefore simplified their idea, assigning to each object a single pivot.

Consider for instance a complete polymetric structure S_1, S_2, S_3 derived as

{a _ b c d _ e , a _ f _ g h _ , j i _ a _ i _}

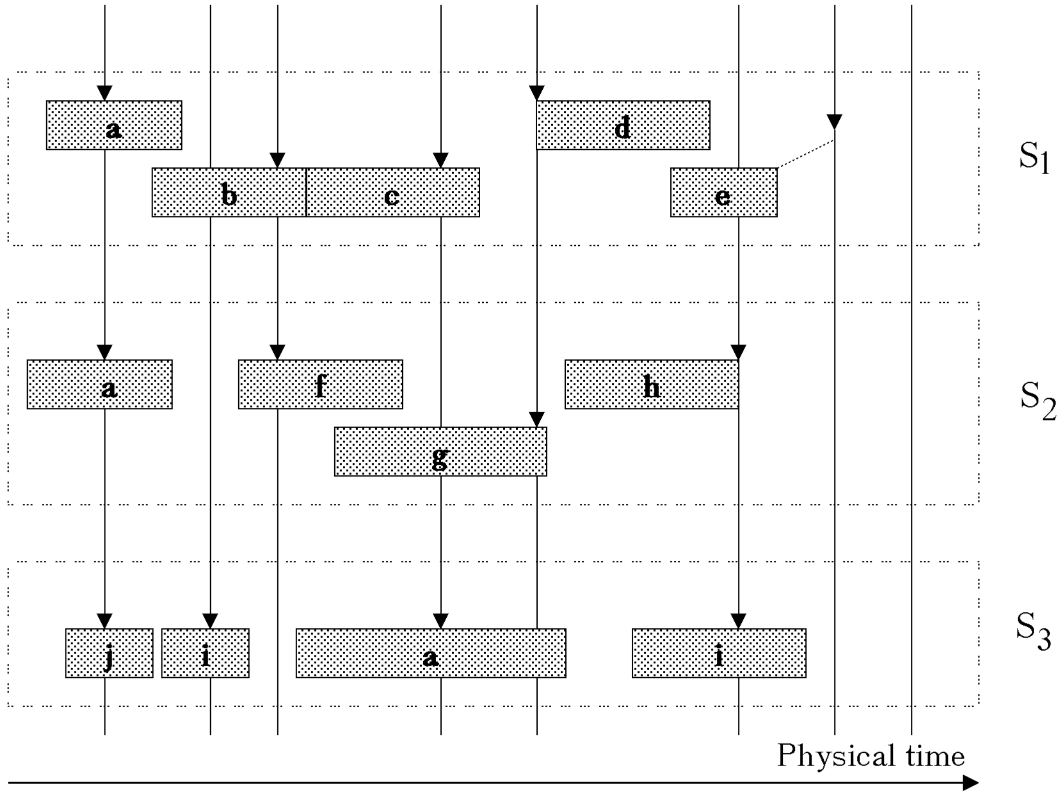
yielding the phase diagram

a	_	b	c	d	_	e	NIL
a	_	f	_	g	h	_	NIL
j	i	_	a	_	i	_	NIL

The definition of each sound-object contains the relative location of its pivot and metrical properties allowing the calculation of its "time-scale ratio" – informally, a factor adjusting the duration of the sound-object to the current speed of performance.

Ex.4 is a graphic representation of a possible instance of this polymetric structure as displayed by BP2:

Ex.4 – A structure of sound-objects



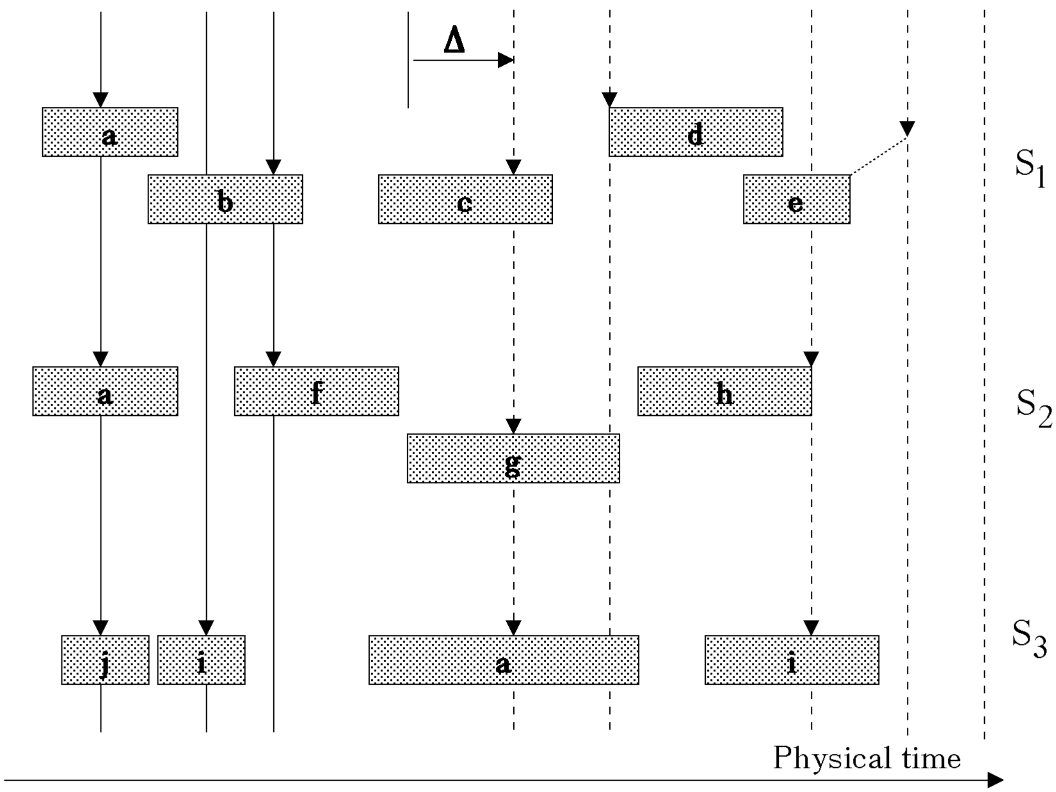
Here, the structure of time is an irregular pulsation represented by vertical lines (time *streaks*). Each sound-object's time-span is seen as a rectangle with arbitrary vertical width and position; these positions were chosen to separate objects in the diagram. It is clear, for example, that "c", "f", "g" and "a" have overlapping time-spans between the third and fourth streaks. Lengths of rectangles represent the physical durations of sound-objects. Out-time objects, if any, would appear as vertical segments. Vertical arrows indicate time pivots. As with "e", the pivot is not necessarily a time point within the time-span of the sound-object.

This diagram shows the *default positioning* of objects with their pivots located exactly on time streaks. Although it is reasonable that instances of "c", "f" and "a" overlap between the third and fourth streaks since they belong to distinct sequences performed simultaneously, it may not be acceptable that "f" overlaps "g" in a single sequence S_2, the same holding for "d" and "e" in S_1. It may also be unacceptable that the time-spans of "j" and "i" are disjunct in S_3 while no silence is shown in the symbolic representation.

How could one deal with a constraint such as *the end of sound-object "f" may not overlap another sound-object in the same sequence*? If object "g" is relocatable then it may be delayed (shifted to the right) until the constraint is satisfied. We call this a *local drift* of the object. Yet the end of "g" will now overlap the beginning of "h". Assume that this too is unacceptable and "h" is not relocatable: we should then look for another solution, e.g. truncate the beginning of "h". If this and other solutions are not acceptable then we may try to shift "f" to the left or to truncate its end. In S_1 it might also become necessary to shift or truncate "a"...

So far we suggested constraint propagation within one single sequence. In the time-setting algorithm the three sequences, taken in order, are S_1, S_2, S_3. Suppose that the default positioning of objects in S_1 satisfies all constraints but no solution has been found to avoid the overlapping of "f" and "g" in S_2. A new option is to envisage a *global drift* to the right of all objects following "f" in S_2. The global drift is notated Δ on **Ex.5.** All time streaks following the third one are delayed (see the dotted vertical lines).

Ex.5 - A solution using global drift



This solution is called “break tempo” because its effect is similar to the *organum* in conventional music notation. Although the global drift increases the delay between the third and fourth streaks, the physical durations of sound objects are not changed because their time-scale ratios have been calculated beforehand.

Now the positioning of objects in S_2 is acceptable, but it might have become unacceptable in S_1: there may be a property of “b” or “c” saying that their time-span intervals cannot be disjunct, so that “c” could be shifted to the left, etc. Evidently, whenever a global drift is decided the algorithm must start again from the first sequence.

The process of locating – i.e. *instantiating* – sound-objects, as illustrated in this example, is the task of the *time-setting algorithm* imbedded in BP2. If no global drift is created, the time complexity of the time-setting algorithm is $O(nmax.imax^3)$, where “nmax” is the number of sequences and “imax” the maximum length of a sequence. In the worst case, the time complexity is given by $O(nmax^2.imax^3)$. The algorithm is described in great detail in (Bel 1991-1992).

4. Conclusion

Work with Bol Processors BP1 and BP2 has been beneficial in finding a workable compromise between general formal language models, the mathematical properties of which are well established although they often bear little musical relevance, and ad hoc representations fulfilling the requirements of only particular musical tasks.

Polymetric structure interpretation and the constraint-based time-setting of sound objects contribute to compensate the rigidity of the timing of computer-generated musical pieces, as the synchronization and accurate timings of concurrent musical processes are handled by the computer on the basis of (possibly incomplete) information on structures and sound-objects.

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1. E.g. ftp://ftp.hawaii.edu/mirrors/info-mac/gst/midi/

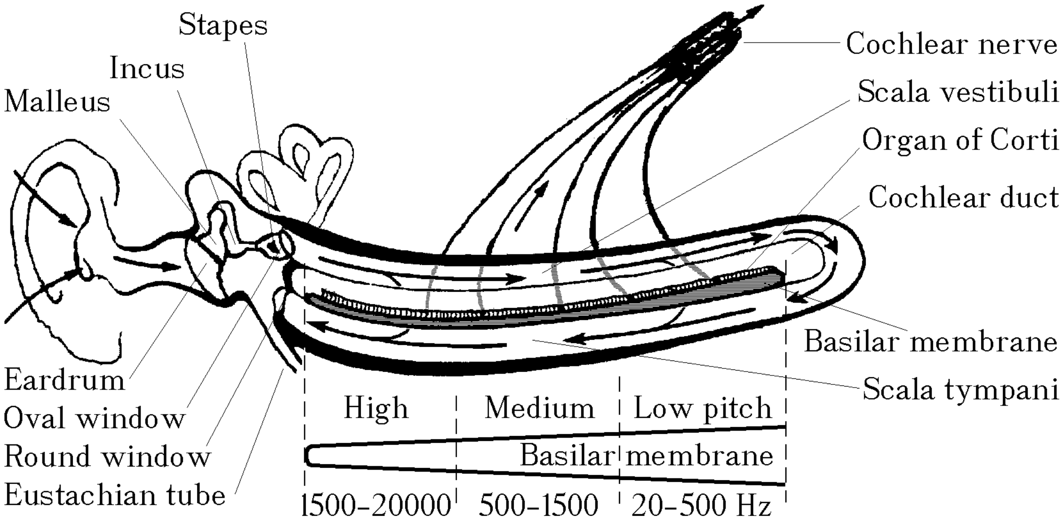
James Tenney

The Several Dimensions of Pitch

The title for this talk, "The Several Dimensions of Pitch", was intended to be slightly provocative, because we usually think of pitch as being one-dimensional, like frequency. But I'm going to suggest that there are, in fact, two different *aspects* of pitch perception, and that one of those aspects can also be thought of as *multi-dimensional*. In considering such fundamental questions regarding the nature of auditory perception it is often useful to think about the evolution of hearing, and I would invoke the image of a primitive human animal trying to survive in the jungle (after all, our ears surely evolved as means of survival, not for musical ends). What would the auditory system of this primitive human animal need to be able to do?

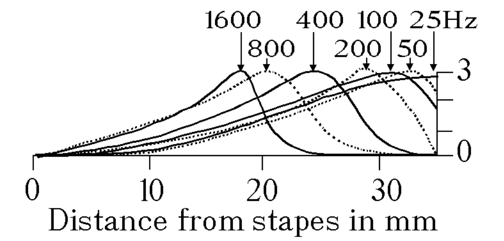
First, it would have to be sensitive to *changes*, with time, in the properties of a sound, since such changes are indicative of physical changes in the environment. In addition, however, it would need to be able to do two complementary if not contradictory things, namely (1) distinguish between or among sounds issuing from different sound sources, and (2) recognize when two or more sounds – though different – actually arise from a single sound source. It seems that nature has been very generous to us in this respect, since we have been given two different mechanisms of pitch perception. Fortunately, these two mechanisms work together in such a way that we can scarcely distinguish the two aspects. Thus, although the two mechanisms affect the pitch percept in different ways, they are very easily confused, and perhaps for that reason have not previously been distinguished in the literature of psychoacoustics or of music theory. The first mechanism by itself would yield a rather diffuse pitch percept, but it is highly effective in the detection of rapid changes of pitch. The other mechanism lends the pitch percept its more precise, focussed quality, but it requires more time to be effective.

Fig. 1 – Schematic diagram of the "unrolled" cochlea and basilar membrane[1]



The first mechanism carries what I call the *contour* aspect of pitch perception, correlated with the distribution of mechanical and neural activity on the basilar membrane and the organ of Corti. The inner ear, as we all know, is shaped like a snail shell (*cochlea* in Latin). If we imagine unrolling that shape, it can be represented schematically as in **Fig.1**. The input to the cochlea is at the oval window, where the vibration is sent to the basilar membrane in the form of a travelling wave. As Georg von BŬkŬsy demonstrated, the envelope of this travelling wave reaches its maximum amplitude at a distance from the oval window set by the vibration frequency: higher frequencies nearer to the oval window, lower ones farther from it (see **Fig.2**). The basilar membrane vibration elicits nerve impulses in hair cells arrayed along the organ of Corti, with a temporal density which varies directly with the amplitude of the travelling wave. A crude form of frequency discrimination is thus effected in the form of a spatial spread of mechanical and neural activity in the cochlea; this information is transmitted to the central nervous system (CNS) via the auditory nerve in a way that preserves its original spatial order, i.e. tonotopically.

Fig. 2 – Travelling wave envelopes of various frequencies on the basilar membrane[2].



This first mechanism is very sensitive to changes in the properties of a sound, and is the basis for our sense of shape in melody, and for our sense of register, but it is not what gives the pitch percept its “point–like” character. You can see (in Fig.2) how a sharply defined, singular kind of percept is not likely to arise from this mechanism alone, because there is such a broad spatial distribution of activity. Thinking again of the human animal in the jungle, the first of these aspects of pitch perception tells him about the rushing noise of the lion as it comes through the brush.

And it’s very useful for establishing the general characteristics of that noise – e.g. its intensity, bandwidth, and approximate pitch. It is also quite sensitive to changes in these characteristics. But it is not going to be useful for certain other things. For example, it won’t help to find out that the several harmonic partials in the sound of the lion’s roar are actually coming from just one lion. For that, something else is needed – a mechanism that can detect the *constancies* in the signal and thus sense when two or more widely separated frequencies are so closely related (in some other respect) that they probably have been produced by the same sound source.

So what is this other aspect of pitch perception, and what would be its associated mechanism? I believe it has to do with the *temporal ordering* of the neural information. What I have already described involves a spatial ordering; though these nerve impulses are happening in time, their important feature (as far as the first mechanism is concerned) is their spatial distribution – *where* the impulses originate. The basis for the other aspect is time – and it kind of astonishes me that more hasn’t been made of this, because the temporal information is there and available to the CNS, and it seems unlikely to me that the evolutionary process would have allowed for an available mechanism to be wasted. If you take any position along the organ of Corti, and measure what’s happening in the hair cells at that position, any given input frequency produces synchronised pulses in those hair cells, and thus in the auditory nerve. Not every hair cell responds to every signal cycle, but the input frequency will be represented in the auditory nerve by synchronous nerve firings by groups of cells, in “volleys”. So the CNS is being sent time information, which I believe is the basis for the second mechanism, which in turn is responsible for the aspect of pitch perception which I call the *harmonic* aspect.

Now I think the evolutionary reason for the development of a second mechanism of pitch perception is that only in this way could the various harmonic partials in a single vocal sound, whether that of a lion or of another human animal, be correlated, and recognized as having been produced by a single sound source. Because at least in the vowel aspect of speech we hear a set of harmonic partials, and it is the distribution of energy in that spectrum that tells us about the nature of the vowel sound.

C.Barlow: Are you saying you need the temporal information to get the spectral?

J.Tenney: In a certain sense, yes, but more precisely, I'm saying that we need the temporal information to *reduce* the vowel sound from a complex spectrum to a singular percept. In other words, in vowel perception we don't hear "chords". Rather, the several harmonic partials are somehow correlated with each other so that what we hear is a single pitch, with a certain loudness and timbre. But, whatever that correlation process is, I don't think it can be done spatially. I'm aware of the theories that try to explain this in terms of the spatial distribution of activity on the basilar membrane, but I don't think they are workable. The distinction I am making between the two mechanisms is rather like the distinction between the rods and the cones in the retina of the eye. The cone cells are specialized to respond to colour and in brighter light, and have better resolution. The rod cells, on the other hand, act more in peripheral vision, and come into operation when the light is not so bright. And yet they are highly sensitive to movement. The two cell populations are sometimes described as separate visual systems. Analogously, I'm suggesting that there are two different aspects of pitch perception, based on two different mechanisms.

The first mechanism, which determines the contour aspect, is not only very useful but essential, because it can respond quickly to changes in the frequency and other properties of a sound. But a pitch percept determined by this mechanism alone would not have been very precise. The other mechanism, which determines what I call harmonic perception, is much more precise – but it takes time. It takes time because it is a temporal process, because there must be some mechanism to correlate these temporal sequences of neural pulses, and that can't be achieved instantaneously.

A.La Berge: Are you talking about this as a combination of neural and physical activity or simply activity on the basilar membrane?

J.Tenney: When I talk about the auditory system I mean from where the sound enters the ear all the way up to the central nervous system. With both aspects of pitch perception we must look at what's happening in the nervous system, because even though we can see how the spatial distribution occurs in the ear we must imagine that same distribution projected to higher levels, and see it in some kind of physical space in the brain. The other aspect is temporal, but in each case we're looking at everything from the basilar membrane on up.

I will propose a model for the harmonic aspect of perception which is not intended to be a picture of what's happening in the brain, but merely a useful sort of mathematical construct that can display some of the properties of harmonic perception. It takes the form of a lattice structure in what I call *harmonic space*[3]. For a given set of pitches, the dimensions of this space correspond to the *prime factors* required to specify their frequency ratios with respect to a reference pitch. It is a discrete space, not a continuous space, with the line segment connecting any two adjacent points in the lattice symbolizing a multiplication (or division) of the frequency ratio by the prime number associated with that dimension. Thus, the first two dimensions of such a lattice structure would involve the prime factors 2 and 3, and a step from one point to an adjacent point in the lattice would mean a shift up or down of one octave (in the 2-dimension), or of a twelfth (in the 3-dimension). What we have then is a two-dimensional harmonic space that would include any combination of octaves and fifths, i.e. any "Pythagorean" pitch set. Note that, if we imagine this lattice structure extended indefinitely outward in all directions, it must eventually include every possible ratio of two numbers whose prime factors are no larger than 3. The one-dimensional continuum of pitch-height (i.e. "pitch" as ordinarily defined) can be represented as a central *axis of projection* within this harmonic space, as shown in **Fig. 3**. The position of a point on this pitch-height axis may be specified, as usual, by the logarithm of the fundamental frequency of the corresponding tone, and the distance (or *pitch distance*) between two such points by the difference between their log-frequency values.

That is, $PD(f_a,f_b) \propto \log(a/b) = \log(a) - \log(b)$

where f_a and f_b are the fundamental frequencies of the two tones, $a=f_a/GCD(f_a,f_b)$, $b=f_b/GCD(f_a,f_b)$, and $a \geq b$.

In harmonic space another measure I call *harmonic distance* can be defined, for any interval represented by the frequency ratio a:b, as

$$HD(a{:}b) \propto \log(ab) = \log(a) + \log(b)$$

where a and b are in maximally reduced or "relative prime" form.

Fig. 3 - A two-dimensional (2,3) lattice in harmonic space, showing at centre the pitch-height projection axis.

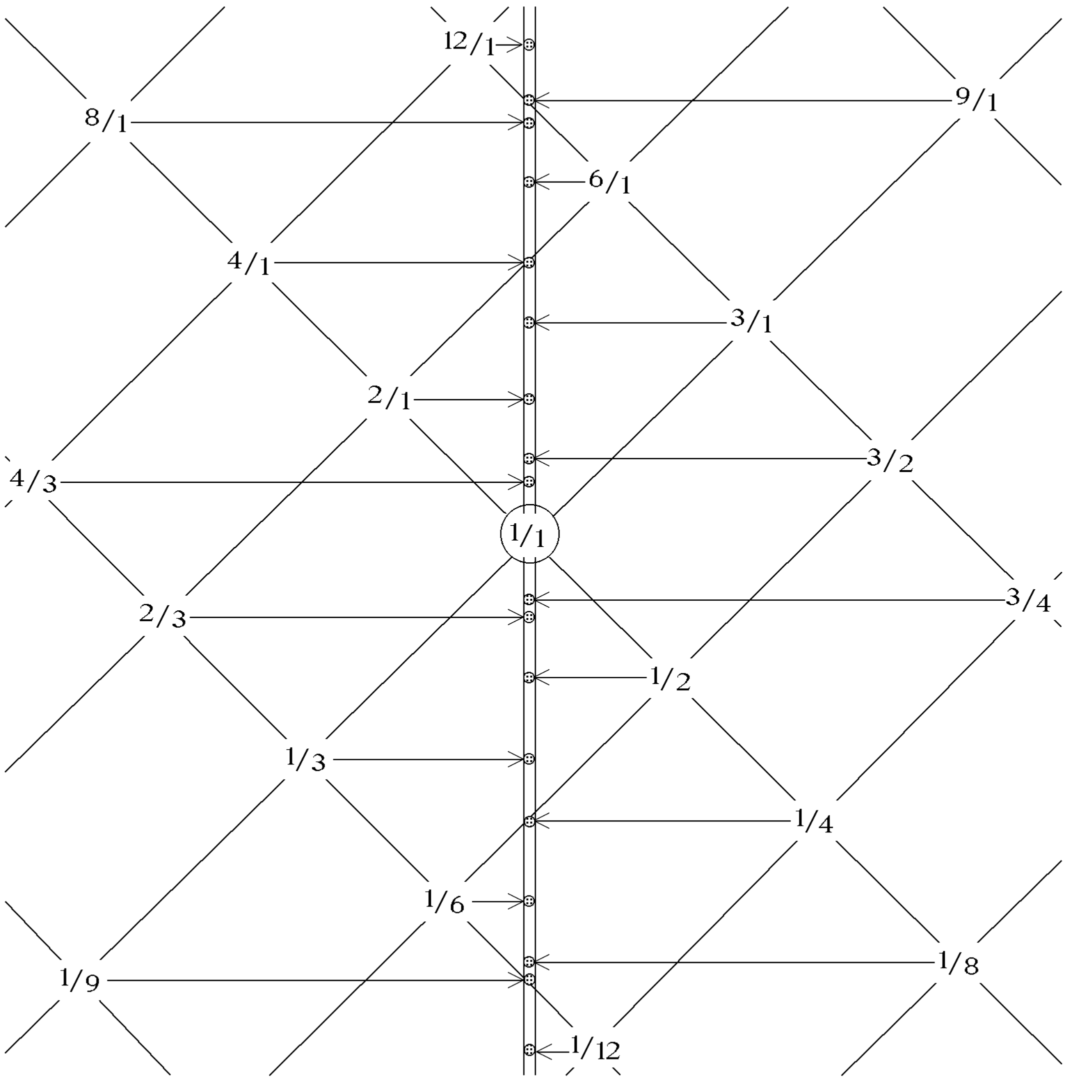
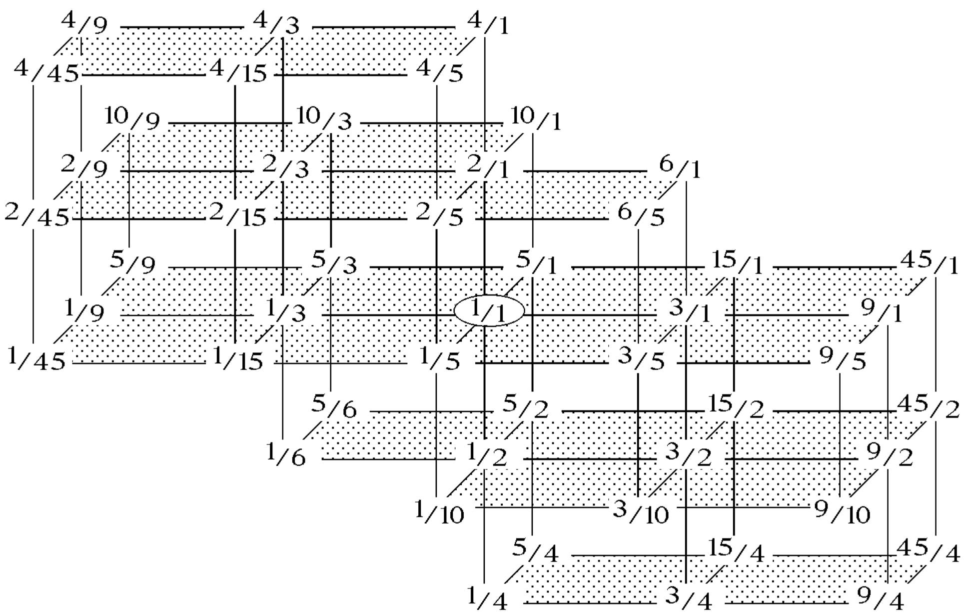


Fig. 4 - A three-dimensional (2,3,5) lattice in harmonic space



In order to go beyond Pythagorean pitch or interval sets, we must introduce one or more new prime factors into our interval ratios, and thus new dimensions in our lattice in harmonic space. In **Fig. 4** an extension into a third dimension associated with the prime factor 5 is shown. Again, if such a three-dimensional harmonic space lattice were extended indefinitely in all directions, every possible frequency ratio involving the prime factors 2, 3, and 5 would eventually be included. If we wish to extend the harmonic space lattice into yet another dimension, we run into the difficulty of representing four dimensions in a two-dimensional graph, but there is a useful device that can be introduced here which invokes "octave equivalence", and involves collapsing all the points of a given "2-vector" into a single point, which then represents not a specific pitch (or interval with respect to 1:1), but rather a "pitch class". I call the resulting space, which contains one dimension less than the original lattice, a *pitch-class projection space*. **Fig. 5** shows the pitch-class projection space derived in this way from the lattice of Fig. 4. **Figs 6** and **7** show the lattice structure for the major and minor diatonic scales (using Harry Partch's labelling convention, whereby a given pitch class is identified by the ratio it has in the first octave above 1:1).

Fig. 5 – The two-dimensional (3,5) lattice in the pitch-class projection space derived from the lattice of Fig. 4.

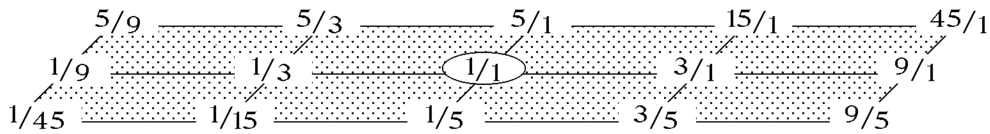


Fig. 6 – The just diatonic major scale.

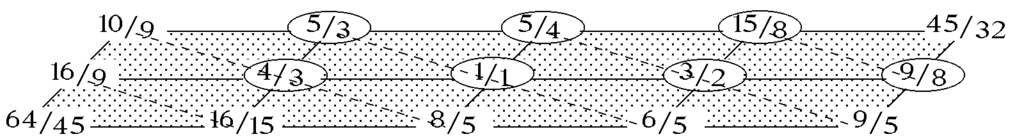
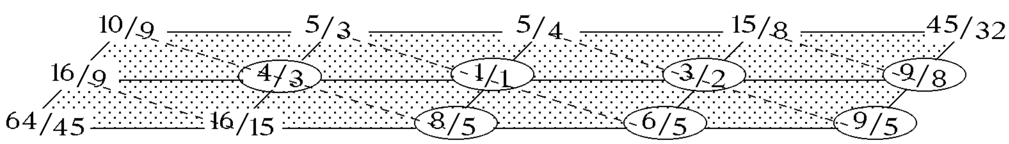
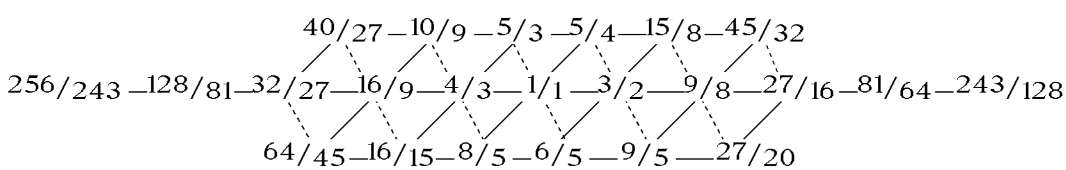


Fig. 7 – The just diatonic minor scale.



Notice that these last structures are compact, and I think that's an important feature of harmonically coherent pitch sets. Clarence mentioned the Indian Sruti system in his talk yesterday, and he described it as a kind of ellipse. In my model it would be represented as a two-dimensional lattice in a pitch-class projection space with prime factors 3 and 5, as shown in **Fig.8**.

Fig. 8 – The Indian Sruti system[4]



So far I have assumed that simple integer or "just" ratios are involved in the specification of a pitch or interval set. The harmonic space concept can be applied to tempered sets as well, but certain new factors must be taken into consideration. The most important is a notion that I call *interval tolerance* – or simply *tolerance*: the idea that there is a certain finite region around a point on the pitch-height axis within which some slight mistuning is possible without altering the harmonic identity of an interval. The actual magnitude of this tolerance range would depend on several factors, and it is not yet possible to specify it precisely, but it seems likely that it would vary inversely with the ratio complexity of the interval. That is, the smaller the integers needed to designate the frequency ratio for a given interval, the larger its tolerance range would be.

Now I propose as a general hypothesis in this regard that the auditory system would tend to interpret any given interval as thus "representing" – or being a variant of – *the simplest interval within the tolerance range* around the interval actually heard (where "simplest interval" means the interval defined by a frequency ratio requiring the smallest integers). The simpler *just* ratios thus become "referential" for the auditory system – not in any conscious or cognitive way, but rather on a very primitive, precognitive, neurological level.

Another hypothesis might be added here, which seems to follow from the first one, and may help to clarify it: within the tolerance range, a mistuned interval will still carry *the same harmonic sense* as the accurately-tuned interval does, although its timbral quality will be different – less "clear", or "transparent", for example, or more "harsh", "tense", or "unstable", etc. I should note that both of these hypotheses are based on a consideration of how the CNS might identify the harmonic interval between two tones. I suggest that this involves a comparison of neural pulse trains synchronous with the fundamental frequencies of the tones, and that this comparison is mediated by something like a "coincidence neuron" (or some equivalent neural network) which fires only when two input pulses arrive simultaneously. The output of such a neuron would thus be another neural pulse train with a frequency determined by the common period of the two input pulse trains.

But since neural pulses are of finite duration, we must replace the notion of absolute or discrete simultaneity with one of a finite *window of effective simultaneity*. I have no experimental data on which to base an estimate of the duration of such a "window", but a minimum duration – on the assumptions of my model – might be deduced from an estimate of the tolerance range itself. Thus, for example, if our tempered major third is functioning harmonically as a 5/4, the tolerance range must be at least 14 cents (=400–386), and neural pulse trains at these two relative frequencies (just vs. tempered) would be 5/4 vs. $\sqrt[3]{2}$ or 1.25/1.2599=0.992, so they differ by only eight tenths of one percent! Thus if we play a major third on a tempered piano, where it's 14 cents sharp, we "understand" it as a 5/4 relationship – i.e. it has the same harmonic sense as a 5/4. It may sound out of tune, but it's that particular (5/4) relationship "out of tune". It's not just some arbitrary abstract thing.

W.Swets: Can I put it like this: that reference which we have in our heads is any ratio we have become accustomed to. You say that when we hear a tempered third then we hear a third in relation to a pure third (386 cents) and we keep that in mind. But isn't it so that if we had e.g. a third with a very complicated ratio it becomes ours by having listened to it every day? If I made a special flute, like a primitive shepherd for example, and my religion tells me to make a gap on a certain place and it produces a certain third and I get accustomed to it – it is that which makes it possible for me to produce that third any time I need with the restriction you explained just before. Isn't it like that?

J.Tenney: I think our cultural experience is very important here. But I still think that even some very exotic interval is going to be "understood" (not, I repeat, in a conscious, cognitive sense), but spontaneously interpreted by the nervous system in this way, as a variant of the simpler, "referential" interval.

W.Swets: No… for example, the equidistant 7–tone scale of Thailand. Someone born over there has his third in that scale.

J.Tenney: I would suggest that in that case there are *cultural* reasons for maintaining the temperament, let's say, or the tuning. But even there my sense of it is that the shepherd's or the Thai musician's third is a variant of the simpler third. If I draw a circle, freehand, and then begin to talk about "the circle", you all know what I'm talking about, even though it may deviate a great deal from a perfect circle. For some reason, perhaps having to do with energy conservation or some minimization process, we "understand" this as a circle. I don't mean this in some "platonic" sense, but as the simplest form within a certain tolerance range of what I've actually drawn. I think something like that is happening with these ratios in auditory perception.

B.Thornton: Why is that not platonic then?

J.Tenney: Because it's not like it exists somewhere else. It has to do with the function of the nervous system.

B.Thornton: A platonic idea exists as a function of the soul. You've just given it a different meaning.

J.Tenney: Yeah? OK. I was unnecessarily anticipating an objection that hasn't actually arisen. Whatever it is, then!

A.La Berge: You could just see neural science as a philosophy.

B.Thornton: It's OK – what you're saying in a sense is that you don't want to look at it philosophically.

J.Tenney: I don't *think* of it philosophically. I think of it as something physical. I think of it as a physical manifestation of operations in the nervous system.

C.Barlow: I don't see why there should be any conflict between the idea of, for example, understanding the semantics of a third of 5/4 or 81/64 or whatever and still singing it somewhere else or playing it somewhere else. But it could have a certain semantic context which could be described in terms of a lattice system, or my own continuity field system, or whatever. At the same time, however, certain timbral vibrancies might excite you so that you can move off. All these intervals have their own timbral attraction. For example, the sixth we heard yesterday in the recording played by Wim van der Meer – that sixth could have a semantic 5/3 meaning while being sung where it was sung.

W.Swets: Do you seriously believe that a person somewhere in Central Africa who has his own third which is not 386 cents – he has in mind that it should be?

C.Barlow: I'm not saying that everybody is conscious of the workings of the brain. We are not all experts in how the brain works. We here who are thinking about things like this can talk about the brain and its workings. But, to take your very example: the language of somebody living in the middle of Africa contains a certain "Ah" sound. Does he think about the formants causing that "Ah" sound? No. But they are there.

W.Swets: No, I don't mean that. Say that I go over there and I meet that person, and I tell him "This is a perfect third", and I play for him 386. He hears that it is consonant, because his ear is like ours. So he will be conscious of the consonance of it. But if he *likes* it is another thing. Now had I not gone there and not performed for him that perfect major third, would he then have had the imagination, without hearing it before – because it's not there in his culture – would he have been able to imagine that there is such a thing as a perfect third? No!

J.Tenney: We can draw ellipses, we can draw all kinds of shapes here, right? We can speak about preferring one shape to another, but that's not what I'm talking about. I'm not talking about preference.

W.Swets: No, no! I speak about imagination. The capacity to imagine this perfect interval is not there in that culture. Now, just one moment – this is very important. In our culture we did not use equal temperament before 1700. In our time, we think in equal temperament, we live with equal temperament, and look at the problems we have in our ensembles in Europe when we want to play mediaeval music in mean-tone tuning. Who can now sing in mean tone?

C.Barlow: I don't think Jim's talking about that. We should listen to what Jim has to say. A subject like this is a very basic one. Actually it's the very question – should one think about intervallic relationships at all or not? Should the Ratio Symposium take place at all or not? That is the basic question. I think that as we are here we assume that it should.

W.Swets: Yes. The thing is, we love a ratio to which we have become accustomed, not because it is 5/4. It might be 2351/1020. But if we love it, we love it. That is the point, and that is why we have ratios.

J.Tenney: That's one reason why I introduced my topic by saying that there is a whole other aspect of pitch perception that is essential, not only in our day-to-day experience in the world, but in many kinds of music. Harmonic perception is not always happening. It can only take place when we have stable and salient pitches. We must hear a sound as a precise pitch, and it must remain fairly constant long enough for the nervous system to process it. And there is lots of wonderful music that has nothing whatsoever to do with this. To begin with, even in the West the percussion ensemble literature is working with sounds for which it is irrelevant whether they are clear pitches or not. The actual pitch of that wood block doesn't matter to us, we speak of higher or lower.

And that's relating to the first aspect of pitch perception that I talked about. It's essential, it's musical, and it's important, but it's different. Many musical cultures make very precise distinctions as we do in our culture, even when they modify them. For example, I would suggest – though I have no way of proving this – that the Thai seven-tone equal temperament was chosen historically, evolutionarily, because it contains pretty good approximations to perfect fourths and fifths, but there is also a wonderful ambiguity about the thirds. The third is kind of a neutral third – it can function in some ways harmonically like either a major or a minor third. And that ambiguity is important.

Our twelve-tone equal temperament exists not because twelve is a nice number to divide things up into, or because it has interesting group-theoretical properties, which serial thinking might suggest, but because it developed as an approximation to 5-limit just intervals. Similarly with Indonesian *pelog* and *slendro* scales.

I think they were chosen or selected historically because they suggest certain harmonic relationships, but they also carry some ambiguities that are interesting and musically useful. So when I suggest that these simple ratios are referential, I'm trying to avoid what I take to be a wrong headed dogma held in some quarters of the just intonation community, that these simple ratios represent the only proper way to tune things. I don't agree with that. I think all kinds of tuning systems are potentially useful, including equal-tempered systems, but I still think that even the tempered relationships are being interpreted by the auditory system, quite unconsciously, as functioning like the simplest ratio within the tolerance range. That's all I'm suggesting.

W.Swets: I don't agree with that. That it is referential, ok, but not in the way you interpret it.

H.Touma: I agree with Wouter. I think if you try to play a melody which is originally Arabian on the piano, an Arab will be shocked and will reject it. He will not think of it as referential, he will say it is wrong. So what you are trying to say here, maybe, is you are trying to find a universal which has no basis.

J.Tenney: Wait a minute – the piano is not a good representative...

H.Touma: Or the saxophone or any tempered instrument: when an Arabian melody is played on it, it will not function as referential to any Arab familiar with that music – he'll reject it, he'll say it's wrong, it has no spirit – that is the word they use. It has no spirit!

C.Barlow: Maybe we can discuss this tomorrow. Both of you are questioning the very existence of this kind of thinking, so let's go through with the thinking itself and then discuss its existence.

J.Tenney: Let me say a few more things that *can't* be argued with. First of all I am a composer, and only secondarily and occasionally a theorist. This notion of harmonic space serves me as a composer. I can see my music as *activity in harmonic space*, motion in that space. I almost imagine these points like little lights that flash on when a certain sound occurs. It's also useful in scale development, for working out new pitch sets, new tuning systems. I have in fact done many pieces where the tuning of the piece developed out of a lattice like these diagrams I've used for this talk. The reason I said it can't be argued with is that this does not interpret something *else*. The problem of applying these ideas to pre-existent music is large, of course, but I just ask you to realize that I am quite aware that there are many different factors involved here. Even if I'm right on the referential character of simple ratios, there are so many other factors crucial to the final result in a tuning system, or to what a music sounds like, factors of history, organology, or of ambiguity, extremely valid in art – in this context, the ambiguity that can arise when a given tone, precisely because it *is* mistuned, can function harmonically in different ways, suggesting different relationships without even being changed, just by a change in its context. If you start considering all these other factors it becomes, of course, very complicated to try to describe an existing music. I certainly don't suggest that something as mathematical or abstract as this harmonic space model could be in any sense a complete explanation of musical activity. But it might be one component.

1 from and after P. D .Anderson: *Clinical Anatomy and Physiology for Allied Health Sciences,* W. B. Saunders, Philadelphia, 1976

2 after Georg von BŬkŬsy: *Experiments in Hearing*, McGraw-Hill, New York, 1960

3 I'm not the first person to conceive of pitch relations in a ratio lattice structure; important work has already been done in this respect by the American composer Ben Johnston and the British scientist H. Christopher Longuet-Higgins, among others.

4 according to ratios given in P. Sambamoorthy: *South Indian Music*, The Indian Music Publishing House, Madras, 1963.

Pascal Decroupet

Logic and Permutation in the music of Tom Johnson

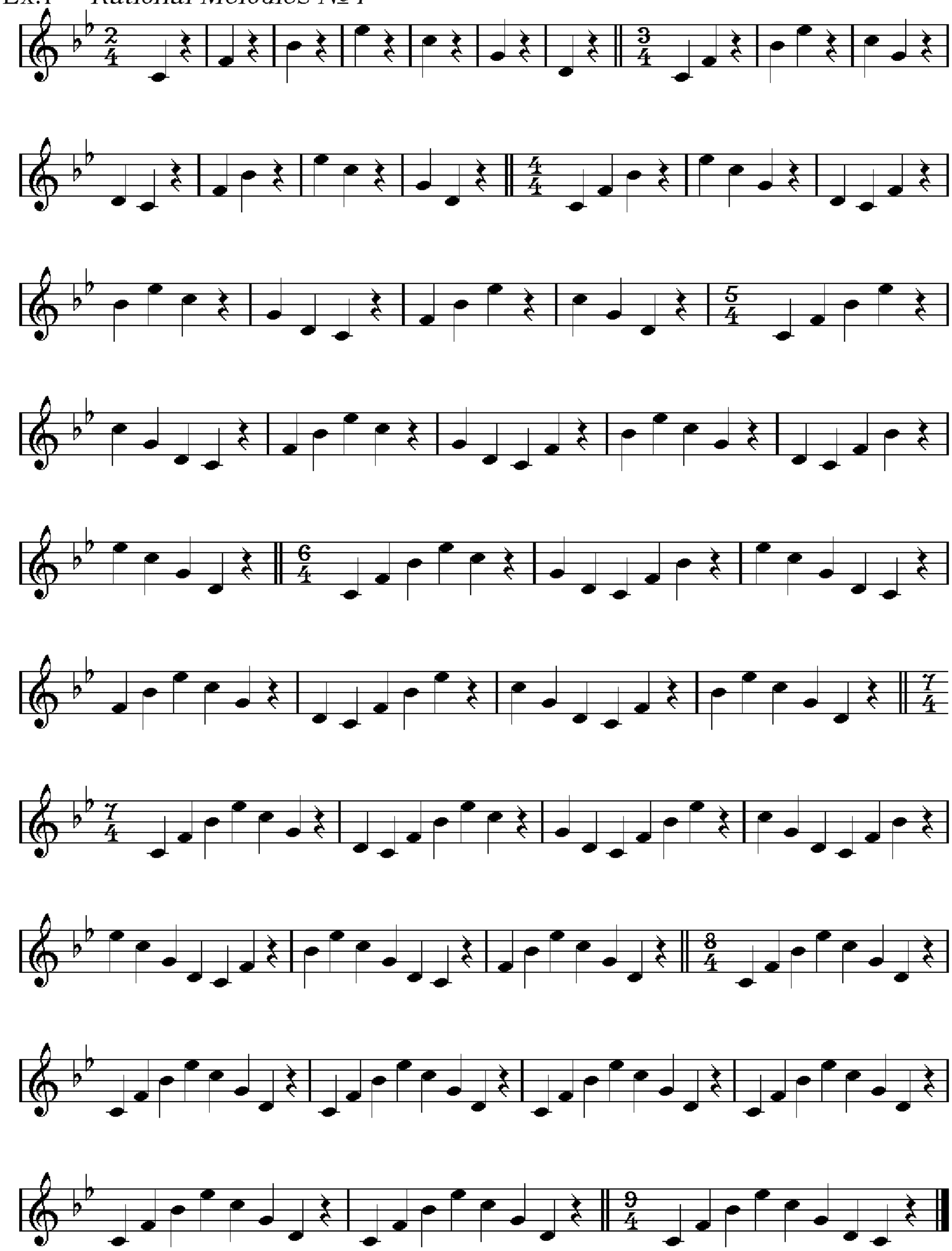
What amazed me the most when I heard a concert performance by Tom Johnson (= TJ) for the first time was the fact that this composer didn't seem to hide anything about his craftmanship. Either he explained what was going on in the music he was playing, or the process was presented in such a transparent way, that it was possible to follow the logical evolution of the music without any other information: the music was in a certain way "self-explicit".

TJ's attitude towards music shares with minimalism the exploitation of a restricted sound universe; but in a sense, he is more radical, at least in his compositions since 1979, from which the following examples are taken. Indeed, the formal logic operating as the basis of his production either generates infinite processes which are presented only partially (everybody could go on beyond or begin the process earlier), or displays all the possible combinations of a limited material ordered by an overall and directed form-process. Directionality becomes here an essential instrument to render the music predictable, a central aim of TJ's compositions.

Before analyzing different types of TJ's algorithms, two elementary conditions of his music must be mentioned. First of all, as the composer explains in his introduction to the *Rational Melodies*, this music "may be played by any instrument, in any octave or transposition"[1]. This is not a music for a specific sound. Secondly, the pitch-scales are always constructed by rational devices based either on a cyclic repetition of one interval or on a regular alternation of two intervals. These scales are systematic in their progression and don't serve any purpose of expression.

Let us look at a first example (**Ex.1**). The principle: a sequence of seven pitches is constantly repeated and arranged in different groupings of increasing number – first section: group-density 1, second section: group-density 2 etc.

Consequently, each section needs a number of pattern repetitions equal to the density index of its grouping. Furthermore, each section starts with a low [C], the first note of the pattern. Unexpectedly, the piece ends with a first group of eight notes.

Ex.1 – *Rational Melodies №4*

TJ explains:

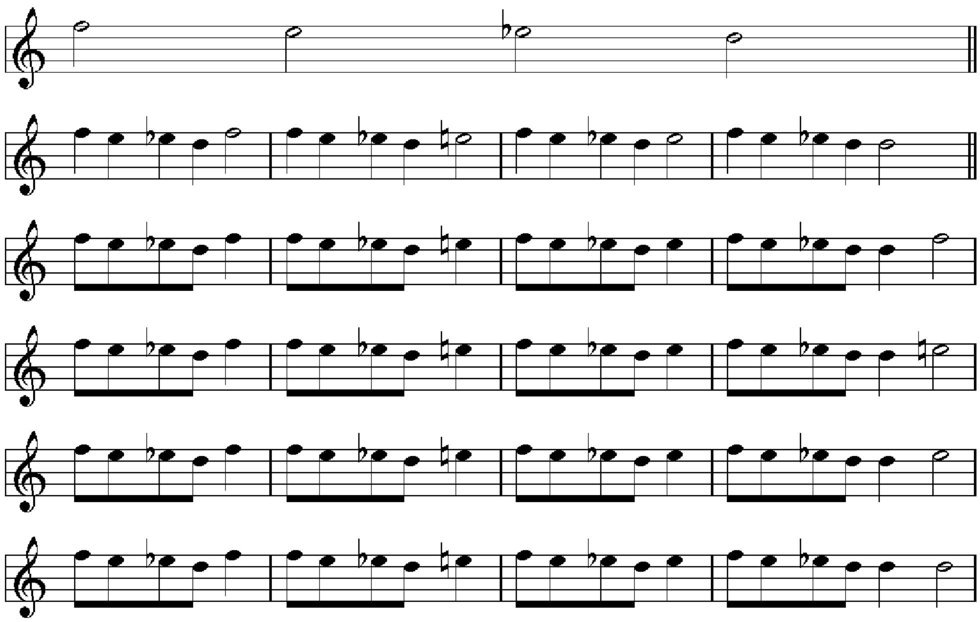
> The logic could lead to eight-note phrases, nine-note phrases and so on to infinity, and it is often difficult in such cases to decide where to cut it off. It would be just as logical to stop with the first seven-note phrase, which finally gives us the complete melody unbroken; or with the last seven-note phrase which completes 49 (7x7) bars; but I ended with the first eight-note phrase, the first one that begins and ends with the primary low C. Did I make the best decision? This is a good example of how, even when one is committed to making choices by strict logical deductions, one may still be forced to choose between several equally persuasive logics.[2]

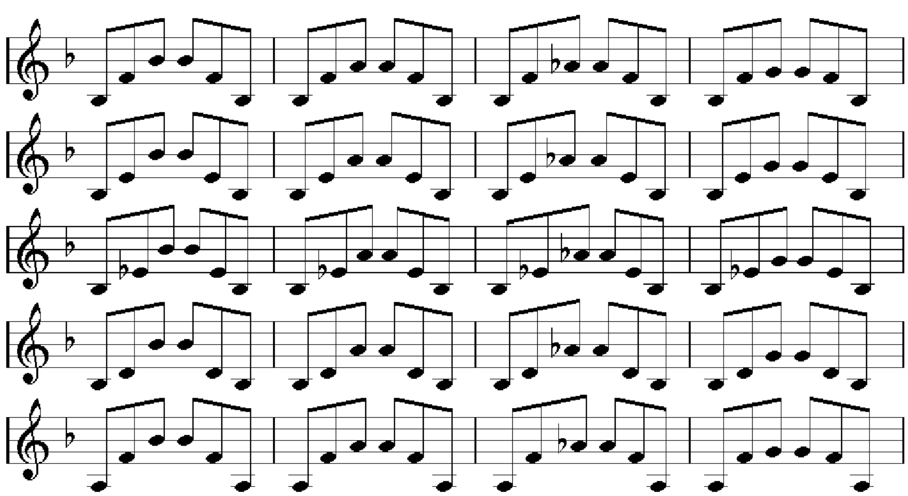
It is remarkable that if one looks at the piece independently of this description, the last sequence raises an interpretational ambiguity for the whole piece: is it really based on a seven-note melody? Or is it an eight-note melody linked to its repetition by the principle of the common tone? From the latter point of view, to end with the first appearance of the complete melody would be the most striking solution.

The case is similar in *Rational Melodies №1*: the counterpoint of a six-tone melody and a thirtyseven-note rhythm result in a rest of one note at the end of each rhythmic sequence. Both patterns are repeated until the return of the first phrase, each sequence beginning with another pitch, reflecting the six-tone melody on a higher structural level. This relation between melodic micro-form and structural macro-form seems in the present case to be a secondary result of the primary contrapuntal process rather than an intended feature. But there are other pieces in TJ's production where "self-similarity" works as the basic compositional device.

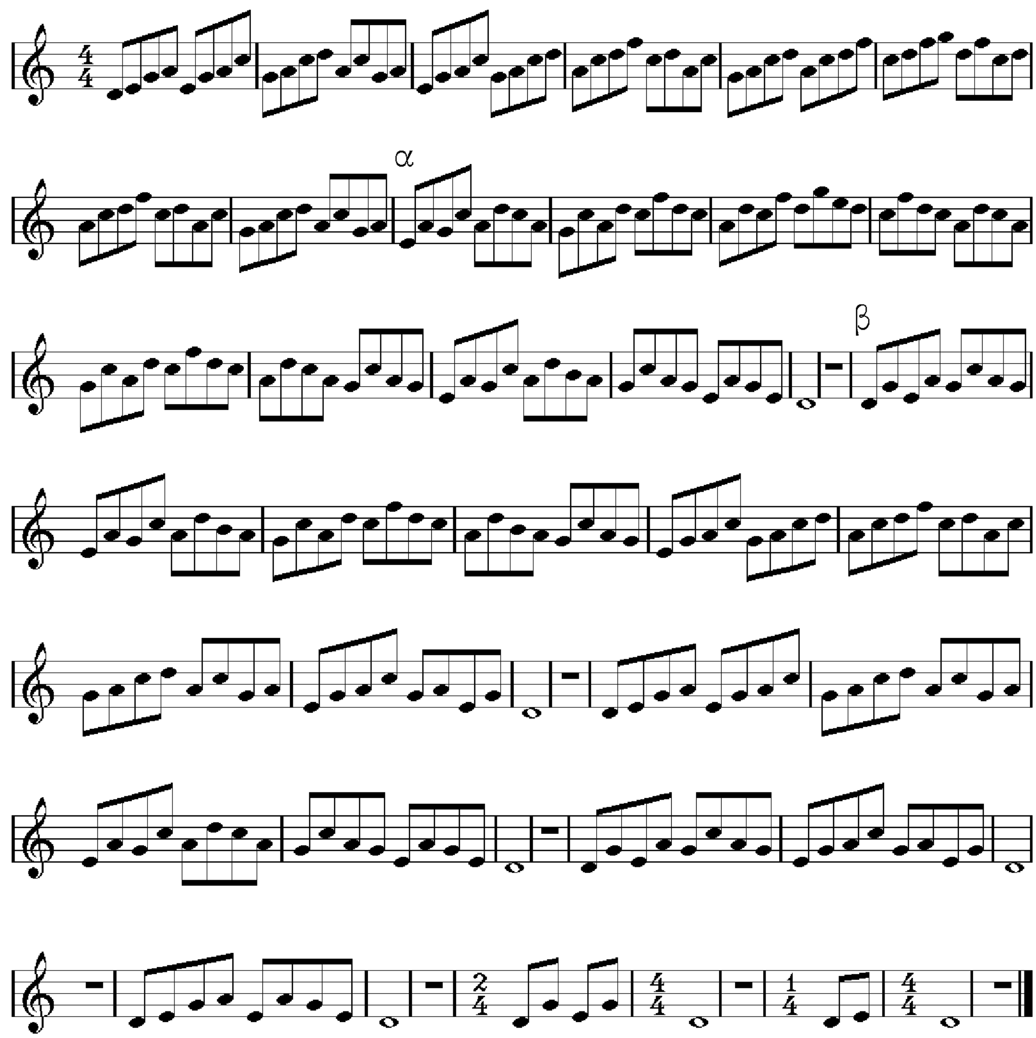
In recent times, the notion of "self-similarity" is usually related to Mandelbrot's fractals and to chaos theory while in composition it's an old objective. Schoenberg called it "economy". The two following excerpts (**Ex.2**) present the same procedure, once in a melodic interpretation, once as compound melody or "virtual polyphony". In both, the basic progression is a descending chromatic four-note pattern. In the melodic version (№8), the different layers of the hierarchy become perceptible through the different durations of the notes at each level, groups of shorter durations being always completed before a sound of the next higher layer appears. In the virtual polyphonic version (№10), the hierarchy is translated by the tempo in which the sounds move in each voice. The upper voice repeats the motif every four bars (totalling sixteen occurrences); the middle voice moves down one degree every four bars (displaying the pattern four times) ... and the lowest voice is heard only once (in this excerpt, it progresses one step down while the other two voices come back to their starting point).

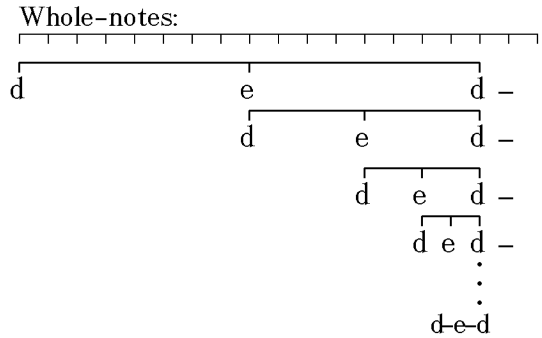
Ex.2 – *Rational Melodies №8* and *№ 10*

№8


№10

&c.

Let's read through the score of *Rational Melodies №16* (**Ex.3**) phrase by phrase, trying to understand the process as early as possible, so to be able to predict the next sequence. In the first phrase, we notice a phenomenon of self-similarity: the first sixteen pitches are identical to the initial pitches of the first sixteen four-note groups. At the [e] in bar 9 (marked "α"), a retrograde begins: this [e] is an axis of symmetry. This observation doesn't really fit into the usual rules of self-similarity, but there isn't yet an answer to this exception and so we have to go on. In the second phrase (marked "β"), we find a similar combination of self-similarity and symmetric arrangement.

Ex. 3 - *Rational Melodies №16*

Ex.4 – The formal scheme of *Rational Melodies №16*



The phrase shape is however different: it reflects the second part of the first phrase (from "α") transposed to the initial pitch [d]. And the length is half the length of the preceding phrase. This process goes on until the phrase is reduced to the neighbour-tone figure [d–e–d], the skeleton of all the phrases. This results in the graph in **Ex.4**.

At the back of the collection, TJ gives another explanation:

> Special rules are used for inserting new notes between each pair of existing notes, in order to make the melody twice as long. In this case we begin arbitrarily with the scale degrees 1-2-1 and proceed by examining each pair of notes. If they are adjacent we insert the next highest scale degree between the pair. Since our first pair of notes is the adjacent pair 1-2, we sandwich in the next highest note, giving us 1-3-2. Since our second pair is 2-1, we again insert a 3, giving us 2-3-1. Thus the second level of our melody ends up as 1-3-2-3-1. The derivation process continues in this way:
>
> 1 2 1
> 1 3 2 3 1
> 1 2 3 4 2 4 3 2 1
> 1 3 2 4 3 5 4 3 2 3 4 5 3 4 2 3 1
> 1 2 3 4 2 3 4 5 3 4 5 6 4 5 3 4 2 4 3 5 4 6 5 4 3 5 4 3 2 4 3 2 1
>
> Several curious things occur as side effects of this logic. The second half of the pattern always ends up as the reverse of the first half. The sequence moves one scale degree higher with each level. The melodic motion is of one type on the odd levels and another type on the even levels. The actual piece consists of the first seven levels, presented in reverse order.[3]

Going back to the score, it is now evident that the second phrase (from "β") reproduces the first by taking every other note only.

In his book *Kunst und Computer* (1971), Abraham Moles gives the following definition of "permutation", a device of which he shows the different applications in different arts and to which he devotes a whole chapter of his book:

> Permutation is a combinatorial procedure on simple elements of limited variety through which the immensity of a field of possibilities becomes perceptible. [. . .] Permutation realizes precisely the *variety* in the *uniformity* which is a fundamental element of all work of art.[4]

To show the whole potential of such a field, all the possible permutations of a limited material need to be presented.

Two examples taken from literature will illustrate this (**Ex.5**). The words may vary in their outer shape according to syntactic necessities: the principle is the positioning of the word-roots.

Ex.5 - Harry Mathews: *Le savoir des Rois. Poèmes à proverbe "Trois Carrés Lescuriens" No2*[5]	Chagrin d'amour dure toute une vie	1 2 3 4
	Chagrin d'amour vit tout en dur	1 2 4 3
	Chagrin de dur aime toute une vie	1 3 2 4
	Chagrin de dur vit tout amour	1 3 4 2
	Chagrin de vie aime tout dur	1 4 2 3
	Chagrin de vie dure tout un amour	1 4 3 2
	Amour de chagrin dure toute une vie	2 1 3 4
	Amour de chagrin vit tout en dur	2 1 4 3
	Amour de dur chagrine toute vie	2 3 1 4
	Amour de dur vit tout en chagrin	2 3 4 1
	Amour de vie chagrine tout dur	2 4 1 3
	Amour de vie dure tout un chagrin	2 4 3 1
	Dur de chagrin aime tout une vie	3 1 2 4
	Dur de chagrin vit tout en amour	3 1 4 2
	Dur d'amour chagrine toute vie	3 2 1 4
	Dur d'amour vit tout un chagrin	3 2 4 1
	Dur de vie chagrine tout amour	3 4 1 2
	Dur de vie aime tout chagrin	3 4 2 1
	Vie de chagrin aime tout dur	4 1 2 3
	Vie de chagrin dure tout un amour	4 1 3 2
	Vie d'amour chagrine tout dur	4 2 1 3
	Vie d'amour dure tout un chagrin	4 2 3 1
	Vie de dur chagrine tout amour	4 3 1 2
	Vie de dur aime tout chagrin	4 3 2 1
Ernst Jandl[6]:	a shape-facing lift	1 2 3 4
	a lift-shaping face	1 4 2 3
	a face-lifting shape	1 3 4 2
	a face-shaping lift	1 3 2 4
	a shape-lifting face	1 2 4 3
	a lift-facing shape	1 4 3 2

The poem by Harry Mathews, a member of OULIPO (*Ouvroir de littérature potentielle*), is paradigmatic of strongly directed overall forms encompassing all possible permutations. It evolves from a certain arrangement, quoted here from a proverb, to its reverse form, using at different higher levels the progression of the elements in the first line. The first columns of the four attendant blocks of digits reflect this original order; the second column of each block progresses two by two in the same way the last three terms of the first line of each block respectively do etc.

The extreme lines of Jandl's poem, where the first element doesn't enter into consideration because it is fixed, are also the reverse form of each other. But the progression is not linear: inside the overall evolution from up-movement to down-movement, the steps are inversed around the center. If I define the linear progression as going from 1 to 6 (as in the Mathews text), for Jandl's poem the result will be 154326.

These examples are all based on three and on four elements. In TJ's *Tango* and *Music and Questions*, the melodic reservoir consists of five notes grouped according to the same rule of progression as in Harry Mathews poem. In each sequence of six groups the first two tones are fixed while the others go through permutations.

This conception of permutation is completely different from the way Karlheinz Stockhausen, for instance, used this device in his *Klavierstück VI* (1954/1955). A six-note form with a characteristic distribution over the range is multiplied on different levels (central tones of groups and their whole pitch content) by means of self-similarity but then permuted so as to break the repetition of this peculiar shape. Permutation helps to avoid isomorphic structures and is therefore nothing but an instrument to guarantee an a priori æsthetical desire of non-repetition on a microcospic level.

From TJ's point of view however, permutation is a principal tool for looking at an object from all possible perspectives. This implies exhaustivity so as not to lose information potentially contained in the material. Again, TJ's æsthetic position is close to ideas of Abraham Moles:

> The work is an experiment. If it is not good, it is possible to begin it anew.[7]

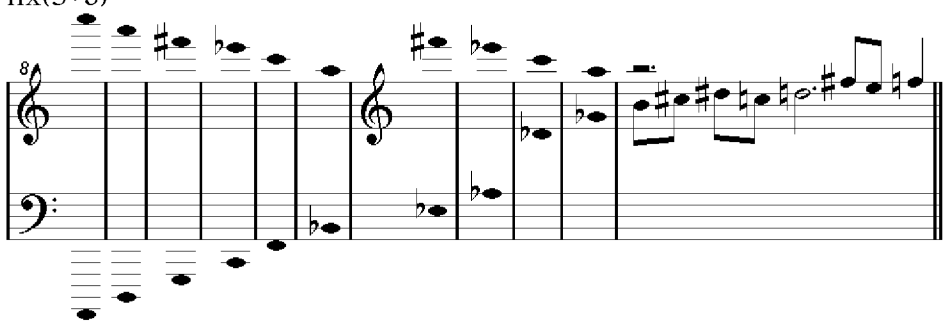
TJ about systems:

> If you decide to use a system, you have to respect it so as to discover the music while you compose it. But if you want to change the logic evolution of the process, then there is no use or business to use a system. This is a romantic attitude. If the result of a system is unsatisfactory, you have to change its basic rules, not to “correct” it here and there.[8]

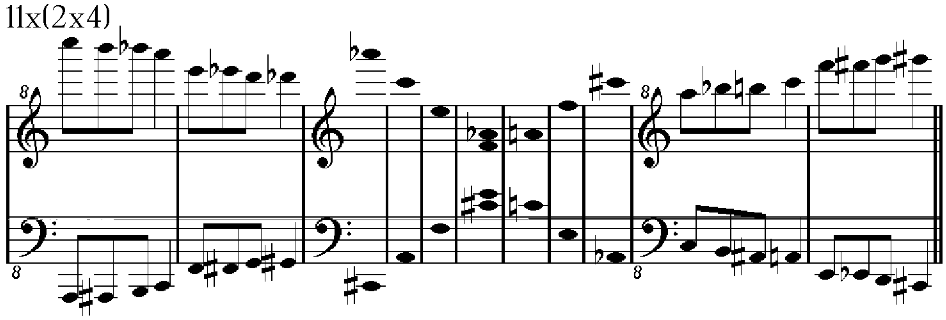
Exhaustive presentation of a limited sound material is also the purpose of one of the sections of *Music for 88* (**Ex.6**).

Ex.6 - Excerpts *from Music for 88*

11x(5+3)



11x(2x4)



In the first example (11x(5+3)), the chromatic scale is used step by step, progessing in both directions: each motif characteristically shows the possible degrees of the pitch collection (+4, -3, +2 / -2, +1), indicating on the melodic level a progression from extreme positions to a more centered tone or at least diminishing the range of the motif by each up and down movement. The two parts of the process will meet each other at the end of the piece a little bit higher than the center of the musical space.

In the second example (11x(2x4)), the progression inside the motif is simpler – a scalar chromatic movement – but with a gap between the end of one motif and the beginning of the next one in the same voice: this gap will be filled symmetrically to the center of the piece by the process of inverted direction, so that the two processes cross each other and both go through the whole range of pitches.

To end, let's recapitulate the different examples from the point of view of *ratio* in its sense of *proportion*.

Ratios take part in the organization of TJ's music either as basic principles or as result of other devices of structuring.

- The pieces counterpointing melodic and rhythmic patterns of different length use ratios as a fundamental definition of the formal logic.
- In the music based on the principle of self-similarity, the ratios between the different structural levels are not contained in the basic rule of the piece but are a supplementary decision: in the melodic example, the ratio from level to level is 1:2; in the polyphonic one, 1:4.
- In the permutation pieces finally, ratio is limited to the number of elements that will be permuted: one part of the elements is fixed, the other is internally mobile. This may also be expressed as proportion. In the case of *Tango* the ratio is of 2:3.

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1 Tom Johnson, *Rational Melodies,* p.2

2 Tom Johnson, *Rational Melodies,* p.36

3 Tom Johnson, *Rational Melodies,* p.38

4 Abraham Moles, *Kunst und Computer* Cologne: DuMont, 1973, p.104 (my translation)

5 in: *OULIPO La Bibliothèque Oulipienne* Jacques Boubard (ed), Geneva/Paris: Slatkine, 1981, p.36

6 Ernst Jandl, *Gesammelte Werke* vol.2., Darmstadt/Neuwied: Luchterhand, 1985, p.63

7 Abraham Moles. op. cit. p.111 (my translation)

8 Personal communication to the author in November 1992

Volker Abel

The Mutabor II System of Computerized Intonation

1. Abstract

Microtonality – or, to be more general: microtonal structures – is a multifacetted subject. This is evident in the light of the fact that it utilises no standardised notation or vocabulary.

Against this background, we have designed a simple yet universally applicable formal language for dealing with microtunings in a comfortable manner. Static tone systems and "mutating tuning logics" of any kind possess similarities on an abstract level. The idea of a "fundamental tone scale", reproduction rules and an abstract meaning of re- and detuning have been developed into a concept, implemented in the computer program Mutabor II, which offers a new experimental approach towards the phenomena of ratio, proportion, temperament and microtonal structures in general.

2. The representation of static tone systems

In our concept of the representation of microtonal structures there are two "hidden premises" that have to be mentioned in the beginning: one is that we consider the meanings of "frequency" and "tone" as the same thing. We concentrate on pitch, but not on timbre. Of course, that is a strong limitation, but it is not yet possible to formulate a precise relationship between pitch, timbre and other influencing elements. The second premise is that our concepts are keyboard-based, so we give a representation of microtonal structures that can be applied to a keyboard instrument's performance.

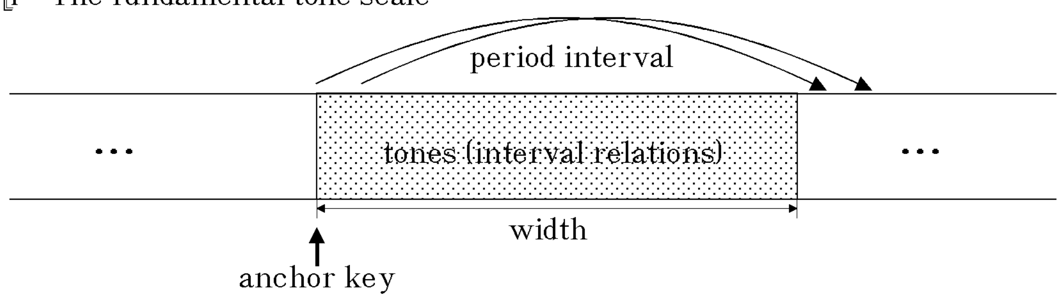
Looking for a general parameterisation of microtonal scales, we had to notice that on the one hand, a formalism has to be as intuitive as possible – on the other hand, we had the demand to reach a state of universality: the model has to fit to historical tone systems as well as to inventions of New Music including enough space for further experiments. The most obvious representation of static tone systems (as we think) is as follows:

Many kinds of music show the “octave equivalence” phenomenon, whereby tones related by a multiple of an octave (ratio 2:1) are equally treated – the complete amount of tones is divided into equivalence classes. In our terms: the frequencies can be derived from a prototype tone scale and a reproduction rule. This reproduction rule is usually a frequency translation with multiples of the equivalence or period interval (not necessarily 2:1).

For a plain definition, we need exactly three parameters: an “anchor” (the key or tone where the prototype scale starts), a set of interval relations or frequencies of the prototype scale’s tones and a “reproducing interval” (first we’ll only allow simple reproduction rules with a single and constant period interval; this concept can be expanded later). It is easier to handle these parameters if we add a fourth one: the “width” of the prototype scale, meaning the number of keys (or tones) it contains. The width is a simple hint for the complexity or redundancy of the tone system (equal temperament scales require a fundamental tone scale of width 1).

To summarize, every static tone system can be represented by the four parameters *anchor key*, *width*, *interval relations* and *period interval*, collectively termed a *fundamental tone scale* – see **1**.

1 – The fundamental tone scale



Some examples shall now demonstrate the use of the principle of a fundamental tone scale:

To define the Pythagorean scale or a mean-tone scale (both representative of an octave-based twelve tone scale) a fundamental tone scale of width twelve is needed. The period interval is of course the factor 2:1, and the anchor key is usually set to the harmonic or melodic center of the scale, e.g. to Middle [C]. Finally, we define the interval relations (or frequencies) of the twelve tones inside of our prototype scale.

Consider equal temperament scales: they are “structureless” and can therefore be interpreted as a fundamental tone scale of width one with a period of the equal temperament interval. To define a quarter-tone system, we just need to set the anchor key (for example [A]) to a fixed frequency (here 440 Hz) and take a simple period interval (factor $\sqrt[24]{2}$). You can get any equal temperament scale just by changing the period interval.

Of course, there are rules for static tone systems which cannot be conveniently expressed in terms of a fundamental tone scale, because they do not have a periodic interval. An overtone scale is an example for a non-periodic system (in our terms of a periodic interval relation). Assume that we want to play an overtone scale on the white keys of the keyboard. We have to define a fundamental tone scale of the type “free definition”, meaning that the fundamental tone scale contains as many tones as there are keys on the keyboard. Every key will get its own frequency, and there is no (relevant) period interval.

3. Mutating tone systems

Now that we've found a general concept for the representation of static tone systems, we will try to apply those ideas on a definition of mutating tone systems:

The basic idea is to have a finite and discrete amount of tones which can be played at a time (represented as a fundamental tone scale) and a set of mutation rules, creating an enormous number of different tones during a piece in an almost continuous way.

A mutating tone system is a discrete variation of the fundamental tone scale's parameters in time, caused by external events.

At the beginning of a piece, there is an initial state that can be represented as a fundamental tone scale. During the piece several events produce changes in the tuning. Specific rules control the changes of the tuning dependent on the different events that occur. We call this construction a “tuning logic”.

Since a tuning logic is a set of rules of the form event → retuning, we still have to define the meaning of “event”. Principally, an event shall be everything that a computer can recognize, when it is connected to a (MIDI-) keyboard. For Mutabor II that means keys pressed on the computer keyboard, MIDI messages and – an extract from MIDI-messages – patterns of keys pressed on the music instrument keyboard. The last one is the most important, because the analysis of key patterns allow the use of simple (or later on more complex) harmonic analysis to control the tuning. You may, for example, construct a tuning logic that changes a harmonic center (this may realise the idea of the tonal net) and sets the micro tuning harmonically based on that (moving) center.

This leads to the most fundamental principle of Mutabor II: the frequency of a tone is calculated directly after the player has pressed a key, depending on the active tuning logic (which may depend on just the key that was actually pressed). The speed of this calculation has to be fast enough to produce the sound without a delay, but that is no problem for modern computer hardware. This concept makes it possible to play an infinite number of tones on an instrument with a finite number of keys, because it is possible to construct a tuning logic where the retunings are not done absolutely, but relatively depending on the current state, especially if such a rule is linked with a harmonic (or better: key pattern) analysis.

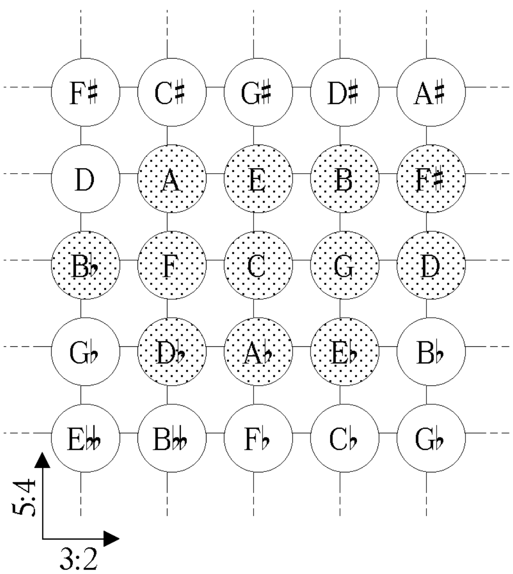
4. A programming language for microtonal structures

The principles of a fundamental tone scale (with the four parameters anchor, width, tones and period interval) and a tuning logic (which means that events produce retunings) can be formulated as a programming language for micro-tunings.

The Mutabor II System of computerized intonation is one possible approach to the integration of two important concepts: A programming language offers unlimited space for experiments, but it has to be easy to handle. We have defined syntax and semantics of a simple programming language, within which the user can express how the instrument is to be tuned, and the way the tuning has to mutate. The user enters this “tuning program” as a text file into the computer, and Mutabor II will set up this tuning as a (MIDI-) keyboard ➔ computer ➔ synthesizer/sampler installation for free performance.

This article ends with the following examples demonstrating a simple Mutabor II program for two static tone systems: a quarter-tone system given the identifier "Quarter_tone" and an excerpt from the tonal net around Middle [C] ("Tonal_Net_C") – look at **2** and **3**: in the latter, the "60" and the "69" represent the anchor key's MIDI number (i.e. Middle [C] and the [A] above it). The microtone programming language syntax implemented in Mutabor II includes some further elements to program mutating tuning logics, but they are as intuitive as those in the list below and needn't be explained in detail.

2 – The tonal net around C
(Chromatic scale shaded)



3 – Static tone system definitions

```
TONE
   C = G – fifth
   Db = F – third
   D = A – fifth
   Eb = G – third
   E = C + third
   F = C – fifth + octave
   F# = D + third
   G = C + fifth
   Ab = C – third
   A = 440
   Bb = F– fifth + octave
   B = G + third

TONE SYSTEM
   Tonal_Net_C =
   60 [C,Db,D,Eb,E,F,F#,G,Ab,A,Bb,B]
                                     octave
   Quarter_tone = 69 [ A ] quartertone

INTERVAL
   octave = 2:1
   fifth = 3:2
   third = 5:4
   quartertone = 24 root 2
```

Hartmut Möller

Trying to understand Horatiu Radulescu's String Quartet Op. 33 "infinite to be cannot be infinite; infinite anti-be could be infinite".

> For whoever will express the music of the heavens most fittingly, to him Clio grants the crown and Urania will give him Venus as his wife. (Johannes Kepler)

Every effort to draw a map of rationality, its clarity and coherence is obscured by paradoxes, riddles, dilemmas and practical self-references. And beyond the different attempts to construct a consistent, plausible model of rational human action, there still remains the immense gap between description and application to human action in fact. For centuries the question remains open, whether music is art of the irrational or of the rational. Proceeding on the assumption that music contains both opposite poles, then it seems appropriate to explore the connnection of this duality in special objects.

In the case of the theoretical and compositional work of Horatiu Radulescu (= HR), I shall concentrate on his *String Quartet Op. 33* for live string quartet and eight prerecorded string quartets . In the first part of my talk I shall try to find a path through this 49 minute work. In the second part, I would take the risk of bringing the quartet into a broader context: its concept of form, the question of meaning, rationality and irrationality.

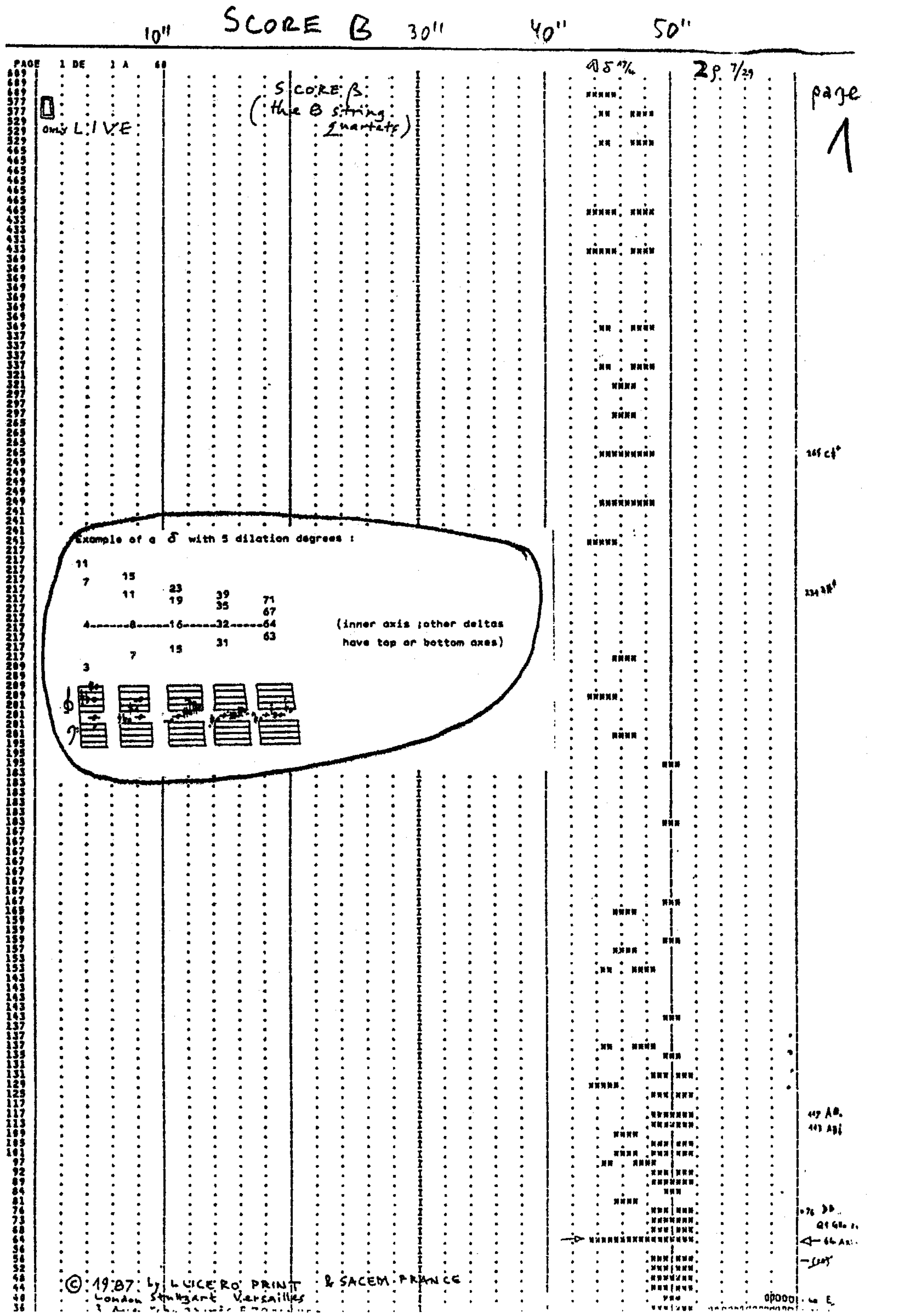
I do not see my task in simply duplicating the composer's explanations or concentrating on technical questions – for example in linking the quartet with the central categories of spectral technique for which HR laid the base in 1969 and which he described in his treatise *Sound Plasma – Music of the Future* (1973): variable distribution of spectral energy ("spectrum pulse"), synthesis of global sound sources, processual micro- and macro-form, different butsimultaneous layers of perceptual speed and spectral scordatura (scales of unequal intervals corresponding to harmonic scales).

As a music historian interested in the place of our time's music in history, my task is not only to tell stories but to think about the hidden premises and assumptions, the ideological baggage of our telling stories to support our Western, rational identity. I must confess from the beginning that the reason why I personally got interested in this quartet is not because it is based on overtones, but because I realized in which sense it is a work of art which has to say something to us. Therefore I tend to view it more from the aspect of art work than from the technical details of the scordatura &c. (Who would take Bach's *Goldberg*-variations only as a starting-point for going into Werckmeister's system of temperate tuning?)

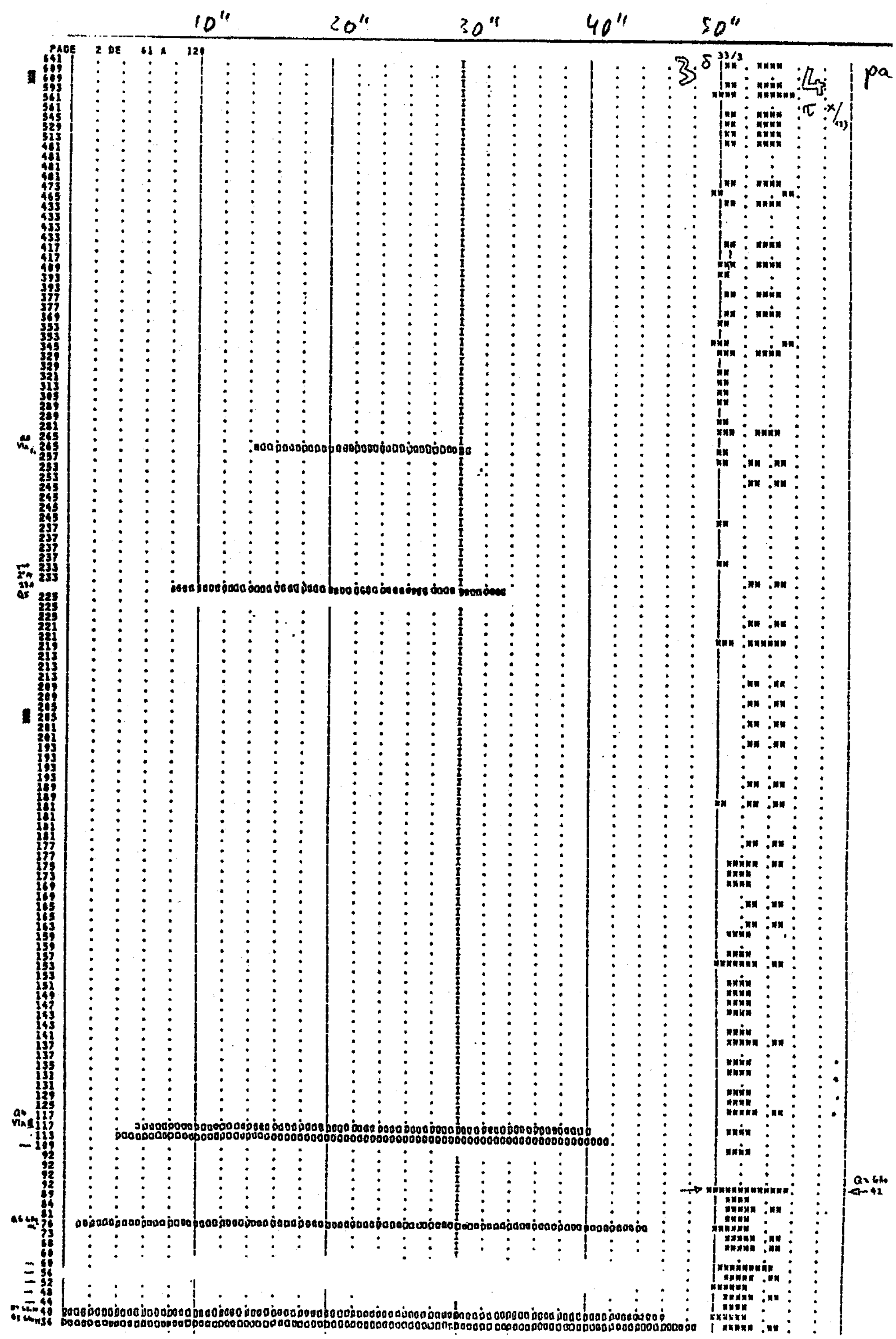
1.

HR's *String Quartet* Op.33 was composed from 1976 till 1987. The quartet divides into two macro-forms, α (alpha) and β (beta), represented by one live string quartet and eight string quartets, live or pre-recorded. Imagine a concert hall, where the live quartet is placed in the center of the space, surrounded by the audience, and all around, at the distant margins of a larger circle, there are eight other string quartets, live or pre-recorded. HR speaks of an "imaginary 128 string-instrument" or of an "imaginary circular viola da gamba with 128 open strings". There is no score for both groups, but instead two independent scores, one for each group: the one quartet in the centre and the eight string quartets surrounding the audience. It's a special way of part-notation (*Stimmbuchnotation*), which comes together only in the moment of realisation. To get insight into the simultaneousness and development of these two groups α and β, both scores are to be simultaneously read.

1a – Page 1 of Radulescu's Op.33



1b - Page 2 of Radulescu's Op.33



> *"Do not ... the fragments of the self each of us believes to be sometimes converge and achieve unity or a semblance of it?"* (Siegfried Kracauer)

Let's start with the score β of the eight string quartets (see Figure 1 on the preceding two pages). Every page of this score is divided into six colums of ten seconds. At the left margin you find the numbers of the strings used. The total number is 128 (eight quartets with 16 strings each). These numbers refer to the imaginary "viola da gamba" with 128 differently tuned strings. The 128 strings are spectrally tuned: they use 128 different frequency components of a fundamental C (at 1 Hz) between 36 Hz and 641 Hz; that ranges from D1 (the lowest D on the piano) to ca. E5, the E in the octave above Middle C. This scordatura has nonequidistant intervals and no isomorphy at any octave.

There are several types of *micro-music* acting on the great scordatura with different inner life (deep structure) and different sound production assigned (bowing and/or special techniques of fingering). On the first two pages given in Figure 1 you see two of these types (others I shall point out later): first a so-called δ-(delta)-micro-music, then a ρ-(rho)-micro-music and again a δ-music with different density. The δ-music is a dilation/contraction of a harmonic formant, as if this formant (or chord) belonged to different formants (higher or lower) of a unique spectrum. An easier example inserted on the left half of Figure 1 may show the principle of the δ-music: The middle c is the inner axis, which jumps (theoretically spoken) octaves upwards. In relation to this axis the numerical distance of the harmonics remain stable, and the result is transposed to the same register. In other words: a spectral chord is jumping on various regions of a spectrum, but keeping constant the vicinity proportions of its elements; and this dilation/contraction is heard in the same register. The special sound production assigned to the δ-music is the "phase shifting" arco on open strings.

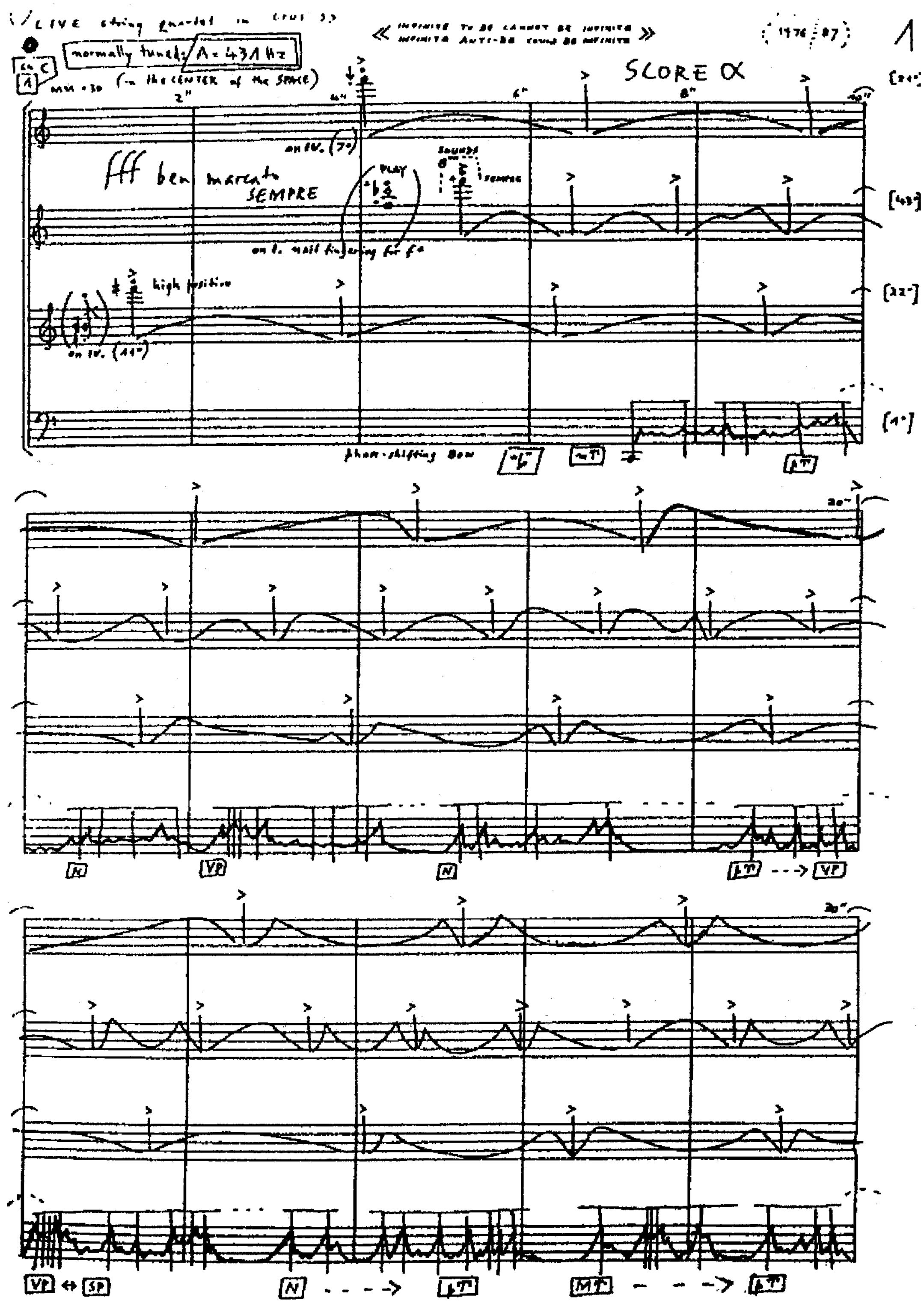
On page 2 of Figure 1, there starts another type of micro-music: the ρ-micro-music, building up self-generative frequency plateaux in live and explicite ring modulation, proliferating until meeting a "vertical mirror", an axis of "vertical time", and then gradually fading out. In the given case the frequency-components 36 and 40 add up to 76, as well as 113 and 117 builds up 231. Finally 34 plus 231 results in 265 as the highest component. The sound production assigned to ρ-music is a fast and irregular change of highest possible natural harmonics of a string and "morse"-signals of the open string, combined with a very fast and flautando bowing in verso/sul ponte; both techniques intermingle in a fast and uneven intermittence.

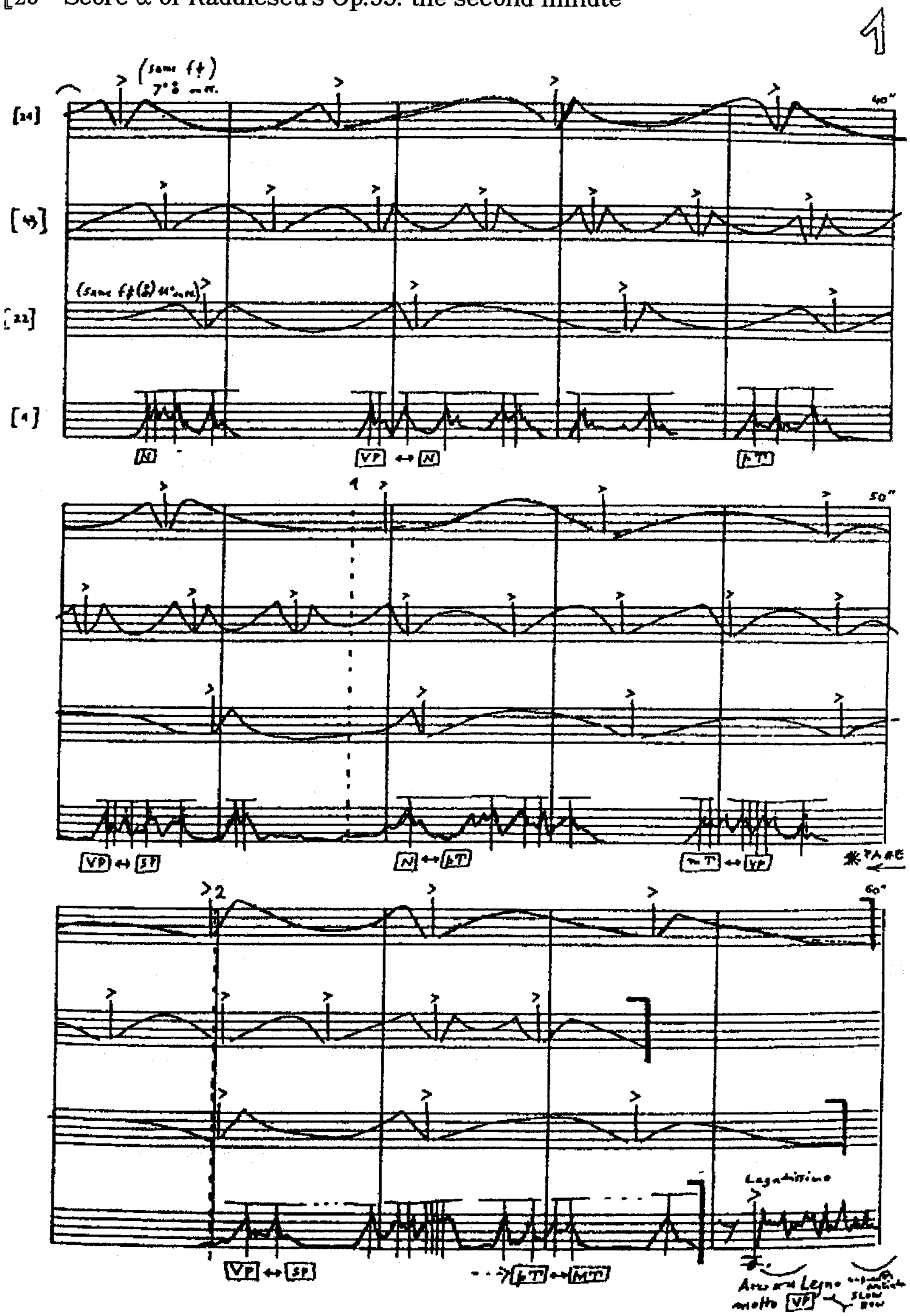
These are just the first three micro-musics, and only two types of it. The macroform of the quartet β is built, in total, of 137 regions of micro-musics with changing density, length, and type. Some of these 137 micro-music modules are intersections of two or three types or micro-music. Even if sometimes related, the 137 micro-music modules are all unique.

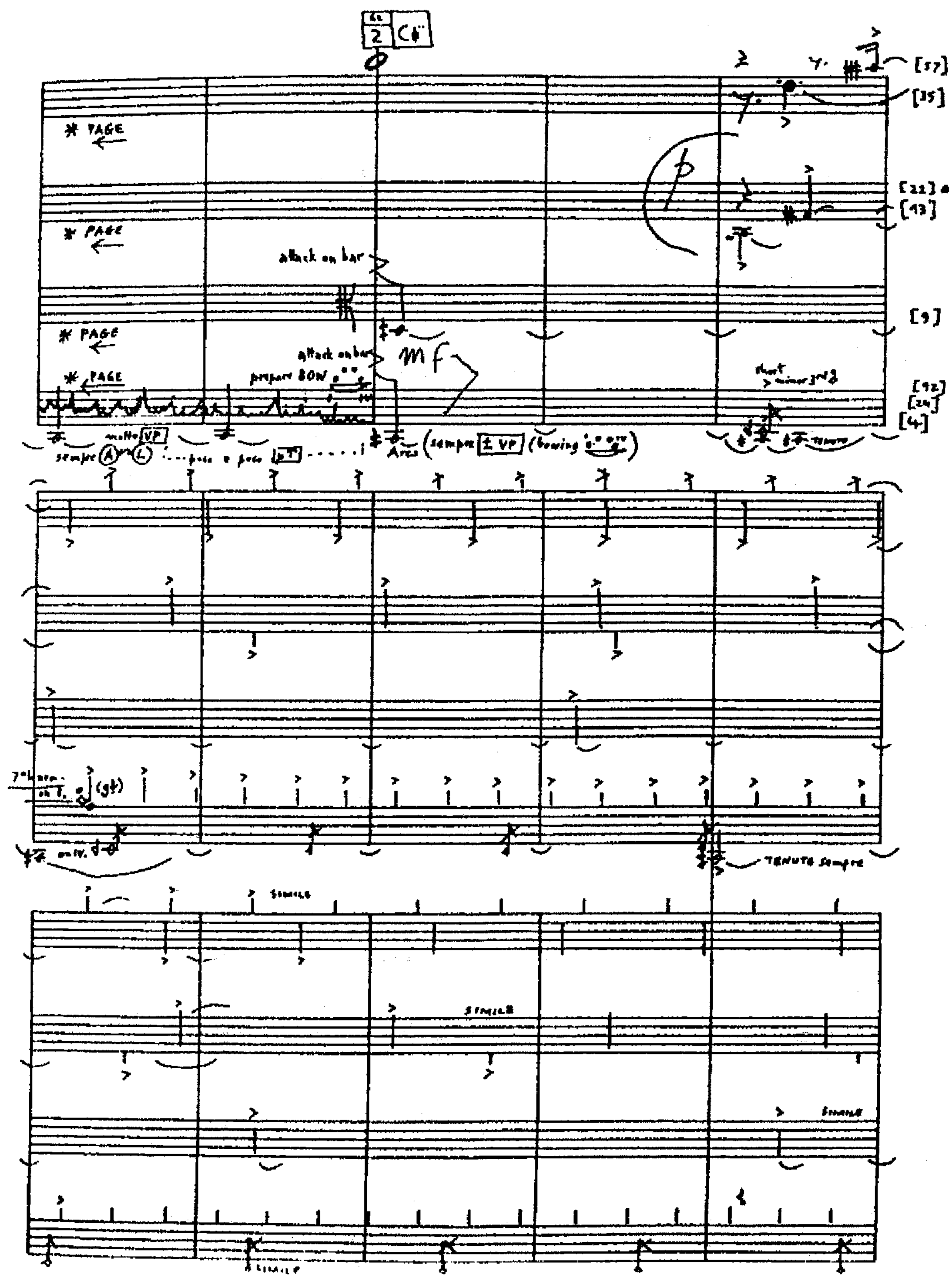
The live string quartet α (see Figure 2 on the following four pages) is written in six blocks of ten seconds, divided into five time-columns of each two seconds per measure. Thus, also for this quartet, one page represents exactly one minute.

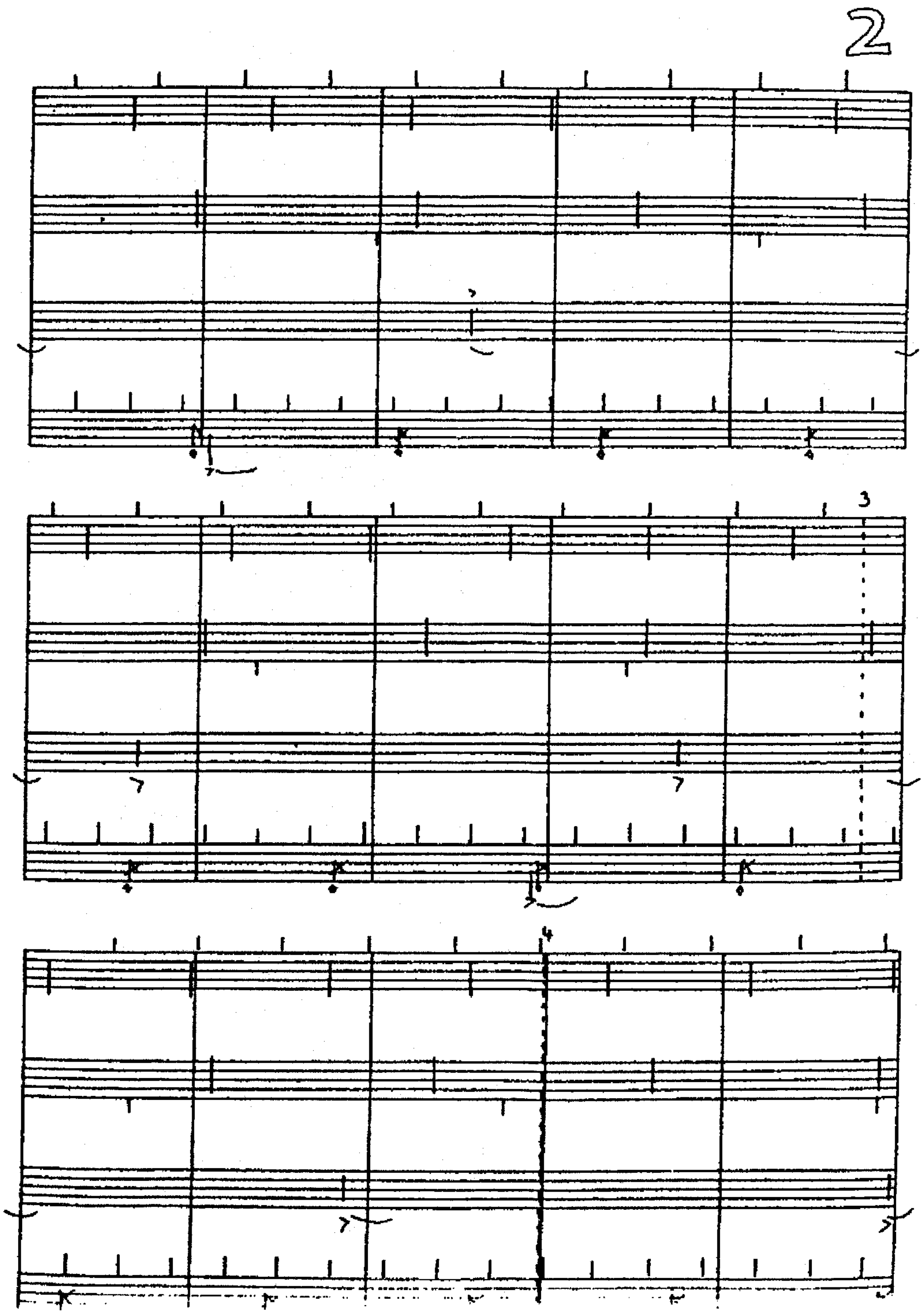
The String Quartet α is tuned to a′ (at 431 Hz) in normal perfect fifths (431 Hz is theoretically based on a C fundamental of 1 Hz; that is: C is the fundamental of both quartets α and β). α uses self generative spectral functions; many of the formants on which the 89 micro-musics are built, were deduced through ring modulation of spectral functions.

Let′s have a look at the first micro-music: it is tuned from C; the four instruments play the frequency components 1, 21, 22, and 43. From formants 21 and 22 emerge formants 43 and 1. The first micro-music lasts 64 seconds, the frequency-components have their own time-pulse marcati according to their frequency plateau. Therefore the component 21 has a strict rhythm of 21 units per 64 seconds, the component 43 has 43 units, etc. The marcati >>>>> of the proportionally strict rhythm issued of the authentical time-pulse of the frequency-components are very important for the individuality, the "inner life" of each micro-music.

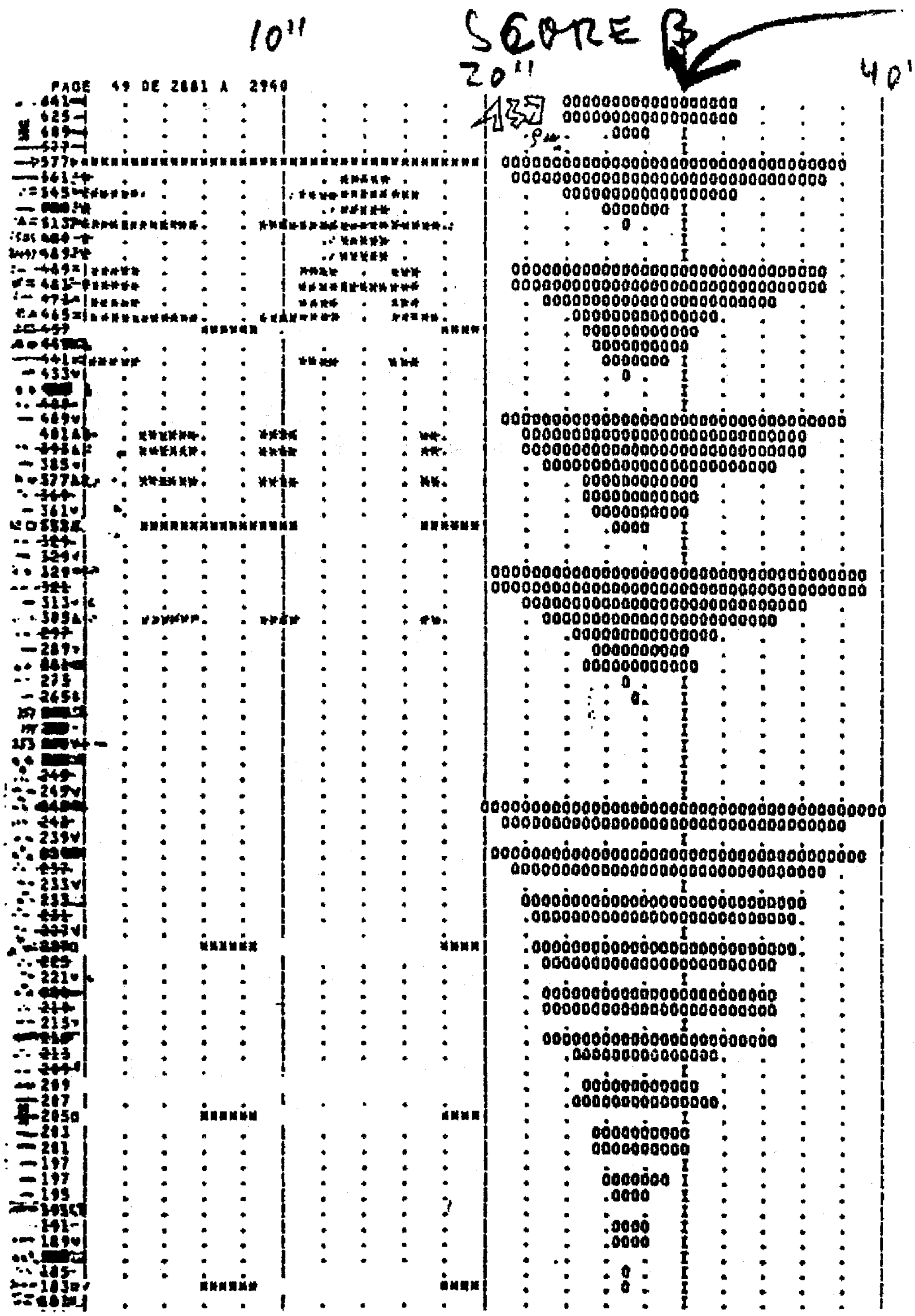
2a - Score α of Radulescu's Op.33: the first minute

2b - Score α of Radulescu's Op.33: the second minute

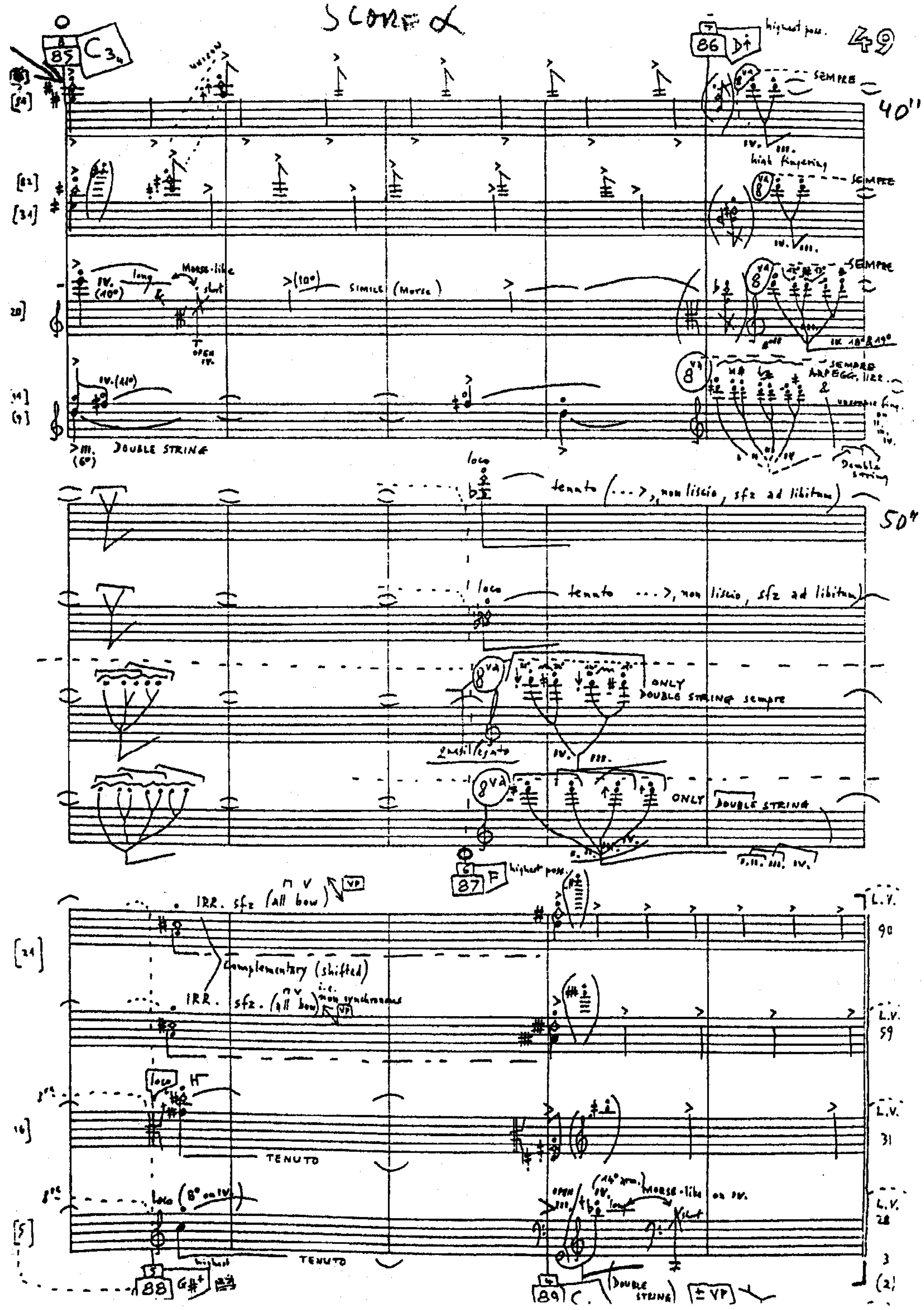


2c – Score α of Radulescu's Op.33: the third minute

2d - Score α of Radulescu's Op.33: the fourth minute



3a – Score β of Radulescu's Op.33: the last minute



3b - Score α of Radulescu's Op.33: the last minute

Interdependance between time organisation and fundamentals

There is another important compositional procedure in connection with the 89 micro-musics: Each micro-music α is tuned according to its duration correlated as C = 1 Hz = 1 second. So the procedural question is: for which fundamental is C the harmonic, given the duration of the micro-music? In case it lasts two, four, eight seconds &c., the fundamental remains C (64 seconds is the maximum length of an α music). In case the duration is, let's say, three seconds: for which fundamental is C the third upper harmonic? Result: the fundamental must be F – and the same is true for a micro-music lasting 6, 12, 24 seconds, and so on. According to the same ratio, a micro-music lasting 13, 26, 52 seconds has a fundamental D♯*. In Figure 2, four seconds after the beginning of the second minute, micro-music number 2 begins, lasting 62 seconds. The fundamental, for which C is the 62nd harmonic, is a C𝄲 (55 cents above C). Summing up: In quartet α, there is absolute interdependance between pitch and time; this means, that the specific fundamental of every micro-music is function of the strict duration of that micro-music.

During the whole quartet, α modulates through 27 spectra of different length. They are all tuned in an acoustic fundamental in function of their duration; in total, there are 89 micro-music "windows" of pulsating spectral "orbits", which modulate from and into 27 different spectra. (The specific trajectory is a point, to which I come later on). On this way through 27 spectra, α returns 16 times to the C spectrum, the length varying between 4, 8, 16, 32 and 64 seconds. The first α-music (as seen in Figure 2) lasts 64 seconds, the last one four seconds.

The very end of the quartet is reproduced as Figure 3 (on the preceding two pages). On the right page you find the last 30 seconds of the α music, on the left the corresponding part of the β music: after 20 seconds starts a ρ-micro-music with its "vertical" time-axis at about 27 seconds. While gradually fading out, the quartet α plays the following sequence of micro-musics: The five concluding micro-musics (numbers 85 to 89) are constantly accelerating from 8 seconds over 7, 6 and 5 seconds to a last micro-music of only 4 seconds. The fundamentals go from C through D♯, F, G♯ to a final C. Thus, the first and last micro-music on this last page have a C fundamental; but both use different harmonics: the first, lasting 8 seconds, has the spectral functions 9, 11, 20, 31, 51 and two times 82; the last consists of the harmonics (2), 3, 28, 31, 59 and 90. In both cases the functions can be deduced through ring modulation:

20+11=31	31+20=51	31+28=59	59+31=90
20–11= 9	31–20=11	31–28= 3	59–31=28

The single functions pulsate the quicker, the higher their order numbers are. (But given the short dimension of these final micro-musics, they cannot pulsate direct-proportionally to their role in the given spectrum.)

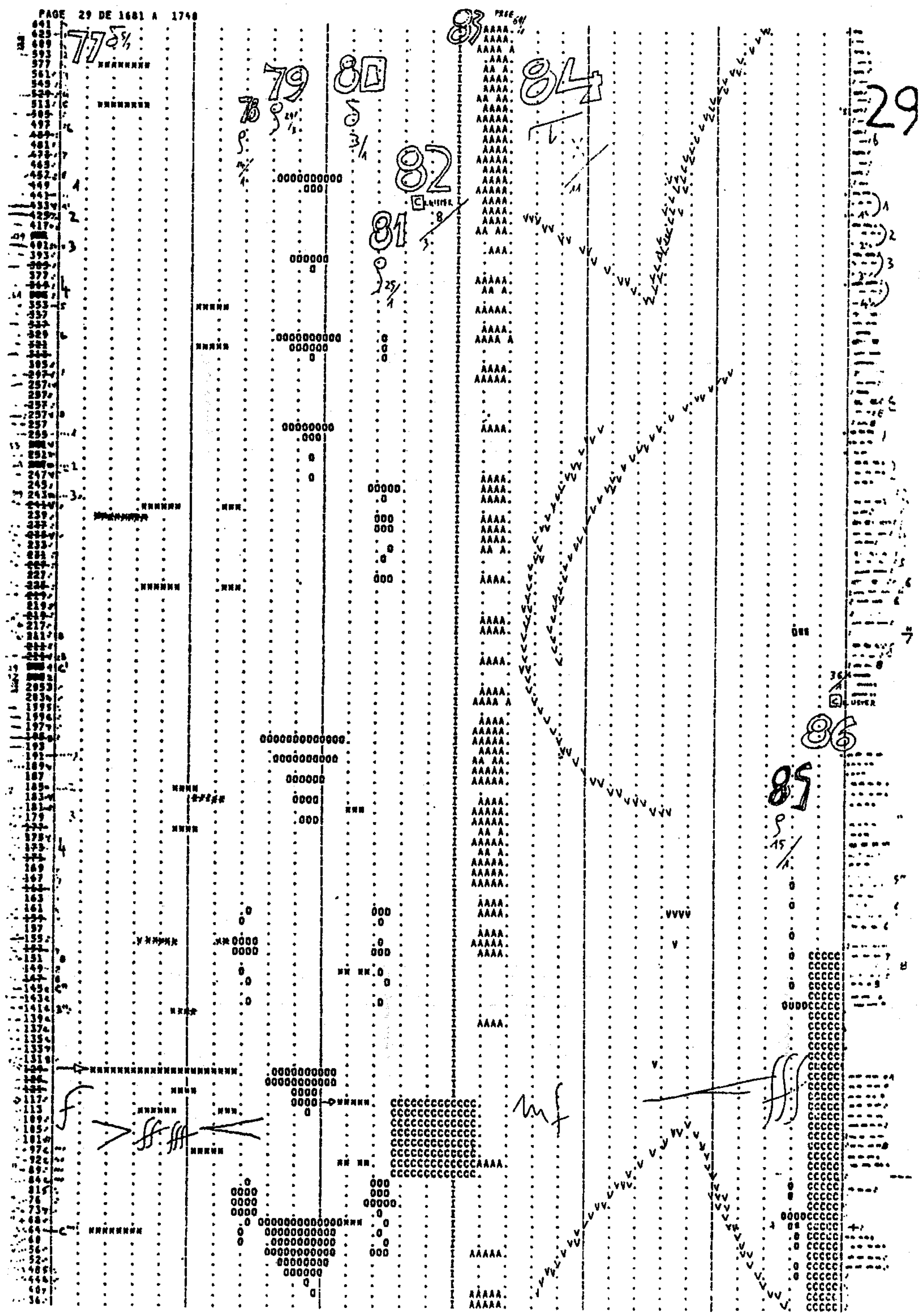
On the way to the infinite: the Golden Sections

> *"Were Pascal, the mathematician, and Pascal, the Christian strangers to each other? ... it may be that the antithesis, correctly considered, is only the mask of a deeper solidarity"* (Mark Bloch)

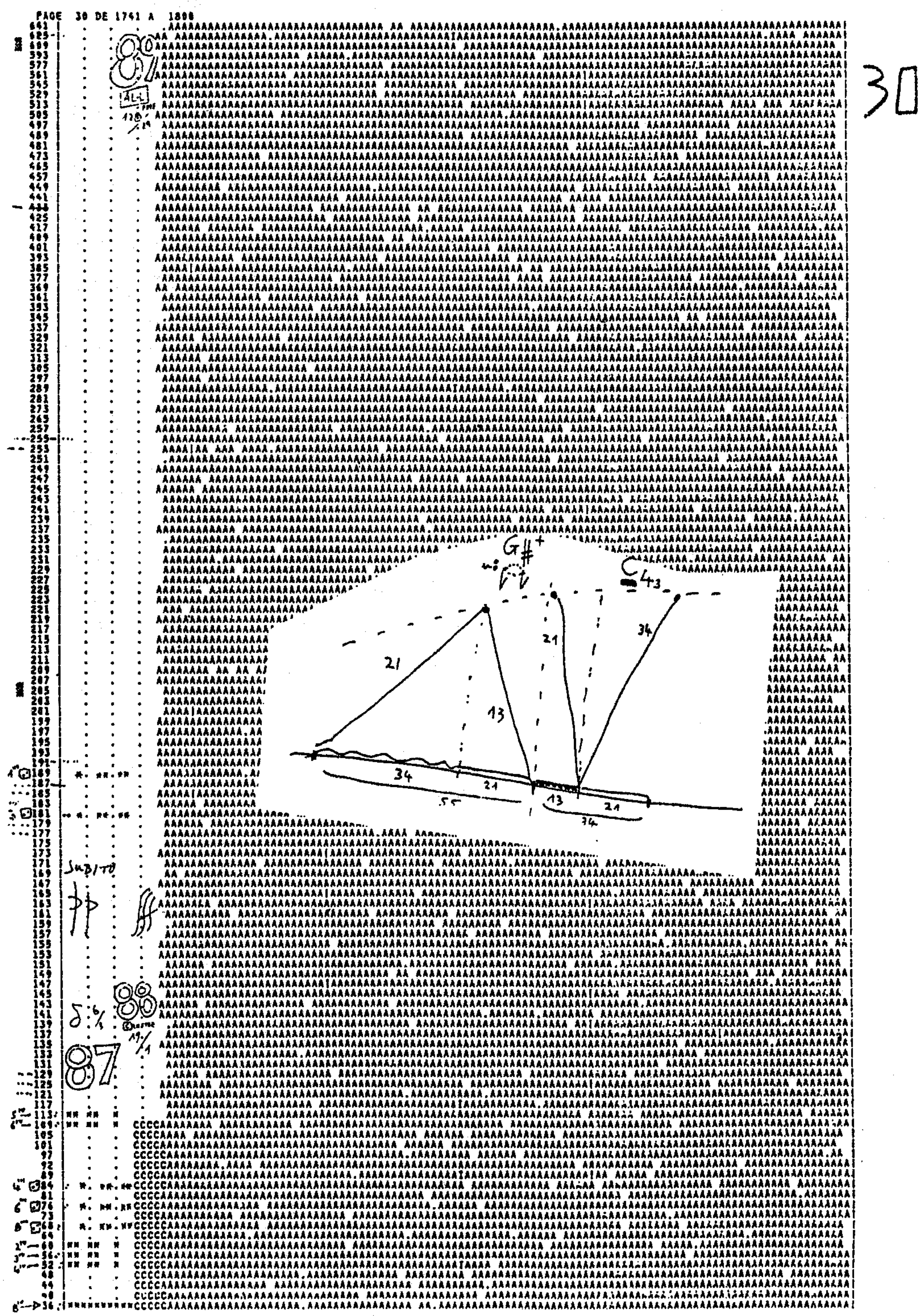
Now let us look at one specific point in the course of the quartet which is (as you will see) of special importance for the overall form: Figure 4 (on the following two pages) shows the minutes 29 and 30 of the β music. After a δ– and ρ–micro-music (which you already know from the beginning of the quartet, see Figure 1), there follows a "cluster" of eight elements, lasting 6 seconds; then a type named "free" (two seconds, and afterwards a type of micro-music, which in its graphic trajectory resembles that of "thundered" lightning. Therefore this micro-music was named τ (tau), which is based on upstroke bowing and "lasciar vibrare" technique at various points along the open strings (sul ponticello, verso ponticello, normal, sul tasto).

The plurivocal designs are difficult to analyse aurally: register tendency, polyphony/heterophony/melody, number of voices (parts), speed/densitiy of distribution. Although periodically written, the graphic display of those upstrokes is to be performed with micro-agogical value-variations as in Baroque music, and thus, nonperiodical. Simultaneous interventions create a quasi-sudden and irregular arpeggiamento in between parts. And then, at minute 30 plus 8 seconds, there starts a "free" music by all 128 strings of the imaginary viola da gamba, lasting 58 seconds (29 units of 2 seconds).

4a - Score β of Radulescu's Op.33: the twenty-ninth minute

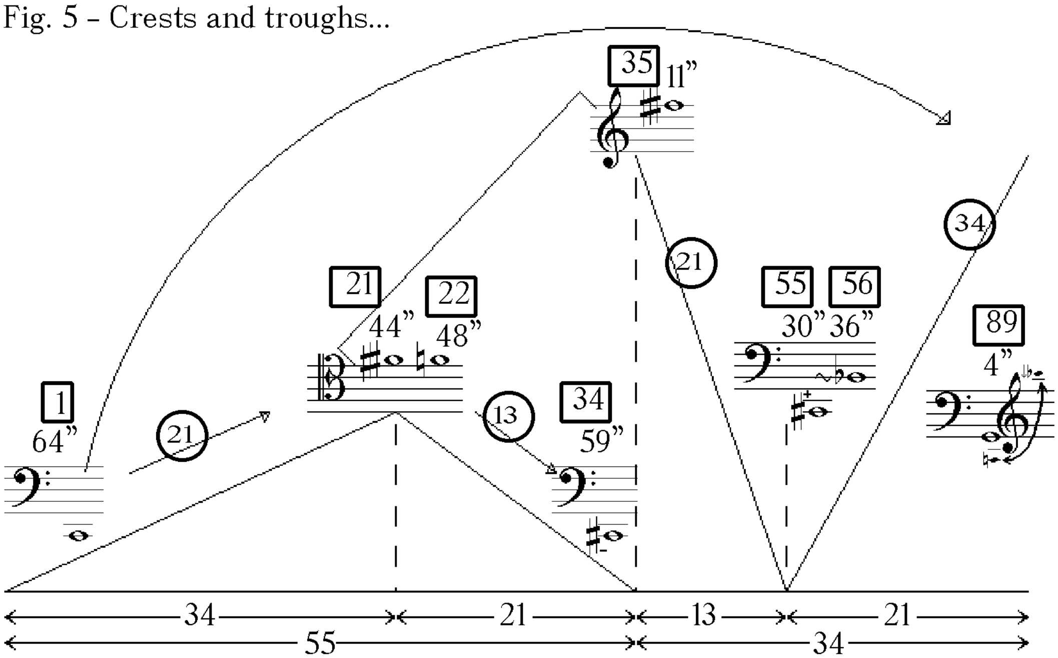


4b – Score β of Radulescu's Op.33: the thirtieth minute



What about the α music going on at the same time? On the top of the excerpt of the β score in Figure 4, I marked the places where α moves into a new spectrum: on page 29 after 20 seconds α music number 33 starts (duration: 58 seconds), and on page 30 after 18 seconds is the beginning of music number 34 (59 seconds). When this micro-music ends (exactly after 30 minutes and 17 seconds), an important point in the macro-form of the piece is reached. HR's little scheme added on the left side of Figure 4 gives insight into his planning of the proportions for the α music of the whole quartet. In the following diagram, I have added extended HR's scheme with informations concerning the fundamentals, durations and numbers of those α musics where the trajectory of the form is changing (see Figure 5). You see a trajectory combining a wavelike movement: 21 elements plus 13 elements downwards, then 21 elements downwards and 34 elements upwards. The upwards/downwards path ends with a micro-music based on a low C♯, lasting 59 seconds (quite near to the temporal dimensions at the very beginning: 64 seconds!) – but then, a sudden jump to a high fundamental, F♯ over two octaves higher and a resulting duration of only 11 seconds. And the end of the α music after the dominant "free" type of the β music, beginning on page 30 is just the point, where both trajectories come together.

Fig. 5 – Crests and troughs...



2.

“ *The antinomy at the core of time is insoluble. Perhaps the truth is that it can be solved only at the end of the Time.” (Siegfried Kracauer)* “

When a line is divided in such a way that the smaller part is to the greater as the greater is to the whole” – this linear ratio was known already in Old Egypt and Babylon, it was described by Euclid and later praised for its divine and magical qualities by Leonardo da Vinci and Johannes Kepler (*sectio aurea*, *sectio divina*). The golden section is always associated with organic matter, and quite foreign to the inorganic world; because of the irrational number in the formula, its occurrence in crystal-forms is precluded.

As you see from the above-mentioned diagram, the macro-form of HR's quartet is a combination of two golden sections: 34 time-units plus 21 in the first part, 13 plus 21 time-units in the second part (the exact time of each section can be calculated by division through 1.82). The point where the two trajectories come together is exactly the point of the overall golden section: 55 plus 34. But the temporal organisation is only one compositional domain which is organised according to the golden section: Also the number of micro-musics in every section is governed by the golden section; in the first part 21 plus 13, in the second part 21 plus 34. Seen together, their form is reigned by a highly elaborated ordering of the Fibonacci numbers 13, 21, 34, and 55: in the first part, every time-unit contains the smaller Fibonacci-number of elements; in the second part, this relation is reversed: the higher Fibonacci-number of micro-musics is contained in the smaller number of time-units – resulting in the accelerating to the end we already talked about.

“Beyond music”

If, as an experiment, we try to adopt Erno Lendvai's famous and at the same time problematic way of analyzing Bartók, we would call the division, in which the longer section is followed by the short one, a “positive” division – and the corresponding one “negative”: a short section followed by the long one. Viewed this way, the macro-form is divided into a “positive” and a “negative” section, which complement each other, comparable to something with its own mirror-image. The overall result, indeed, would be a positive sign. So far a “formalistic” interpretation of the macro-form à la Lendvai. But of course it is problematic just to count time- units... And, what is more problematic: the macro-form of the quartet is not built of dualities of “plus” and “minus”, but forms instead an irregular and, nevertheless, constant increase of organic growth. We should keep in mind, that the different means and layers of “number composition” in this quartet are related to something “beyond music” – as pointed out HR himself: “The depth-truth beauty of the idea is further beyond music, and therefore attracting the music towards that beyond”. But where is this “beyond” situated? The quartet's title “*infinite to be cannot be infinite; infinite anti-be could be infinite*” is intended by HR as the attempt of a modern answer to Shakespeare's famous “to be or not to be”: “even infinite in its aspects, our being, our terrestrial existence cannot be endless, but our infinite anti-being, our eternal, cosmic being – throwing us, as a vibration, towards life and towards death, could be everlasting.” (In the Rumanian language, the title can be expressed only through different intonations of one word in the middle [*nu*]: *infinit a fi nu poate fi infinit*).

Seen from this perspective, the string quartet β represents in its all-surrounding presence the “earth”, the starting-point and point of return on the individual's voyage between spectra. It begins with a first slow attempt to raise and to accelerate, but calms down again and returns near to the very low starting-point. The beginning of the second part reminds us of the experience, which a German proverb articulates *wer hoch steigt, wird tief fallen* : a sudden mental jump high up into space, with accelerated descent. Only the final trajectory upwards is successful, the accelerating is not stopped and ends in a final spectrum – which enigmatically is related with the beginning and also with the fundamental of the sound universe – *alpha et omega*, *harmonia mundi* ... *infinite to be cannot be infinite; infinite anti-be could be infinite*.

But who is able to perceive all these compositional procedures and underlying ideas? They even aren't recognizable in the score (compared, for example, with Tom Johnson's music in Figure 9) – I hear some of you object.

Dufay the colleague

Proportions can be found in a large range of music by medieval and renaissance composers, by Schubert, Ravel, Debussy, Bartók, Stockhausen, Nono, and many others. In some cases, these proportions suggest only subconscious application by the composer, and there are cases, where they tell us only little about the music. On the other hand there are cases where composers are intentionally working with Fibonacci series and golden sections.

In the following miniature HR is seen in conversation with an old friend, "Maitre Guillaume Dufay" from Cambrai, maybe discussing the possibilities of tonality, of microtuning or even the need for an 128 string harp. (With this I don´t want to construct any kind of direct relationship between the work of the two composers; I only want to point out analogies in their formal concepts and in the differenciation between the hidden and the audible.)

Fig. 6 – HR & GD

Dufay's famous early ballade "*Resvellies vous*" was composed for a wedding in 1423 at the court of the Malatesta of Rimini. It is a piece extraordinarily rich not only in its melodic, harmonic, and rhythmic material. As David Fallows puts it, "no other piece of its time contains such a plethora of musical ideas; and it is all the more astonishing that the work should hold together as a musical entity." Beneath the audible surface, however, there lies a threefold silent system of number and proportion, which Allan Atlas deciphered in 1987: gematria (the assigning of a series of ciphers to the alphabet), Pythagorean number symbolism (the marriage numbers 5, 6, and 7) and the golden section. In our context we concentrate only on the last feature.

As you can see from the following diagram, Dufay uses the golden section at three levels: the piece as a whole, each of the three sections, and, at times, the individual phrase. As Allan Atlas has demonstrated, important musical and symbolic highpoints of the piece fall precisely on points of articulation, that form golden sections at one of the three levels.

Fig. 7a

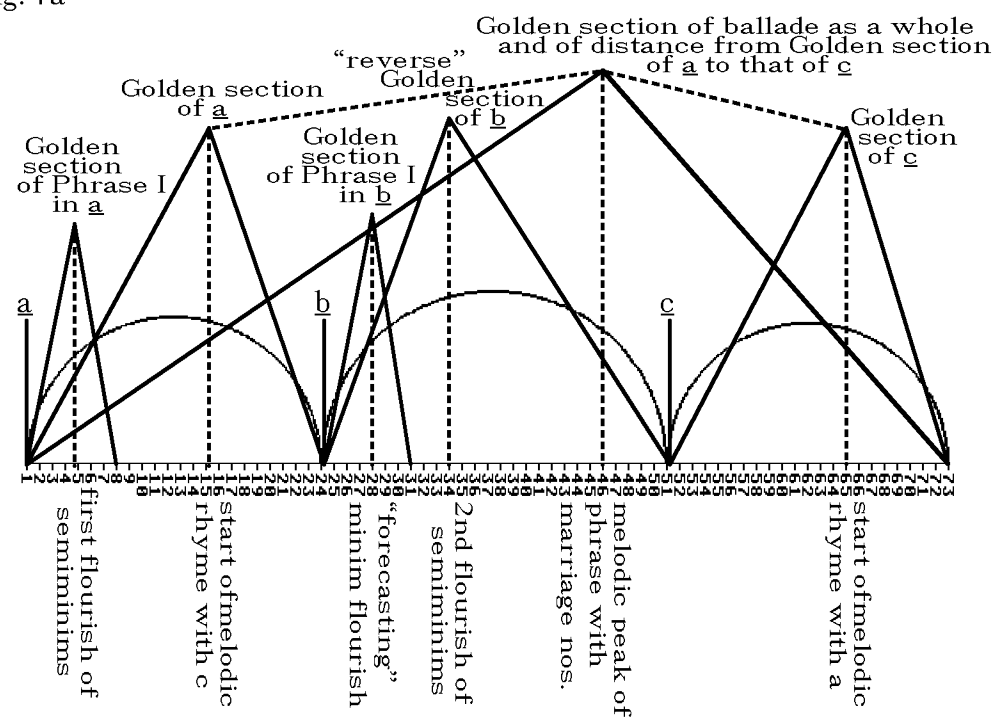
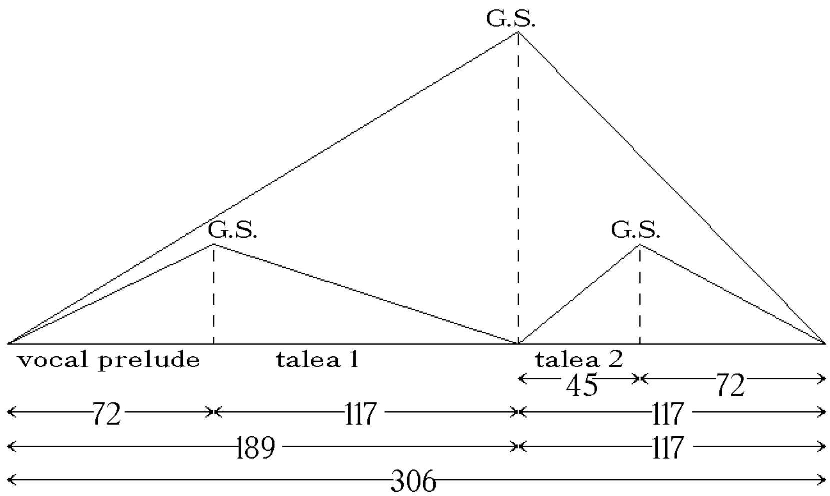


Fig. 7b – Resvellies vous et faites chiere lye (No.11)

Resvellies vous et faites chiere lye	Awake and rejoice,
Tous amoureux qui gentillesse ames,	All lovers who love nobility.
Esbates vous, fuyes merancolye,	Enjoy yourselves, flee melancholy.
De bien servir point ne soyes hodés.	Be not unwilling to serve well,
Ca au jour d'ui sera lie espousés,	For today will be the wedding
Par grant honneur et noble seignourie;	With much honour and noble company,
Ce vous convient ung chascum faire feste,	So it behoves each of you to make merry
Pour bien grignier la belle compagnye;	And smile upon the guests,
Charle gentil, c'on dit de Maleteste.	For noble Charles, who is of Maleteste.
Il a dame belle et bonne choysie	He has chosen a good and beautiful lady
Dont il sera grandement honnourés;	Who will do him great honour,
Car elle vient de tres nolble lignie	For she comes of noble lineage
Et de barons qui sont mult renommés.	And of lords well renowned.
Son propre nom est Victoire clamés;	Her own name is Victoire
De la colonne vient sa progenie.	From kings she is descended.

What is responsible for the audible fact that the work holds together as a musical entity? The end of the first section and the close of the refrain are identical, and there are correspondences between bold juxtapositions of harmonies at the beginning and the third part (m. 50–53 "Charle gentil": g–C♯), as well as between the opening measures and their reinterpretation (m. 54–56). The numerical unity, on the other side, remains unperceived, and – according to Allan Atlas – "no doubt intentionally so." But anyway, Dufay placed the important landmarks in his piece with the proportions of the golden section. Thus, *Resvellies vous* is, at the same time, a tribute to the noble Malatesta famili, a musical allegory of the wedding of 1423; it is "a joy to the melody-oriented, early Quattrocento Italianate ear, and a treat for the ultramondane scholastic intellect". In another of his works for the Malatesta family of Pesaro, Dufay uses the golden section in a way, which is very similar to the scheme underlying HR's quartet: In *Vasilissa, ergo gaude* a vocal prelude of eight lines is followed by two talea of thirteen lines – thirteen is not only the seventh number in the Fibonacci progression, but also a symbol for the Byzantine Emperor, who was considered to be the thirteenth apostle.

Fig. 8 – Dufay's *Vasilissa, ergo gaude* in semibreves, mensuration 0



The number 13 is of special importance not only in this piece: *Vasilissa, ergo gaude* belongs to a group of three motets commissioned for events surrounding the rela tionship between Byzantium and the West. As you know, the desperate struggle of the Byzantine Empire with the Turks ended in 1453 with the fall of Constantinople. Dufay composed a *Lamentatio Sanctae Matris Ecclesiae Constantinopolitanae*, also on a cantus firmus based on the number thirteen. *Vasillissa, ergo gaude* celebrated the marriage between a son of the Byzantine emperor and the daughter of the Malatesta family. As you can see from the scheme, each of the smaller divisions form golden sections; and the golden section of the entire piece falls at the beginning of the second talea.

But what has Dufay to do with his younger colleague HR, what are the analogies between motets like this and HR's string quartet?

I see the following parallels: the use of the golden section as a means of structural articulation at different levels, the plethora of musical ideas, some on the audible surface, others silent, and all working together in the service of structural, aesthetic and symbolic ends.

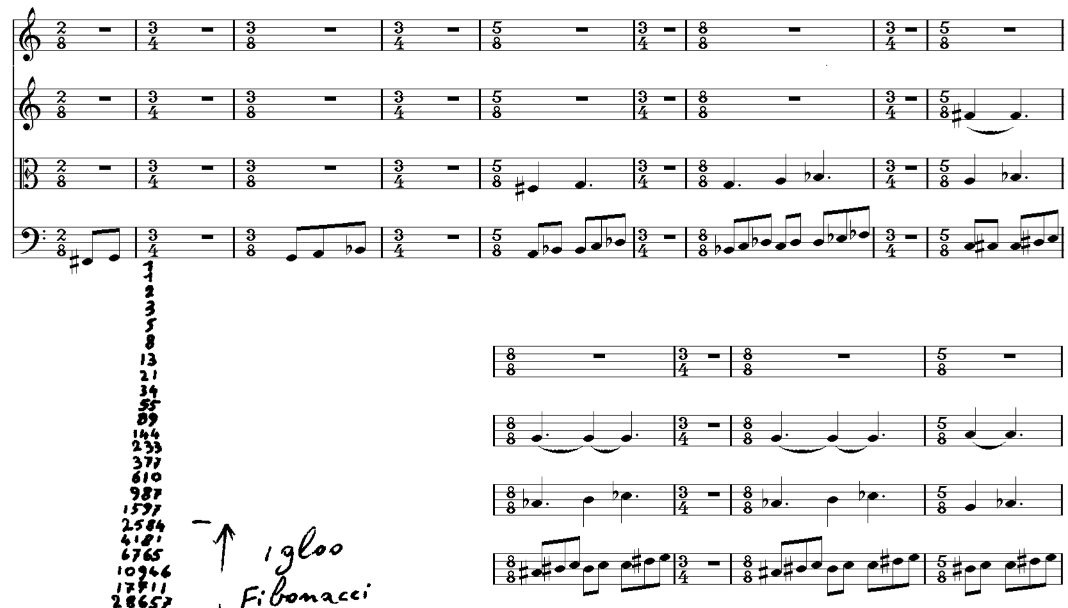
Temporal subjectivity and multiplicity

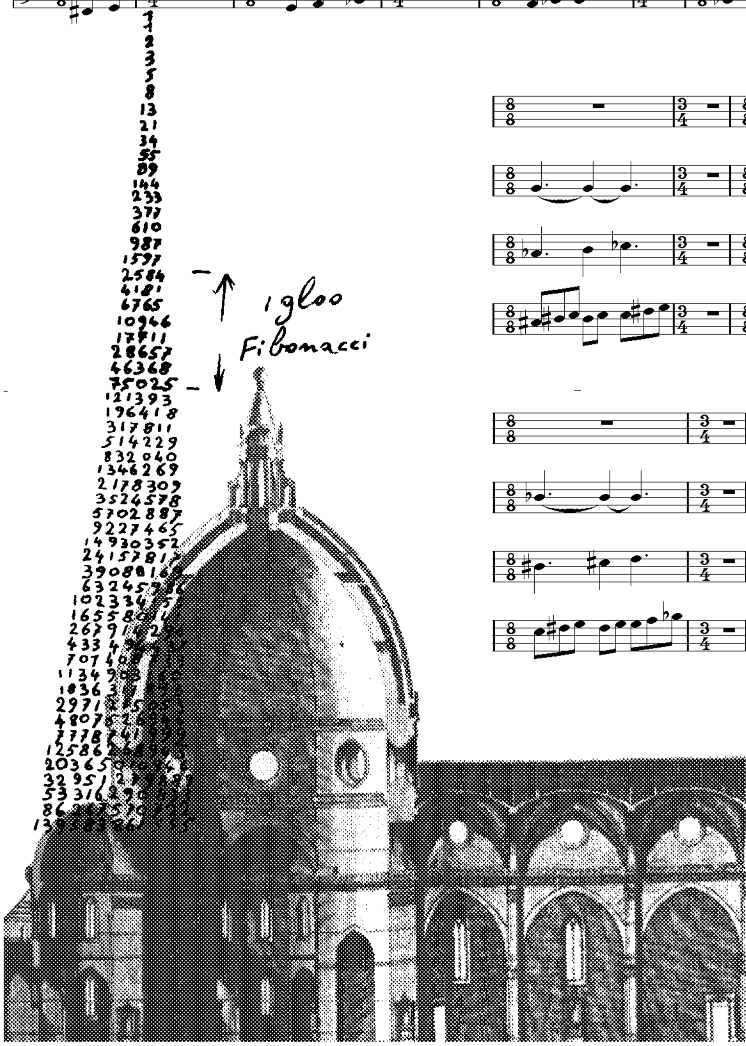
In a work like HR's string quartet we are confronted with a multidimensional piece of art which demands our ability of interpretation. As Susan Langer once formulated, "life is always a dense fabric of concurrent tensions, and each of them is a measure of time, the measurements themselves do not coincide." Music, like life, can also be – and is in many, many cases – "a dense fabric of concurrent tensions".

Our society knows a multitude of life-styles; each of us lives in a variety of environments which are experienced more alternately than progressively: One person can carry on several existences in several places – lives that have little contact with one another. Someone working at a computer, for example, will find little continuity between his work among grey metal and blinking lights and, say, an hour spent in a park together with his daughter, or participating in a conference in The Hague ... It is as though the various lives exist simultaneously, and the participant merely checks each one periodically to see what has been happening. In these increasingly subjective worlds of contemporary culture, cause and effect is no longer the only possible relationship between events. The temporal order in which we experience does have significance, but that order is nonetheless fundamentally irrational, without meaningful cause, without significant effect.

In contemporary music, there are indeed many pieces whose logic is like the logic of contemporary life; many compositions since the 50's by Stockhausen, Boulez and Cage, Brown and many others are multi-directional, composed of a series of minimally connected moments. One part – but only one – of HR's quartet can be seen in this tradition: the β music with its planned irrationality of order and durations takes part in the logic of contemporary life – or better: represents the irrational temporal order we all experience. This representation of contemporary time experience is confronted in the α music with a different kind of life, a development of those parts of our existence which are not bound to the everchanging time in our terrestrial existence. Thus, the two macro-forms are not just two "animals" (as HR once called them in conversation), but a musical representation of that strange being, called a rational animal.

Fig. 9 - From four works based on the Fibonacci series:
T. Johnson: IV/bars 1-15 of *Formulas* (19??) for String Quartet [upper middle]
M. Merz: *Igloo Fibonacci* (1970) [centre left]
Side view of *Santa Maria del Fiore* (1434), Florence [lower left]
K. Stockhausen: Cell scheme of *Adieu* (1966) for Wind Quartet [lower right]





144	144	89 55
144	55	8 13 21 13
	89	55 34
144	144	144
144	34	13 (=5+8) 21 (=8+13)
	21	13 (=5+8) 8 (=3+5)
	34	13 (=8+5) 21 (=8+13)
	55	21 34

Ratio – horribile ratio – irratio

Words like reason/reasonable, ratio/rational have a long history and a legacy of ambiguity and confusion. As the philosopher Michael Oakeshott put it, these words are like mirrors: "Like mirrors, they have reflected the changing notions of the world and of human faculty which have flowed over our civilisation in the last two thousand years; image superimposed upon image has left us with a cloudy residue." We all take pride in being rational animals. But what is "rational" and "rationality"? Many philosophers have attempted to find out, what "rationality" means. However they have not reached a consensus. Several attempts of distinguishing different concepts of rationality exist (logical, practical, methodological etc.). And some people try to find out if there are possible types of rationality beyond value-free science and technology (Max Weber and his many followers answered strictly: no). Others reflect on the "impact of science on modern conceptions of rationality" (e.g. Hilary Putnam).

From my own field of music history writing I could tell a lot of stories where assumptions about rationality are a largely unexamined collection of cultural prejudices (and especially we Germans contributed to this quite a lot), beginning with the distinction between rational, male Frankish-Gregorian chant versus irrational, feminine Mediterranean singing, the constructivism of the North versus the *Klangseligkeit* of the South, European versus Oriental, etc.; but also: speaking about Pythagoras, and forgetting (or repressing) Orpheus and the emotional, irrational side of music.

RATIO ? ! ? "Music is the most abstract of the arts ..." – at the same time it is the most immediate, the most sensual of the arts. Our ears, bodies and souls are not seldom in music's hand. Therefore numerical considerations are only one side. Since antiquity aesthetic, ethic, theological considerations play an important role, too (*animos movere* , *effectus musices*, etc.). Leibniz' arithmetic exercise of the soul has its counterpart in the thinking of Augustine, Luther, E.T.A. Hoffmann, and others. Music is both mathesis and emotio, it contains both poles, the rational and the irrational. In music history many very different solutions have been worked out to stand the tension between the rational and the irrational poles of music. And also today we see quite different possibilities of handling this tension (see Figure 9). One possibility, we can be sure, is the path Horatiu Radulescu followed in his quartet, a work which is a kind of stumbling-block for those who try to evade the "rational/irrational" tension always inherent in music.

Notes on Examples

Ex. 1 - 4: from HR's score of his string quartet op. 33, Copyright Lucero Print Versailles, London, Stuttgart 1987; the two diagrams inserted are from analytical texts and material by the composer

Ex. 6: originally the famous idealized miniature showing Guillaume Dufay with a portativ and Gilles Binchois with a harp; Martin le Franc: Champion des Dames, Paris Bibl. Nationale Ms. ffr. 12476; coloured reproduction in Die Musik des 15. und 16. Jahrhunderts, ed. Ludwig Finscher, Laaber 1989, part 1, p. 78

Ex. 7a : from Allen Atlas' article

Ex. 7b: from the text and notes to Guillaume Dufay. Complete Secular Music, The Medieval Ensemble of London, 6 LPs, Edition de L'Oiseau-Lyre D 237 D6

Ex. 8: after Allen Atlas' article

Ex. 9: - Beginning of Nr. IV from Formulas for String Quartet by Tom Johnson: canonic imitation with audible groupings according the sequence of Fibonacci numbers; [by permission of Tom Johnson] - -

Santa Maria del Fiore del Fiore, Florence, finished 1434 with proportions following the Fibonacci series [from musica 39 (1985), pp. 129,130] -

Karlheinz Stockhausen: Adieu (1966) for wind quartet. Fibonacci durations of cells and Fibonacci proportions [from Kramer, The Time of Music, p.316] -

Mario Merz: Igloo Fibonacci, 1970

* Editor's note - The signs 𝄲, ♯ and 𝄰 (meaning one, two and three quarter-tones raised) replace the terms *monesis*, *diesis* and *triesis* in the original manuscript, nice extensions of the common Latin *diesis* for "sharp".

Daniel Wolf

Why Ratios are a Good/Bad Model of Intonation

This is a talk that is in transition. What had started as rather a straight-forward talk has become something more like a rhizome. It's going to go in many different directions so I'll be skipping a little from A to J to B to Z. Please excuse me. I'm going to do that. I hope this caveat covers me.

The reason I'll be skipping about so is that a lot of the input from yesterday's presentations and today's presentations has caused me to rethink what I have to say – because a lot of what I would have said has been altered by what has been said before; and other issues have been opened up.

For example, I didn't expect that much of our discussion would be turning on what we used to call the nature/nurture debate, and I hope we pursue this in a deeper way. And I'm going to make a proposition in this regard that perhaps there is some facility in our hearing organs that operates rationally, rather there is a set of facilities, a set of ratios that could be in operation, but that the ones that we are familiar with, that we accept as familiar in our musics and the degree of tolerance that we accept in identifying these certain ratios is largely culturally defined.

That's sort of a cheap way out, and there's more to it - Clarence Barlow and James Tenney have certainly fleshed out the psychoacoustics better than I am able. In the context of this talk, though, I hope this is sufficient, although I will point out later that this interval of tolerance tends to pop up in very similar ranges (interval sizes) throughout the world.

The "ratio" I am describing here is principally intonational, which has been my principal concern both as a composer and as someone who does avocational ethnomusicology on Saturday mornings (if principally as an excuse to eat Indonesian food), but I assume that this notion of ratio – and degree of tolerance – is also applicable to other musical domains (rhythm, form, etc).

Does rational intonation exist? My flat answer is no: at some time, at some point you're going to have beats. Something's bound to go wrong, at least as far as our lifetimes are concerned. I will play an example later on my little synthesizer where, objectively, you will recognize beats perhaps every 92–93 years. It's quite an accurate synthesizer. But when those beats come, they're very much there, and you never quite know when they'll appear.

So the beats will happen along whether it's because of faltering house-current or an oscillator reaching the point in the cycle where the approximation – and a very good one, at that – finally rings untrue.

The strings of string instruments ring untrue. Our breath will be uneven or just run out. Temperature and humidity affect the bars of idiophones. Something like that gives out. That's part of our human access to music.

Do we ever approach a rational intonation? This is perhaps a more interesting, more relevant question. In my experience it happens only at moments in musical performance, for me mostly in moments of vocal music, but then I know of one, perhaps two early music singers who are very conscious of this fact and talk about intonation in terms of numbers. And in my experience, I know of no barbershop quartets that speak in terms of ratios. And in my experience, I haven't heard vocal intonation better than that achieved by American barbershop quartets, if I may be allowed a prejudice like that.

Even someone like La Monte Young, who has had access to a tremendous amount of resources – very good equipment, some money, and lots of time – in the end, even though he has a fully rational plan, accepts what sounds best subjectively to him on the instrument at hand, although his measuring devices tell him that he is missing a rational interval. In the end he chooses to tune by taste rather than exact number.

The real instruments that you use in music conspire against you. For example: stretched piano strings with their notoriously stretched octaves, or solid pieces of metal. It varies from piece of metal to piece of metal. For example, in the West Coast of the US, the habit is to build gamelan out of slabs of aluminum, rather than cast bronze or iron as in Java (this is mainly because aluminum is something you can cut through like butter with a good sabre saw, and it doesn't necessitate hiring a forge to do all your work. In North America it's also plentiful and cheap. That's the practical end of it.).

However, the upshot of it is that aluminum seems to prefer a "more" just intonation. It's a metal that seems, when it's in a nice combination (a nice alloy), to be a little more sweetly disposed towards the harmonic series. And Javanese bronze, let alone iron, is a little more aggressive towards the harmonic series. So that the *materia musica* is one thing to take into consideration in the pursuit of music tuned on a rational plan.

More interesting, perhaps, would be to listen to various musics (and I say musics in the plural; I will always do that if I can), to find out if we can hear whether a relationship (or better, a dynamic) exists between the sonic surface of the real musical practice and some rational, possibly platonic ideal.

Are pitches representative of ratios? This is one question. I'll rephrase it a little more poetically. Do works of music stand sacramentally? That is, as an outward and physical sign of some inward and spiritual grace (I remember the definition of sacrament from my catechism). Or, do ratios have an interpretive role with regard to pitch behaviour? Is the ratio on the input side of music making or on the output side? Does the ratio exist in the compositional mind or the perceptive mind?

We saw earlier today some graphs that are useful for dealing with rational intervals. Following Jim Tenney, I will assume octave equivalence, in spite of all evidence of non-linearity (and Clarence Barlow's impressive consonance formulæ).

Let's consider some familiar scales. I'm going to take a pentatonic scale because there are only five notes. It'll be easier to deal with since we haven't much time. We heard yesterday a scale that went something like [C-D-E-G-A]. Could someone suggest a tuning for that scale?

C.Barlow: You mean something out of the ordinary?

D.Wolf: Just something ordinary.

C.Barlow: There comes to mind Pythagorian thinking.

D.Wolf: Yes: 1:1, 8:9, 64:81, 2:3, 16:27. That's one way of representing it when it's folded into a scale through reduction into an octave modulus. Let's put it instead on the graph of perfect fifths, in the order [C-G-D-A-E], which is tuned, again under octave equivalence, as 1, 3, 3^2, 3^3, 3^4.

There are some interesting things happening here. The one I want to point out is that between [C] and [E], or [E] and [C], there is an interval that doesn't quite close a circle. It's not the same as the rest. But in some certain functional ways it's the same. For example, let's go melodically up the scale in groups of four tones [CDEG], [GACD], [DEGA], [ACDE] and [EGAC], whereby the exact interval position of the final [C] is anomalous.

This is one of a group of scales having the property that the Californian theorist, Erv Wilson, calls "Moments of Symmetry", wherein one has linear tuning of some sort where all the linear (or generating) intervals – but one – are of a given average size, yet all of the linear intervals have this scale-subtending quality.

What's nice is that if you want to go from one moment of symmetry, say from 5 tones to 7 tones, you have to add 2 tones and you can add <u>any</u> 2, provided the interval between these 2 new tones is of average size. Clarence demonstrated that you can take any tone at random...

From the audience: [F].

D.Wolf: [F]. That's no fun!

From the audience: [F♯].

D.Wolf: [F♯]. So we can have an [F♯] and from this [F♯] we make an interval that would be an average in this group. So if we are looking at a set of fifths we take another fifth, our average interval.

Let's take [F♯]. From this we get [C♯] (we might even call it [D♭] – it doesn't make much difference). We put it back into a scale, getting [C–D♭–D–E–F♯–G–A].

C.Barlow: What do you mean by average, sorry?

D.Wolf: We've got these fifths and I'm taking another fifth that would not, when added to the sum of these fifths affect the average. It would be also possible to do this with a major third in place of one fifth and a minor sixth in another place, so it ends up not affecting the average.

C.Barlow: You add the interval sizes and take the mean?

D.Wolf: Yes. In cents, for instance. Back to the example: We can reconstruct this new seven–tone scale as a series of – functional – fifths, and our new series of "fifths" sets off as [C–F♯], [F♯–D♭], [D♭–G], [G–D], [D–A], [A–E] and [E–C].

These are all functioning here as melodic fifths, with seven–tone group properties, which are important in a lot of musics. A potential method of modulation from one type of material to another is through identification of these scalar functions. I could have used any other seven–tone scale and maintained these seven–tone scale functions. I can go from one tuning to another and no matter what intervals, I will maintain this scalar order dimension, even though I may have fifths that are really irregular, that are not 2:3 fifths. But the average, again less this gap at the end, will remain a perfect fifth. Try it for yourself.

Another scalar possibility for this pentatonic scale uses ratios of 5: [A–E–C–G–D]. We have an anomalous interval gap here between [A] and [D], anomalous in size, but yet functioning by subtending the same number of scale degrees. And if I look at this anomalous interval, in this case between the extremes of [A] and [D], I can close a cycle with the interval 27:40, analogous to the Pythagorean pentatonic example I closed with [C] and [E] in the ratio 81:128. If I go on up to a seven–tone scale, for example a seven–tone Pythagorean scale, the gap closes at the interval of 512:729.

From the audience: I don't understand how that's a cycle.

D.Wolf: Because I'm bringing it back to the beginning in some way. I'm mechanically folding it back. And this folding back with this anomalous interval is one type of musical scalar syntax. The next one, if we go to the seven-tone scale, folds back on the tritone. It's what's left over. The interval of the tritone is something we Westerners in Western music harmony classes treat very carefully. It's the instrument of dynamism in the system because it is eccentric in its size yet conserves functions of the normative intervals. And the same thing happens at the next level: when we listen to a twelve-tone scale, tuned in a Pythagorean sequence of fifths, what happens between the two end points?

C.Barlow: A Pythagorian comma, isn't it?

D.Wolf: Yes. We miss the octave of the first tone in the series by a Pythagorean comma, and there's an interval, a fifth, that differs from the normative fifths by the Pythagorian comma. This fifth carries the lovely name of "wolf".

What I find very useful is to think of all of these scales, regardless of their intonation, in terms that distinguish between nominal values and real values. It didn't take me long to figure out that if I heard "Happy Birthday To You" played on a piano attempting in its tuning an equal temperament, and "Happy Birthday To You" played on a metallophone attempting in its tuning a just intonation of some sort, I would still recognise it as "Happy Birthday". I mean there is something very simply in common here, even though it is something – like people struggling over the size of *shrutis* for a thousand years – that is very difficult to pin down in terms of numbers. So we give it a name instead of a number, names like for instance [C D E F G] etc., place holders.

In notational systems these place holders become very important. In Western scale notation we've got a set of seven place holders, and it's an excellent way of managing whichever group of seven tones is in play at one time. And it's based on a group of seven tones that are consecutive along the series of fifths. I think it's useful to think of the notation strictly as a management device. I mean, "this is what I have available to me at this moment". The pedal mechanism of the concert harp is somewhat similar.

With regard to intonation, these place holders describe a kind of tolerance margin for intervals varying in size, mode of generation etc.; the dynamic between rival generating schemes (the ratios) and scalar order (the nominal series) is a central issue in music theory and an essential pleasure in music.

To go beyond this requires some extra operation. If I'm in the key of C, that extra operation may be the addition of accidentals, which have their interpretation on a graph or lattice as some addition of some new point to the graph. The notational equivalent is simply that of an accidental change.

Let me take an example of moment of symmetry in a somewhat obstreperous mode.

C.Barlow: Just one more question. Your choice of 5, 7 and 12 as scales you folded over. Was that accidental?

D.Wolf: I hope to answer you more fully in a bit. For the moment I'll say only that these are scales where it happens to work. There are theories in this direction. The most famous belongs to Joseph Yasser, whose "theory of evolving tonality" posited a continuously developing musical vocabulary from a five-tone scale and a seven-tone scale somehow co-habitating in a twelve-tone scale. The next development he predicted would be a nineteen-tone scale, which he advocated and for which he had an instrument built.

I'll come back if I can. I'm now going to take one fairly obstreperous little scale, Javanese *Pelog*, with which I've spent a lot of time working. Just thinking in terms of the contour, I'm saying that a *Pelog* mode goes something like this: the first tone (call it [1]), a flat second ([2♭]), a flat third ([3♭]), a fifth ([5]), a flat sixth ([6♭]) and we'll add the octave ([8]) up at the top. I'm not telling you how big that fifth is, but it's something like a fifth. That's the scale. Its basic characteristic is that there are this relatively small second and large third. This second degree of the scale moves up and down, but it tends to be on the low side, at least in singing and rebab playing. The interval between the second and third degrees tends to be something like a major second, and those between the flat third and the fifth and between the flat sixth and the octave are something like major thirds.

Now we could analyse this also as a series of fourths or fifths, as [1-5-2♭-6♭-3♭] and we're back to [1]. Now you noticed in that sequence there was a diminished fifth and the anomalous major sixth at the end. If we knock out one of the anomalous intervals it averages back to a series of fifths.

These fifths are musically very important and we can also document that in Javanese theoretical practice, the only terms they have had for intervals are words indicating octaves and the intervals separated by one key and two keys, which on a pentatonic instrument are fourths and fifths. They have names for these intervals, and the elaboration techniques used on the instruments are associated with these, so we can see existing Javanese indigenous theory, independent of European influence, thinking about these issues.

However, when someone says *Pelog*, the first thing that springs to mind may not be a five-tone scale. The thought is of a seven-tone scale. What they do is start something like a [4♯–5–6–1–2], so it's a fifth (in this case a *Pelog* fifth) below. And then a fifth higher: [5–6♭–7♭–3♭]. Now obviously something is going to give here, in that we want a small interval, a [2] in the higher octave, and the Javanese let something give.

In the mode that begins on [1], you have a [2♭] in this lower group of three notes, a lower second. In the mode that begins on [5] in the upper group, the upper interval [7♭–3♭] is a bit wide, as is sometimes this interval. It is quite flexible. It is akin to a European well temperament in Baroque practice, in that when you go from one *patet* (mode) to another you are not only changing your pitch height and the relative melodic contour, you're also changing the intervallic content. And at the end of an evening-length *Wayang* (shadow puppet play), after spending time in each of the other *patets*, when you come into the last *patet*, it's like going into heaven. It's quite different. It's really an extraordinary experience, just because of the intervals' size, the interval content, has changed. But we have maintained the linear organization, the structural content, the nominal content.

There are interesting gaps in the cycle. Some theorists have suggested there is a nine-tone scale behind all of this. You could reasonably well approximate *Pelog* with seven tones selected out of a nine-tone equal scale. This suggests that the Javanese have come up with another family of moment of symmetry scales. One that begins with 5 going on to 9, and then others like perhaps 16, 23, something like that. It's another family of scales.

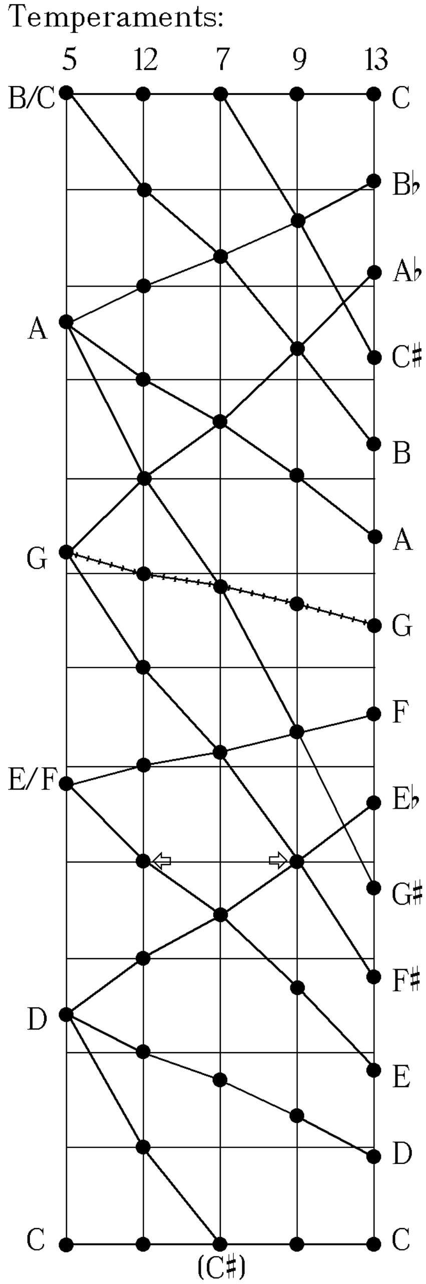
I've thus far avoiding pinning ratios on the intervals of this *Pelog* family, a family which maintains – if my demonstration was sufficent – certain functional characteristics of the linear fifths seen in Pythagorean and just pentatonic scales. However, the melodic sequence, the scale of *Pelog*, would seem to demand intervals substantially different from 2:3 perfect fifths.

I became <u>very</u> interested in the *Pelog* family when something surprising started showing up in the intervals. I knew already that the *Pelog* fifth wasn't reiterating 2:3s, so if I wanted a just interval, I'd have to look somewhere else – between degrees [1] and [3], [4] and [6], [5] and [7]. And between [2] and this hypothetical new pitch. And between [6] and this hypothetical new pitch and [1]. This interval started averaging out to be something like 6:7. And if you stack a series of 6:7s, you will make a nice moment of symmetry, a nine-tone scale but you're fifth is not going to be 2:3.

A way of locating families of scales is to line them up as equal temperaments, starting with the twelve-tone scale, with a fourth of 500 cents and a fifth of 700 cents – see **Ex.1**. What if we had a synthesizer programme where our fifths were gradually squashed? We're playing along some kind of music and my fifth sails down to 685 cents (seven-tone equal temperament). Some pitches start to collide. We lose five chromatic tones, which curiously reappear when we go down to 667 cents (nine-tone equal temperament), sometimes sharing a position. I like the crossing of [F♯] and [E♭] on the nine-tone axis (marked with an arrow). And continuing on out to thirteen tones ([G] at 646 cents), both [G♯] and [A♭] co-exist.

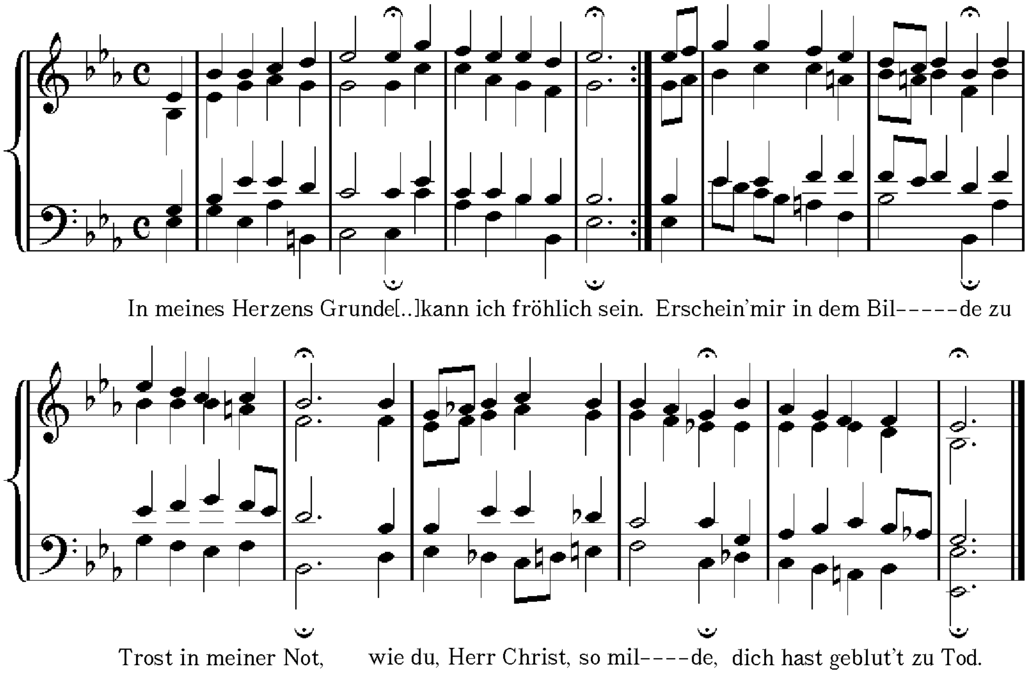
I'm suggesting this as another technique of modulation. With my imaginary synthesizer I am playing a Mozart sonata and my fifths change gradually, and I end up playing my Mozart sonata in a seven-tone *Pelog*. Or, I can take one of my favourite Javanese pieces and modulate back to Vienna.

Ex.1 – Transitional "fifth squashing" by lining up equal temperaments



I'm more or less convinced that if Western music has a temperament, then Javanese music has a temperament too (and perhaps two – but my thinking about *Slendro* tunings is increasingly unclear). And the degree of tolerance accepted in these two musics – I promised I wouldn't pursue the issue of tolerance much more than this – is quite similar. Just take a look at the two pitches marked here with arrows: the major third in the twelve-tone system and something that would be a *Pelog* major third (when approximated by a nine-tone equal scale) are both about 400 cents, which suggests they are tolerating a major third very close to the major third heard on the piano. I hope this modulation exercise suggests that interconnections between ratio and function are dynamic, not fixed, and that a margin of tolerance allows alternative tonal systems that emphasize alternative intonation characteristics without wholly sacrificing functions more immediately associated with particular intonations.

Ex.2 – Chorale No.52 from the *Johannes-Passion* by J. S. Bach



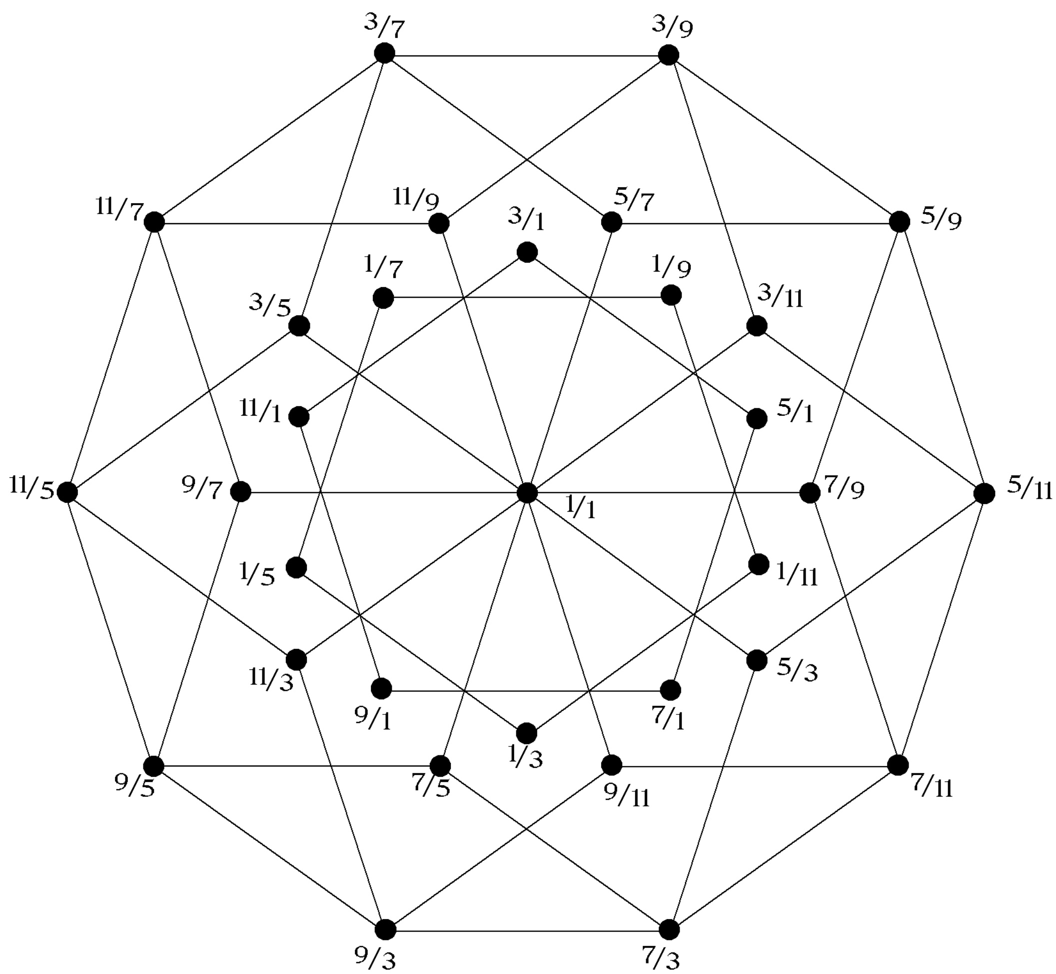
One more issue. **Ex.2** shows a Bach chorale you might be familiar with, No.52 from the *Johannes-Passion*. Let me call attention to something that bears on Volker Abel's talk this morning on the *Mutabor II* system of computerized intonation. I tried making a musical example for this afternoon by putting this choral into a just intonation, but I ran into a problem. The problem basically is, that if I start calculating my ratios in one direction, starting at one end and tuning up the intervals harmonically and melodically one after the other, something would have to give in the middle[1]. One thing that's important structurally (as I imagined hearing the piece and as my none-too-latent Pythagoreanism would have me hearing it) was the ascending series of fifths [E♭-B♭-F-C-G-D]. It's something that I think would be important in the music and something I would like to bring out in performance. Unfortunately I need some of those notes to serve in other functions. For example I want the [C] to be a minor third under my original [E♭]. I've got a problem in this example coming and going. And I finally decided I wasn't going to try to tune this up for you (I couldn't tune it without giving up something important) but rather suggest that these rational graphing techniques are a way of getting at, of locating problems in the music, analysing the music for particular ambiguities.

I have to make some distance right now between the analytic use of graphs that I propose here and the graphs of Professor Vogel in Bonn, whose project includes publishing editions of classical works with a just intonation notation so that they can all be played once and for all in a definitive, disambiguated intonation. I defy anyone to make a convincing just intonation of this chorale. This music is simply not just intonation music. Mr Bach is playing a pun on us. He is allowing pitches to have one meaning coming and another meaning going. One thing I noticed while considering European musical history – I am after all an American ethnomusicologist doing my field work in the exotic continent of North West Asia (I'm sorry if you're taken aback by that, but in the United States we learned that [Eur-]Asia is one continent, not two) – is that there was a period of music with a highly developed musical rhetoric. One of the characteristics of this rhetoric was the use of fixed pitch instruments as a ground for the musical performance. A way of closing, reining things in, controlling tonal and rhythmic progression. And a lot of tricks, a lot of the musical rhetoric we miss are contained in these kinds of intonational puns.

I first had this notion while listening to a piano performance by Glenn Gould where I had the illusion, in a recording of Mozart, that the pitches were moving up and down. He was doing something with his articulation, such that even though this ton and a half of steel was not physically moving in any way (the pins were standing still, the wires were not objectively changing pitch), he was doing something in his articulation of the music, something that created this illusion. Perhaps playing a little lightly on the thirds of a major triad, a little more strongly on the third of a minor triad. I don't know exactly what, but he was doing something in his articulation to bring out this aspect of the music. And my corollary to this is that I think the XIXth century, the century of the equal tempered piano (which is the century of music that I paid the least attention to in my school days), may (ironically) be a treasure-trove (simply on the basis of a body of orchestral music without keyboard accompaniment – contrasting with the keyboard driven music of the XVIIIth century) of exotic modulations into rational intonation territories we haven't encountered elsewhere.

My time is short, so very quickly, a couple of pretty pictures. Modulation is, I believe, the most interesting territory for the use of ratios in new musics. First consider **Ex.3**, a graph by Erv Wilson labelled the *1-3-5-7-9-11 Diamond*. If you are familiar with the works and writings of Harry Parch, this is a notation of his diamond. It's a notation using a wonderful graphing technique developed by Wilson that allows him to graph more than two or three dimensions. Note that a lot of the connecting lines that could be placed on this graph have been omitted for clarity. What I want to convey from this drawing, if possible, is that you've got a very centred system. Absolutely clear where the tonality of Parch is: 1/1.

Ex.3 - The 1-3-5-7-9-11 Diamond by E.Wilson (after his original drawing)

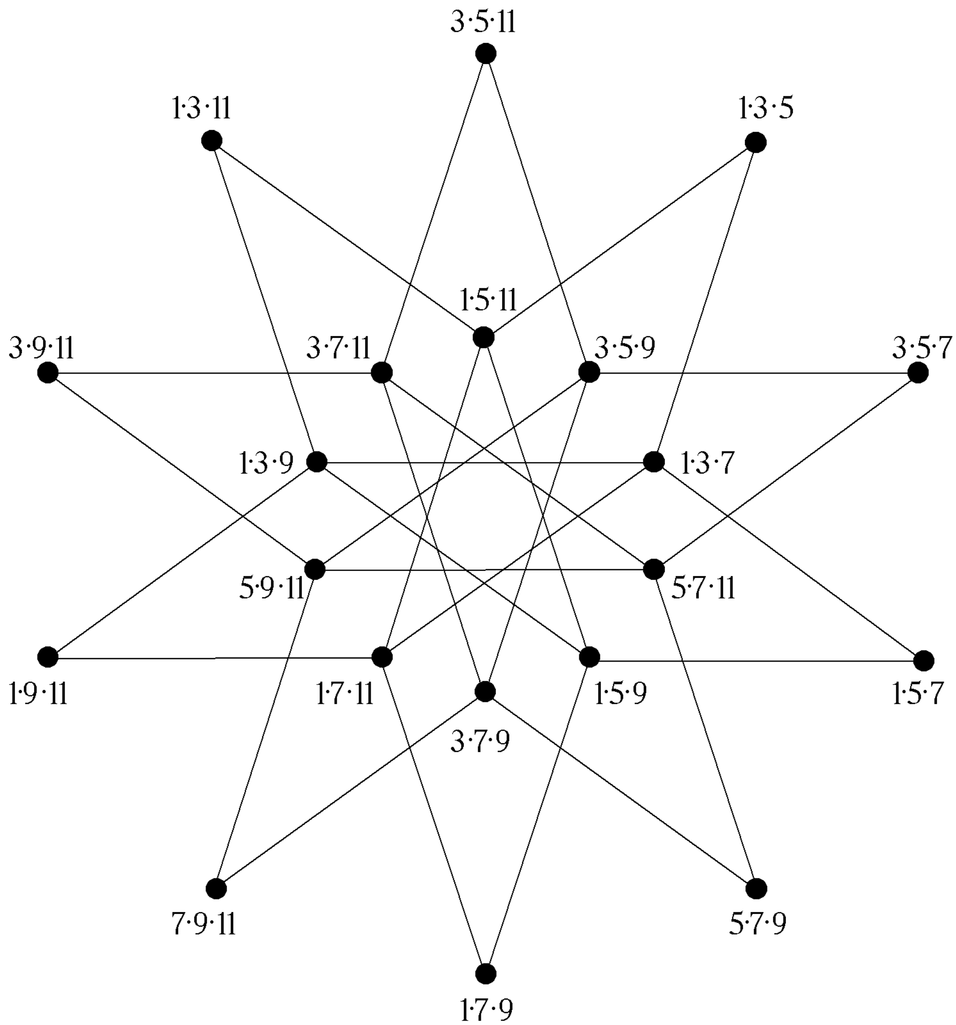


Now here's another system, the *Eikosany* (**Ex.4**)[2], where we have the same numerical factors 1 3 5 7 9 11, but instead of putting them in ratios comparing factors as numerators and denominators and all related to some tonic (as Partch's diamond did), Wilson has just taken groups of three factors out of this set of six possible factors.

From the audience: I don't understand it. It's a ten-pointed star. Where's the 1 3 5 7 9 11?

D.Wolf: Okay, these are factors. One pitch class has the factors 1 3 and 11, another the factors 3 5 and 11, so there's a major third relationship between these two pitches. If we go from 3x5x11 to 1x5x11, there's another perfect fifth relationship.

Ex.4 - The 1-3-5-7-9-11 Eikosany by E. Wilson (after his original drawing)



You can calculate this for yourselves and you end up in very interesting territory. I'll play one small example of my own music. This is a birthday present to Lou Harrison. This is just a little random-walking music programme that is simply a series of phrases alternating between the set of ten pitches with an 11 as a factor and the set of ten pitches that doesn't have an 11 as a factor.

Now, you will not hear ratios of 11 in the phrase of the piece where the harmony is very simple; but at the junctures you will hear some ratio of 11. Whether it's 12:11, 10:11, 18:11, something like that will appear, just an alternation. ... This tape isn't working. We'll hear it later. One technique of modulation.

I'm going to close with some suggestions about horizons in intervals, and interval perception and usage, in that much of the dialogue that we've had in the past two days indicates that there are limits to the rational intervals that we can use and perceive. And I suggest we have yet to really discuss what those limits are.

A good example to my ears of an expansion of... well, I'll give you two examples: One is the use of sound sculptures and installations where the temporal domain is substantially extended. I've always thought that this was the ultimate extension of serial techniques in that, if these equate all of the forms – permutations, modulations, possibilities – of a given row, there's no particularly temporally privileged beginning or end, and so any end or beginning that you set is arbitrary. Thus some sort of sound environment where the audience can enter or leave at any time is naturally appropriate.

I'm going to play a very short excerpt from an installation of mine with very accurately tuned pitches here on my synthesizer. This is a gallery piece. It is with some seventeen pitches that are played simultaneously.

(Sound example; J.Tenney and D.Wolf continue talking over it)

J.Tenney: What are those frequencies?

D.Wolf: These are frequencies above a fundamental of 6.25 Hertz. If you turn your head you're getting a very different sound.

J.Tenney: How have you got the amplitudes?

D. Wolf: The amplitudes are inverse to frequency. What I've done is jammed seventeen pitches into a space smaller than a perfect fourth, intending this as an object that could be perceived. The numbers are all primes or octave multiples of primes, except for the outer barrier intervals, which are in the ratio of 7:8. And then it goes on to another chord.

I've installed it in a gallery. There's a pause like the white space on the wall between the paintings. Then we move to the next chord. It's the same sort of structure using 6:7 as a barrier interval. This room is a little big for this particular one.

I'll leave it on, and suggest that the other possibility for a frontier in rational interval perception was one suggested to me by the work of Maryanne Amacher, who has given concerts of what she calls "Post Cochlear Music", based on the thesis that we do too much of our listening with our cochleas, and that it's about time to do something else, i.e. direct contact with the interpretive organ. This is as yet a little frightening for me. I'll leave it at that. Thanks.

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1. Editor's Note –
An attempt to rationally tune this or any other chorale of Bach's time may reasonably rest on the following two premises:
a) Perfect intervals between notes of individual or consecutive chords, i.e. unisons and repeats, octaves, fifths (and their inversions, fourths), are held at values based on the maximally 3-limit [1:1], [1:2] and [2:3].
b) Thirds (major and minor and their inversions) within each chord are held at values based on the 5-limit [4:5].
By so proceeding, it was found this chorale is indeed rationally tunable, but that the pitch level drops three syntonic commas in the process: at the words *mir in dem Bilde*, at *in meiner Not* and at *geblut't zu Tod*. The initial $^1/_1$ [E♭] in the top voice winds up disquietingly at $^{512000}/_{531441}$ (65 cents lower) at the end, due to the harmonic sequence [I (vi) II V] which occurs at the places mentioned. Indeed, even the simple melodic form [1-3-6-2-5-1] (here [E♭-G-C-F-B♭-E♭]) in using the interval set [2:3:4:5] cannot but assume the tuning [$^1/_1$-$^5/_4$-$^5/_3$-$^{10}/_9$-$^{40}/_{27}$-$^{80}/_{81}$], thereby dropping a syntonic comma. Thus a third reasonable premise – c) The pitch level must be maintained – can and probably will conflict with the other two.

2 (about the term *Eikosany*)

Keith Howard

Mode as a scholarly construct in Korean music

Introduction

The study of Korean music developed with a series of treatises and score books that detailed court and literati traditions. Prescriptions for court music survive from the early 15th century onwards, a time when a new Korean dynasty, Chosŏn (1392–1910), was seeking to stamp its codes and practices with Confucian legitimacy. The ritual music tradition, dating back to the Dasheng Institute in 12th century Song China, was restored on the basis of Chinese music theory. Modal codes reflect an interpretation of this theory, arguably unattractive in that only two melodies survive today, one in five transpositions, from the repertory of 456 restored melodies transcribed in the 1430 *Aakpo* (Notations of Ritual Music).[1]

The story of Korea's ritual music, *aak* (Jap: *gagaku*; Ch: *yayue*) is the focus of the first part of my paper. I then consider a single instrument, the *taegŭm* (horizontal bamboo flute), where aesthetic concerns are laid down in addition to seven modes in the 1493 *Akhak kwebŏm* (Guide to the Study of Music). The modes and aesthetics have not survived. Is *Akhak kwebŏm* theoretical in approach, appealing to scholars and the ruling elite, but of little relevance to Korean musicians? Finally I move to local folk traditions and argue that mode has little place. Rather, melodic contours and model phrases appear to be the building blocks.

Three diverse and isolated examples make it foolish to suggest any global conclusion. Many gaps show in our historical knowledge of ritual music; data is missing, much of it simply unavailable in today's Korea. On the other hand, too little research has been done to identify model melodic contours or phrase patterns, if indeed these exist, in local traditions. Partly this reflects the approach of Korean musicology, attempting to be "scientific" through the use of statistics and comparison. Partly it indicates that Confucian scholars wrote little about oral folk traditions. Nonetheless, I hope to demonstrate that in Korea, since they are abstractions made by and for scholars, modes have little relevance to musicians.

Korean ritual music (*aak*) stems from a curious moment in Chinese music history when the eighth Song emperor, Huizong, in 1105 supported the founding of the Dasheng Institute. This was an attempt to restore authenticity to ritual music masterminded by the Taoist Wei Hanjin. Several peculiar features mark the institute and underline why this was an extraordinary, now totally sidelined episode in Chinese music history, even though the revised rituals were adopted by the Jin and Yuan courts. Nonetheless, Korean *aak* is today still identifiable with the Dasheng restorations.

The most peculiar feature first:

> The institute set about constructing a pitch pipe for the fundamental pitch from which all others would be derived. The correct traditional procedure, attested in ancient sources, is to line up grains of a particular kind of millet, 90 grains constituting the length of the pitch pipe. Obviously, the length of the pipe and the pitch obtained are functions of the quality of the grain crop. The Ta-sheng (Dasheng) Institute proposed instead that part of one of the emperor's fingers be used as the unit measure. The emperor agreed to this, and the measurement was taken and used (Provine 1988: 133).

A new pitch system was nothing new. Pian points out 35 pitch reforms from the late Zhou to the Ching (1967: 154). Picken provides a brief (and early) survey beginning with the *Lüshi chunqiu* text from 239 BC:

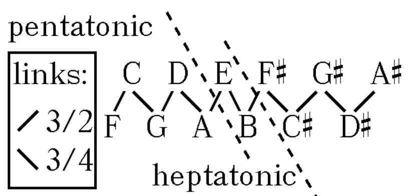
> He [Music Ruler] gathered bamboos in a valley on a mountain pass, taking those grown of uniform bore and thickness, and cut between two nodes; the length of the piece being three inches and nine tenths, he blew it, making this the Yellow Bell [the fundamental pitch].

Yellow Bell is *huangzhong* in Chinese, *hwangjong* in Korean, the essential pitch pipe. From this, other (Chinese) pitches were determined:

> To the three parts of the generator add one part, making the superior generation. From the three parts of the generator reject one part, making the lower generation (Picken 1957: 94).

The male "superior generation" were in the ratio 3:2 to previous pipes, while the female "inferior generation" were in the ratio 3:4, giving a chain of ascending fifths and descending fourths. Picken adds that this should not be considered a chromatic scale, but "an array of all the notes in the Chinese musical firmament" (1957: 95) (see **Figure 1**). We need only consider the seven initial tones generated, which give a *fa* mode. Estimates of the pitch of Yellow Bell vary, given a tube length of 20cm, by as much as a minor third, from F to D[2]. From this principle, 84 heptatonic modes were prescribed by Tang times (618–907), seven basic modes simply starting on each of the seven fa mode pitches generated through the same ascending-descending chain, and transpositions for each of the 12 semitones. However, decline set in, leading to the abandonment of all but the basic *fa* mode.

Fig. 1



At the Dasheng Institute, modes were again changed, giving the second peculiar feature: ritual music, *Dasheng yayue*, now respected a distinction of key based on two tone sets – *zhengsheng* (Kor: *chŏngsŏng*), *zhongsheng* (Kor: *chungsŏng*).

All musical instruments and vocal melodies were defined within this, and the scheme to be followed varied dependent on the season. Sacrificial rites relating to the cosmic forces of *yin* (Kor: *ŭm*) and *yang* identified *yin* (the female) with the *zhongsheng* set and *yang* (the male) with the *zhengsheng* (Song 1985: 8–9; 1992: 172). Again, this is not so strange as it may sound. The *Lüshi chunqiu* had also equated the orderly generation of sounds with other aspects of order: directions, substances, and seasons.

The third peculiar feature concerns the long zither *qin* (Kor: *kŭm*). This had traditionally been constructed with seven strings, but the Institute built one- three- five- seven- and nine-string versions. Note that such unusual *qin* are not mentioned in standard accounts of the zither (e.g. Van Gulik 1969; Liang 1972; Lieberman 1977); the Chinese musicologist Yang Yinliu does group them together in his consideration of the Institute.

The demise of the Institute came in 1125, and two years later the Song capital fell to the Jin. But by then *Dasheng yayue* had been imported to Korea. *Koryŏsa* (History of the Koryŏ Dynasty; 1452) records that it arrived from Huizong in 1116 as a massive gift of 428 instruments together with costumes and ritual dance objects. This followed the 1114 gift of *Dasheng xinyue*, music for banquets, comprising 167 instruments, scores, and illustrated instructions for performance (*Koryŏsa* 13.33b and 70.28a–29b). In 1116, the instruments were to be divided into a terrace ensemble (*tŭngga-ŭm/yin* [female]) and a courtyard ensemble (*hŏn'ga-yang* [male]), with a total orchestra smaller than it would have been in China: the emperor required greater forces than appropriate in a suzerain state. The first performance took place in October in front of King Yejong (r. 1105–1122) at the Kŏndŏkchŏn Royal Audience Hall.

The gift has often been regarded as an unsuccessful political bribe and, indeed, from a Chinese viewpoint, this makes sense (Pratt 1976, 1977; Provine 1980, 1988). Huizong, threatened by Khitan and Jurchen attacks, thought it worthwhile to strengthen cultural and religious ties with Korea to dissuade the Korean king switching allegiance to the increasingly powerful Aguda. As an ill-contrived scheme to purchase loyalty, it clearly failed and, indeed, given the imminent demise of Song, it is unsurprisingly not recorded in official Chinese dynastic histories (Provine 1980: 19-20). Nonetheless, a Korean perspective presents a different interpretation wherein, over time, national political philosophy was increasingly articulated in terms of Confucianism. Korean kings began observing Confucian rites to heaven (*Wŏn'gu*), agriculture (*Chŏkchŏn*), land and grain (*Sajik*) and royal ancestors (at the Chongmyo)(*Koryŏsa kwŏn* 59.1a/b). Such rites were thought incomplete without suitable ritual music. Hence, the first gift, of banquet music, was of limited use. So, Minister Im Chon sent Korean envoys and musicians to China, whom Song (1992) shows – citing Xu Jing's comments in the *Gaoli tujing* and the *Song shi* –, were commanded to try to learn *Dasheng yayue*. Song translates a message from King Yejong, recorded by Minister Pak Kyŏngjak (1055– 1121) and preserved in the 1478 compilation *Tongmunsŏn* (Collection of Eastern Literature), which makes it clear that Koryŏ actually requested the first gift:

> Some time ago, Koryŏ sent a message with a special envoy to request the new music. The Emperor has listened to Koryŏ's desires and has been sympathetic to Koryŏ's sincerity. And, unexpectedly, he has bestowed the new music (cited in Song 1992: 177).

Both gifts were requested and, indeed, Huizong sent a message along with the second:

> Since the Three Dynasties, ritual has been scattered and music destroyed... A thousand years later we, reflecting upon the pitches and tunes of the Former Kings, have arrived at notes with such style and refinement as to fill the whole country, making visitors feel settled and giving pleasure to strangers. From far away in your country...you have asked permission to send officials, and these are now at court... Now we answer your request, and are sending (this gift) to your country. Though our borders are different and our lands separated, fundamentally there is great harmony (between us). Is this not good? (*Koryŏsa* 70.5b cited in Pratt 1976: 209).

Koryŏsa tells us little about how *Dasheng yayue* fared in Korea. By 1134 it was incorporated in additional sacrificial rites, and by 1188 indigenous Korean music, *hyangak*, had been added to some of these same rites (*Koryŏsa* 14.17b and 16.28a, Yi Hyegu 1967: 149–50). Later, in a 1361 attack, all Chinese instruments except two sets of metal bells and stone chimes were lost, leading to successful appeals to the Ming court in 1370 and 1406 to send a few more instruments and help with instruction (Provine 1988: 10–11).

The *Aakpo* (Notations of Ritual Music) is appended as chapters 136–137 to the *Sejong shillok* (Annals of King Sejong) and describes a thorough revision of the ritual music conducted in 1430 by four government officials: Yu Sanul, Chŏng Inji, Pak Yŏn, and Chŏng Yang. The revision is characteristic of an East Asian dynastic beginning. Reflecting the policy of the new Chosŏn rulers, it adopted a neo-Confucian theoretical perspective, outlined in Chŏng's preface. Accepting that the authentic voice of the past had been irretrievably lost, the compilers began with an examination of two Chinese texts, Lin Yu's *Dasheng yuepu* (Collection of Dasheng Music; 1349) and Zhu Xi's *Ili jingjuan tongjie* (Complete

Explanation of the Classic of Etiquette; early 13th century). The first of these, although ostensibly recording rituals current in 1316, seems to derive largely from the 12th century Dasheng Institute (Provine 1988: chapter 5). It is now forgotten in China. The compilers, incidentally, also knew Chen Yang's 12th century *Yueshu*.

In the Korean *Aakpo* revision, new pitch pipes were built from brass, but these were deemed too long and held too many grains of millet. The pitches diverged from those on the Chinese bell and chime sets which survived in Korea, so the ancient theoretical measurements were discarded. Stone from a quarry at Namyang was used to construct new chime sets. The many versions of the *qin* are mentioned, but these too were soon discarded, for the first chapter of *Akhak kwebŏm* (Guide to the Study of Music; 1493) describes only the 7-string instrument, although it refers back to the *Dasheng yuepu*.[3]

The *Aakpo* returns to earlier modal theory, particularly the 1187 *Lülü xinshu* (New Treatise on the System of Pitches) by Cai Yuanding,[4] in which only the first five pitches generated by the ascending-descending sequence are considered proper cadence tones. The five form an anhemitonic pentatonic scale with philosophical overtones (**Table 1**):

Table 1 – Scale degrees and their connotations

pitch	character	Korean name	Chinese name	material (5 elements)	Association (for correct govt)
(pentatonic)					
fa	宮	*kung*	*gong*	earth	ruler
sol	商	*sang*	*shang*	metal	ministers
la	角	*kak*	*que*	wood	people
do	徵	*ch'i*	*zhi*	fire	affairs
re	羽	*u*	*yu*	water	objects
(heptatonic)					
si	變 徵	*pyŏnch'i*	*bianzhi*		
mi	變 宮	*pyŏn'gung*	*biangong*		

There were 12 Zhu Xi melodies to consider. The *Aakpo* compilers discarded six because these were not in a fa mode and therefore did not cadence on fa. An interpretation was offered of the Confucian Book of Rites, whereby no tone should assume greater importance than the ruler's fa. Disorder was deemed to occur in the six discarded melodies because they cadenced on sol, the ministers' tone. The six surviving melodies each had a number of verses, each of which started and concluded on fa. With the exception of the fourth, each verse was taken as a complete piece, to give 26 melodies in total: 1 (3 verses) 2 (5), 3 (5), 4 (4), 5 (4), 6 (5).[5] By the same argument, although Lin Yu recorded 16 songs, three were in improper modes and were discarded. One other, though in a fa mode, had inappropriate notes to the pentatonic system. So, only 12 were retained. Here is the justification:

> Music theorists are very concerned about having 'ministers' and 'people' usurp the 'rulers'... In the functioning of a government, successes and failures are all related to (the five tone) classification. When the *Chou li* (*Zhou li*) (Rites of the Chou [Zhou] Dynasty) says, "The Grand Master grasps the *yin* and *yang* pitch pipes in order to listen to military sounds and predict whether things will go well or badly"; or when the "Essay on Music" (in the Book of Rites) says, "When the five classifications are not disordered, there are no ominous sounds", they both refer to this. If a note were placed between fa and sol, it would be...a perverse note. The same holds true between sol and la, and between do and re. Above the fa note, alien sounds are especially unwelcome (Chŏng Inji, translated in Provine 1988: 168-9).

To this point, then, there were 38 melodies. Next, two mechanical adjustments were made. One utilized a literal but not necessarily correct interpretation of Zhu Xi to reduce the range of songs to a major seventh, lowering tones outside this range by an octave. The second transposed all melodies to give fa as Yellow Bell, *hwangjong* to Koreans. Each melody was then transposed to begin on each of the 12 possible semitone pitches, i.e., 26x12=312 for Zhu Xi and 12x12=144 for Lin Yu, totalling 456 melodies. This created an additional problem, and further downward octave transpositions, because the sixteen tones available on the metal bell and stone chime sets prescribed a total range of a minor tenth (**Figure 2**).

Fig. 2 – *P'yŏnjong* (16 bronze bells) and *P'yŏn'gyŏng* (16 stone chimes) – Illustrations from 1493 *Akhak kwebŏm*

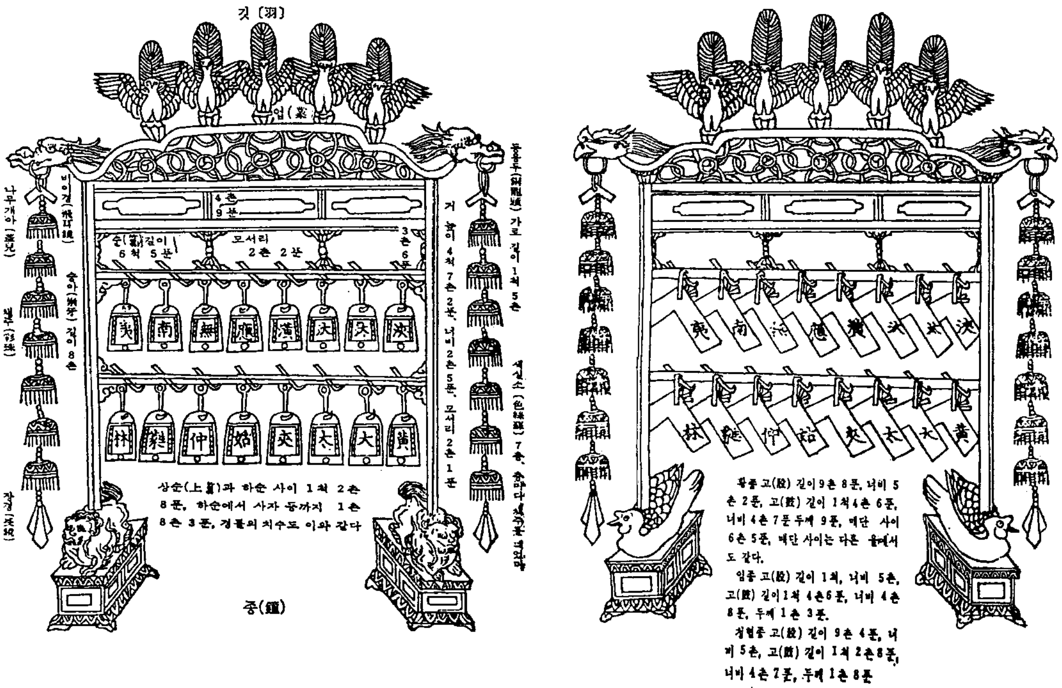
Pitches –

top row: *ascending»»»»»»*

i (G♯) *nam* (A) *mu* (A♯) *ŭng* (B) *hwang* (C) *tae* (C♯) *t'ae* (D) *hyŏp* (D♯) *ko* (E)

bottom: ︽ *««««« ascending*

im (G) *yu* (F♯) *chung* (F) *ko* (E) *hyŏp* (D♯) *t'ae* (D) *tae* (C♯) *hwang* (C)

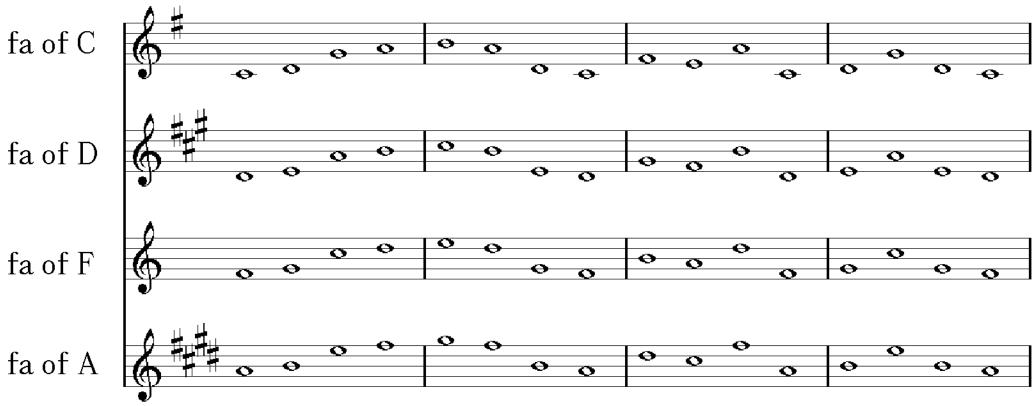


The justification is curious. Having stated concern that ministers and people usurp the ruler, the *Aakpo* preface continues:

> ...they have continued to use the (higher octave) pitches, because this makes it possible to avoid instances when sol and la surpass (i.e., have a lower pitch than) fa... Chu Hsi (Zhu Xi) says that using higher octave notes to begin pieces was not the ancient method. However, he also says (elsewhere), "There are 12 individual pitches, but only seven are used at a time; if an additional pitch is inserted, then it is perverse" (translated in Provine 1988: 168–170).

The whole process drastically changed some melodic shapes, as **Figure 3** shows, giving *hwangjong* as C, a pitch which it retains in contemporary ritual use.[6]

Fig. 3 – Transpositions of a single Lin Yu melody

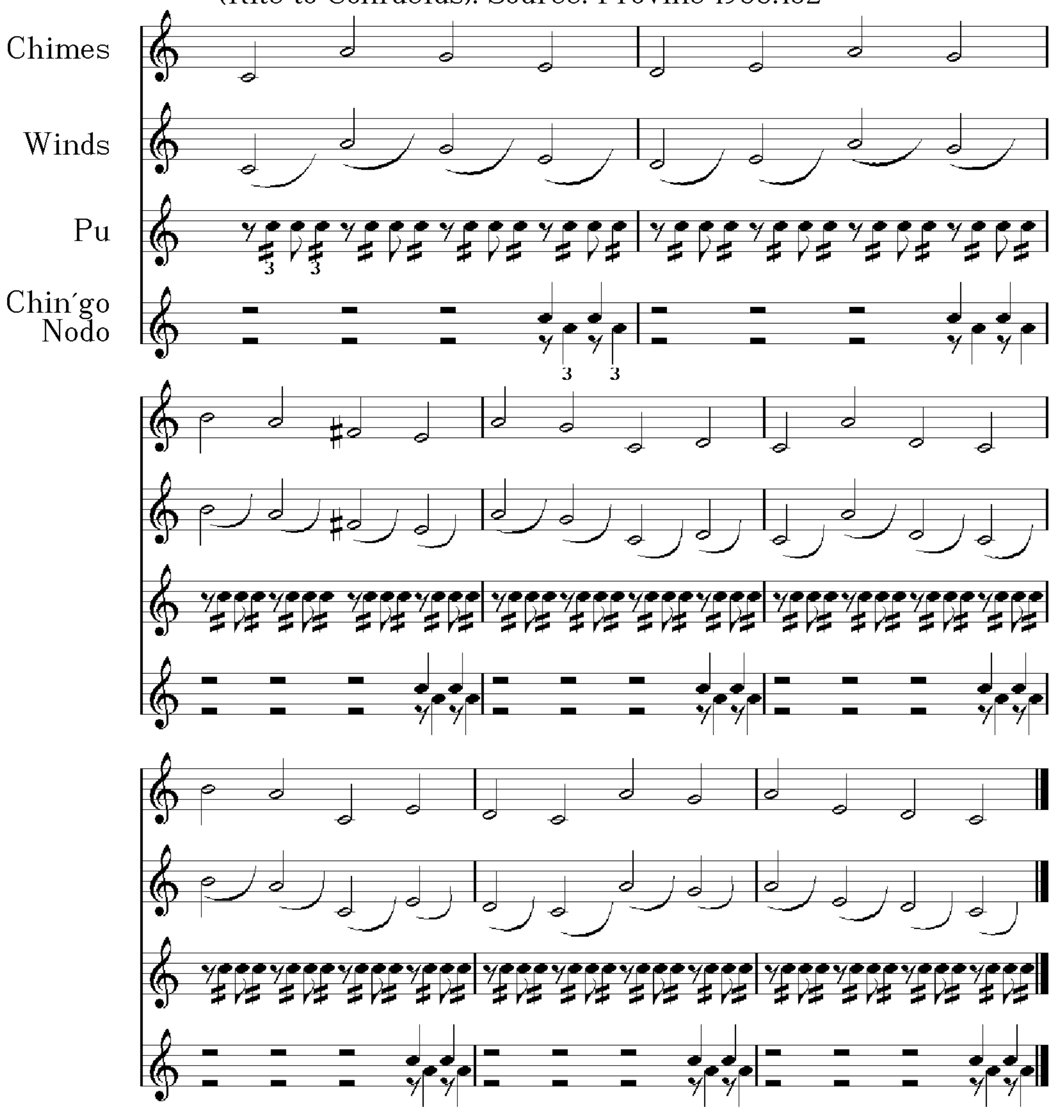


Only one ritual survives in Korea, still using any of these melodies:the twice annual *Sŏkchŏn* Rite to Confucius, performed in the Confucian shrine compound (*Munmyo*) at Sŏnggyun′gwan University in Seoul. The antiphonal orchestral division is retained, but only two basic melodies have survived from the 15th century. Each melody strictly adheres to Lin Yu′s uniform structure of eight equal phrases each of four regular notes, accompanied on *pu* (baked clay pot with split bamboo beater), formulaic patterns at the end of each phrase on *chin′go* ("advancing" large barrel drum) and *nodo* (double barrel drum struck by rotating leather thongs). Set percussive signals for opening and closing pieces distinguish between terrace and courtyard orchestras, using *puk* (clappers), *ch′uk* (wooden trough), *ŏ* (scraped wooden tiger), and drums. Melodic instruments play in unison, though a Korean innovation appears to be a slow upward glissando on wind instruments at the end of each note. Until the 1970s string instruments and voices were silent but have now been restored (Provine 1987: 7-10).[7] **Figure 4** gives the initial melody; the text, for ushering in the spirits, runs:

Tae chae sŏn sŏng, to tŏk chŏn sŭng,
Yu chi wang hwa, sa min shi chang,
Chŏn sa yu sang, chŏng sun pyŏng nyung,
Shin ki nae kyŏk, o so song yŏng.

"Confucian education has been kept due to the benevolent teacher,
This rite is always honourable, clean and pure,
Spirits! Come and receive this offering,
How radiant your holy faces are!"

Fig.4 – *Hwangjonggung* (Ushering in the spirits) from *Munmyo Cheryeak* (Rite to Confucius). Source: Provine 1988:162

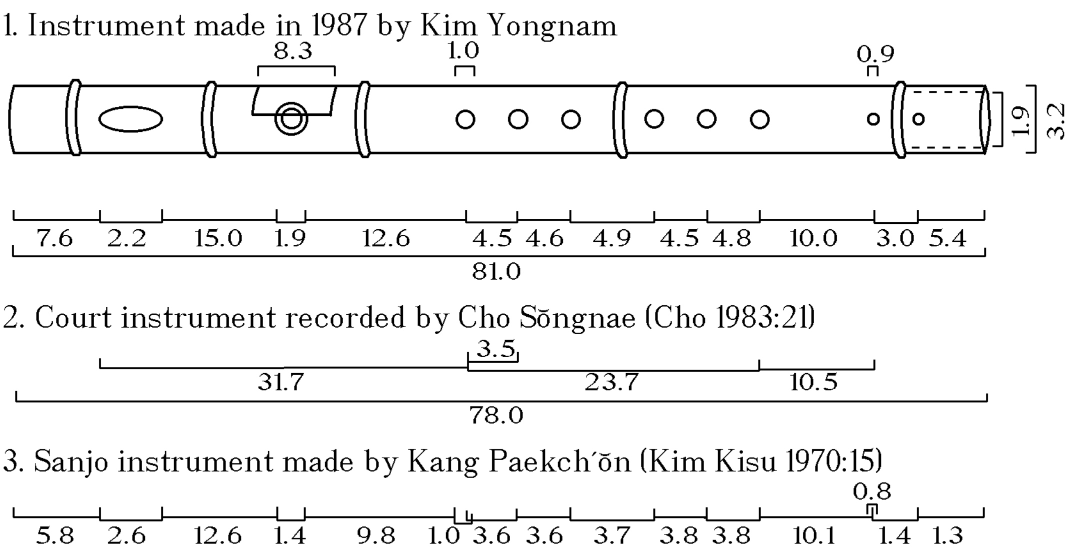


The first piece's five transpositions (with fa as C, E, F, G♯ and A) are repeated in the rite's six initial sections. The second piece, its name prefixed by *songshin*, occurs once, at the ritual's end, when it cadences on C. Both are from Lin Yu's *Dasheng yuepu*.[8] Each ritual section names the same music differently – *ungan chiak*, *myŏngan chiak*, *sŏngan chiak*, *sŏan chiak*, *sŏngan chiak*, *oan chiak*, *ŭngan chiak*. Transpositions are marked for initial and final notes, by the Chinese *lülü* (Kor: *yullyŏ*) system: *hwangjonggung* (C), *kosŏn'gung* (E), *chungnyŏgung* (F), *ich'ik* (G♯), *namnyŏgung* (A) (*kung/-gung*= central tone). This entire music now forms a 90 minute sequence.

The *taegŭm* (*tae* = large; *kŭm* /-*gŭm* = blowing instrument; H/S 421.121.12) is a large transverse flute normally made from a length of yellow bamboo (*hwang chuk*) with prominent nodes.[9] Typically, ducts run along either side of the tube between nodes. The upper end of the instrument is sealed with wax (*mil*) at the first node; the other end is left open. The 1493 treatise *Akhak kwebŏm* describes a standard form said to comprise five years′ growth of bamboo:

- The length should have five nodes and four central sections, since top and bottom are cut between nodes.
- An extremely large blowing hole (*ch′wi kong*) – the size reflects the requirement for considerable vibrato – is cut below the first node in the first section.
- An oval hole (*ch′ŏng kong*), covered with a tissue– like reed or bamboo membrane which acts as a mirliton when a protective metal plate is slid away, is cut into the second.
- Six equidistant finger holes (*chi kong*) are cut, three assigned to each of the remaining two central sections.
- Five additional small holes (*ch′ilsŏng kong*) define the sounding length of the tube and provide decoration above and below the bottom node. *Ch′ilsŏng* translates as the seven stars of the Big Dipper constellation, but there is no evidence to suggest there were ever seven holes (**Figure 5**).

Fig. 5 – Three instruments (all measurements in centimetres)



In practice, there appears to be no standard form. The six finger holes are initially cut small, typically to the template of an existing instrument. Pitches produced at each hole are then sharpened or flattened by enlargement towards or away from the blowhole. Clearly, this implies the holes are not equidistant. Between two and five small holes are cut: five is generally considered unnecessary. And, although *Akhak kwebŏm* gives the length as 86.5cm, today's instruments tend to be shorter. Two examples, both producing the standard range, differ in length by 3.2cm, with 1cm difference in the distance between first and second finger holes (i.e., 3.5cm and 4.5cm) (**Figure 5**). The physicist Pak Hŭngsu has measured *hwangjong*, Yellow Bell, on two old instruments and as played on contemporary instruments by seven musicians (Pak 1983, 1990). The results run from 262.9–275.1cps, with the two old instruments registering near the median at 270.6cps and 271.7cps respectively. Not all fingering possibilities yield such consistent results: **Table 2** gives the results for four musicians, divided to reflect how closely they match just one old instrument. For approximate western tunings, fingering 1 produces B♭, 2 C, 3 D♭, 4 E♭, 5 F, 9 G and 10–12 tones around A♭ to A. In earlier articles (eg, Pak 1980: 389–396), similar results were said to show there has been no significant pitch alteration since the 15th century, despite the fact that the instrument has been shortened (see Chang 1984: 224).[10]

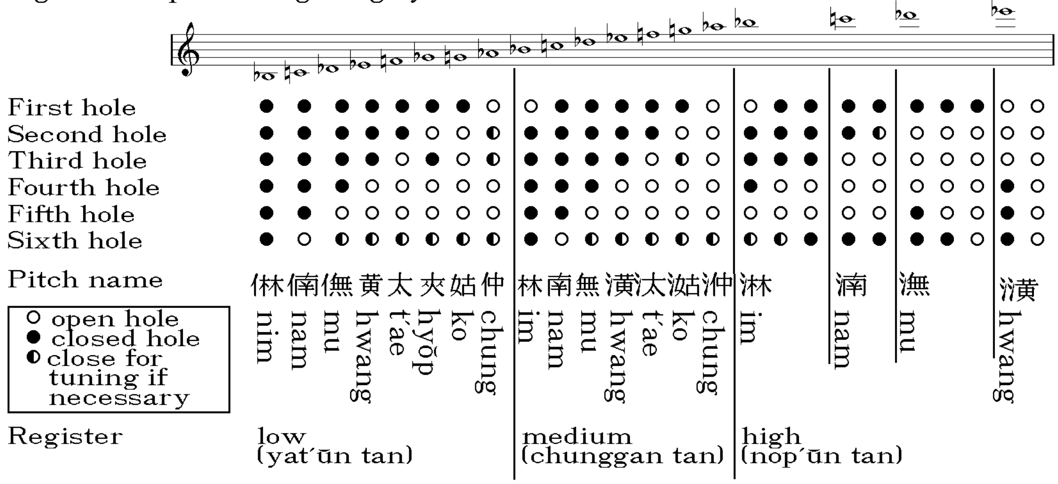
Table 2 – Comparison (in Hertz) of frequencies played by four musicians

fingering		instruments:.. A	B	C	average;	instruments:.. D	E	average.
1	● ● ● ● ● ●	233.3	230.6	240.7	234.9	239.0	237.7	238.4
2	● ● ● ● ● ○	276.9	265.2	276.9	273.0	276.8	282.1	279.6
3	● ● ● ● ○ ○	298.6	292.2	296.0	295.6	302.8	313.1	308.0
4	● ● ● ○ ○ ○	329.1	324.2	329.7	327.7	337.6	342.5	340.1
5	● ● ○ ○ ○ ○	361.4	358.5	362.8	360.9	372.9	378.5	375.7
6	● ○ ● ● ● ●	383.5	363.6	392.0	376.4			
7	● ○ ● ○ ○ ○	391.7	378.9	398.5	389.4	403.5		403.5
8	● ○ ○ ○ ● ○	410.9	389.2	401.0	400.4			
9	● ○ ○ ○ ○ ○	403.9	393.4	403.9	400.4	413.2	412.8	413.0
10	○ ● ● ● ● ○	432.9	405.0	439.0	425.6			
11	○ ○ ○ ● ● ●	457.4	437.1	449.6	448.0			
12	○ ○ ○ ○ ○ ○	445.2	439.3	440.1	441.5	463.4	444.3	453.9
13	○ ● ● ● ● ●	477.0	459.7	476.7	471.1	491.6	483.3	487.5
14	● ● ● ● ● ●	484.6	464.0	477.1	475.2	492.5		492.5
15	● ● ● ● ● ○	542.1	522.6	553.4	539.4	554.9	571.9	563.0
16	● ● ● ● ○ ●	589.3	558.4	592.9	580.2			

A = Kim Sŏngjin; B = Pak Chonggil; C = Cho Chaesŏn; D = Han Yongun;
E = *taegŭm* kept as artefact 2431 at Koryŏ University museum, Seoul.
Source: Pak Hŭngsu 1990: 171

Performers vary as to which holes to cover for fine tuning pitches. Indeed, the large blowing hole facilitates fine tuning so equidistant finger holes might indeed be practical. At the *Kungnip kugagwŏn* (Korean Traditional Performing Arts Centre[11]) I was taught a simplified fingering system of a range of two and a half octaves (**Figure 6**). Performers now distinguish three pitch registers, based on octave overblowing: *yat'ŭn tan* (low), *chunggan tan* (medium) and *nop'ŭn tan* (high). Registers are allied to specific tone colours: clear and highly vibrated *chŏ ch'wi* (soft blowing), elegant and strident *p'yŏng ch'wi* (medium) and triumphant *yŏk ch'wi* (hard), reflecting the mirliton's buzzing characteristics. Pitches are now described in the *lülü/yullyŏ* system; simple verbal notations (kuŭm) are usual, varying slightly between performers, but heeding octave shifts.[12] Modes follow standard court (pentatonic "major" *p'yŏngjo* and *ujo*, pentatonic "minor" *kyemyŏnjo*) or typical folksong patterns.

Fig. 6 – Simplified fingering system



Back in the 15th century, *Akhak kwebŏm* prescribed basic modes for the *taegŭm*. These were theoretical, and appear to descend from the transposition system adopted in the 1430 *Aakpo*. But the 12 potential transpositions were restricted by the then used fingering system on the instrument, in which the lowest octave comprised pitches produced by systematically opening successive holes. There were consequently seven modes, each heptatonic rather than the more characteristically Korean pentatonic: *il chi* (=one hole, i.e., lowest pitch produced with bottom finger hole uncovered), *i chi* (=two holes, i.e., lowest pitch produced with bottom two finger holes uncovered), and so on (**Figure 7**).

Fig. 7 – Fingering charts for *taegŭm* modes from *Akhak kwebŏm*

1. Il Chi

	下		界				界	宮	上	界				界		
	五	四	四	三	二	一	一		一	一	二	三	四	四	五	六
Hole:	夾	仲		夷	無	氵	大	夾	仲		夷	無	氵	大	夾	仲
	姑	蕤	林	南	應	黃	太	姑	蕤	林	南	應	黃	太	姑	蕤
1	●	●	●	●	●	○	○	●	●	●	●	●	○	○	●	●
2	●	●	●	●	○	○	●	●	●	●	●	○	○	●	●	●
3	●	●	●	○	○	○	●	●	●	●	○	○	○	●	○	○
4	●	●	○	○	○	○	●	●	●	○	○	○	○	●	○	●
5	●	○	○	○	●	●	●	●	○	○	○	●	●	○	○	●
6	○	○	○	●	●	●	●	○	○	○	●	●	●	○	●	○

2. I chi

下		界	下			界	宮	上	界				界		
五	四	四	三	二	一	一		一	一	二	三	四	四	五	六
仲		夷	無	氵	大	夾	仲		夷	無	氵	大	夾	仲	
蕤	林	南	應	黃	太	姑	蕤	林	南	應	黃	太	姑	蕤	林
●	●	●	●	○	○	●	●	●	●	●	○	○	●	●	●
●	●	●	○	●	●	●	●	●	●	○	○	●	●	●	○
●	●	○	○	●	●	●	●	●	○	○	○	●	○	○	●
●	○	○	○	○	●	●	●	○	○	○	○	●	○	●	○
○	○	○	●	●	●	●	○	○	○	●	●	○	○	●	○
○	○	●	●	●	●	○	○	○	●	●	●	○	●	○	○

3. Sam chi

	下		界				界	宮	上	界					
	五	四	四	三	二	一	一		一	一	二	三	四	五	六
	夾	夷	無	氵	大	夾	仲		夷	無	氵	大	夾		夷
	林	南	應	黃	太	姑	蕤	林	南	應	黃	太	姑	林	南
1	●	●	●	○	○	●	●	●	●	●	○	○	●	●	○
2	●	●	○	●	●	●	●	●	●	○	○	●	●	○	○
3	●	○	○	●	●	●	●	●	○	○	○	●	○	●	●
4	○	○	○	○	●	●	●	○	○	○	○	●	○	○	○
5	○	○	●	●	●	●	○	○	○	●	●	○	○	○	○
6	○	●	●	●	●	○	○	○	●	●	●	○	●	○	○

4. Hoengji

下		界				界	宮	上	界			
五	四	四	三	二	一	一		一	一	二	三	四
夷	無	氵	大	夾	仲		夷	無	氵	大	夾	仲
南	應	黃	太	姑	蕤	林	南	應	黃	太	姑	蕤
●	●	○	○	●	●	●	●	●	○	○	●	●
●	○	●	●	●	●	●	●	○	○	●	●	●
○	○	●	●	●	●	●	○	○	○	●	○	○
○	○	○	●	●	●	○	○	○	○	●	○	●
○	●	●	●	●	○	○	○	●	●	○	○	●
●	●	●	●	○	○	○	●	●	●	○	●	○

5. Ujo

	下		界				界	宮	上	界			
	五	四	四	三	二	一	一		一	一	二	三	四
	無		大	夾	仲		夷	無	氵		大	夾	仲
	應	黃	太	姑	蕤	林	南	應	黃	太	姑	蕤	林
1	●	○	○	●	●	●	●	●	○	○	●	●	●
2	○	●	●	●	●	●	●	○	○	●	●	●	○
3	○	●	●	●	●	●	○	○	○	●	○	○	●
4	○	○	●	●	●	○	○	○	○	●	○	●	○
5	●	●	●	●	○	○	○	●	●	○	○	●	○
6	●	●	●	○	○	○	●	●	●	○	●	○	○

6. P′alcho

下		界				界	宮	上			
五	四	四	三	二	一	一		一	一	二	三
	大	夾	仲		夷	無	氵	大	夾	仲	
黃	太	姑	蕤	林	南	應	黃	太	姑	蕤	林
○	○	●	●	●	●	●	○	○	●	●	●
●	●	●	●	●	●	○	○	●	●	●	○
●	●	●	●	●	○	○	○	●	○	○	●
○	●	●	●	○	○	○	○	●	○	●	○
●	●	●	○	○	○	●	●	○	○	●	○
●	●	○	○	○	●	●	●	○	●	○	○

7. Mak cho

	下		界				界	宮	上	界	
	五	四	四	三	二	一	一		一	二	三
	大	夾	仲		夷	無	氵	大	夾	仲	
	太	姑	蕤	林	南	應	黃	太	姑	蕤	林
1	○	●	●	●	●	●	○	○	●	●	●
2	●	●	●	●	●	○	○	●	●	●	○
3	●	●	●	●	○	○	○	●	○	○	●
4	●	●	●	○	○	○	○	●	○	●	○
5	●	●	○	○	○	●	●	○	○	●	○
6	●	○	○	○	●	●	●	○	●	○	○

As in the *Aakpo*, the lowest pitch was also the central tone. Pitches were described in two ways, using dual characters from the *lülü/yullyŏ* system and a Korean system known as *oŭm yakpo* ("five tone simplified notation"), thought to have been invented during King Sejo's reign (1455–1468). The latter merely denotes a position above or below a central tone (*kung*), and consequently does not designate pitch. *Oŭm yakpo* also adds the Sino-Korean character *kye* (from *kyemyŏnjo*) to signify a shift by a semitone. *Kye* tones replace standard tones in pieces regarded by Korean scholars as being (or having once been) in a "minor" mode:

Table 3 – *Lülü/Yullyŏ* and *Oŭm yakpo* Notation Systems

Akhak kwebŏm	Pitch today	name	characters	name today (with translation)
C	E♭	hwangjong	黄 鍾	hwang (yellow [bell])
D♭	E	taeryŏ	大 呂	
D	F	t'aeju	太 簇	t'ae (big)
E♭	G♭	hyŏpchong	夾 鍾	hyŏp (side or assist)
E	G	kosŏn	姑 洗	ko (husband's mother)
F	A♭	chungnyŏ	仲 呂	chung (middle)
G	A	yubin	蕤 賓	
G	B♭	imjong	林 鍾	im (forest)
A♭	B	ich'ik	夷 則	
A	C	namnyŏ	南 呂	nam (south)
B♭	D♭	muyŏk	無 射	mu (nothing)
B	D	ŭngjong	應 鍾	
		ch'ŏng	氵	ch'ŏng (water=8ve higher)
		kung	宮	kung (central tone)
		ha	下	ha (beneath)
		kye	界	kye (semitone above)
		sang	上	sang (above)
		il	一	il (one)
		i	二	i (two)
		sam	三	sam (three)
		sa	四	sa (four)
		o	五	o (five)
		yuk	六	yuk (six)
giving combinations such as				
		kyeha il	界 下 一	in *kyemyŏnjo*, one below 宮
		ha sam	下 三	three below 宮
		kyesang il	界 上 一	in *kyemyŏnjo*, one above 宮
		sang i	上 二	two above 宮

N.B.– today's term *t'ak* (octave lower) omitted; Korean pronunciations only

Akhak kwebŏm is the major source for historical musicological studies of music and musical instruments in Korea today. But, was *Akhak kwebŏm* really used by musicians, and if not, what relevance does it have to practical music making?

Local traditions: modes or melodic cells?

In Korea today, musicology remains more theoretical than practical. Yet, before the advent of scholarship, local music was never precisely defined. Scholars, who are still today trained primarily in the study of court traditions, continue to define abstract modal parameters. In effect, and ignoring problems associated with the terms, this imposes the Great Tradition (originally imported from China to the Korean court) over the Little Tradition (which many Koreans in the 1990s would describe as the culture of the masses – *minjung munhwa*).

To scholars, the old is considered most worthy, yet study of the past is pretty nigh impossible in the oral traditions of rural Korea. Hence, what I have argued elsewhere to be both an appeal to "scientific methodology" and a Confucian respect for one's predecessors (Howard, forthcoming), has led in Korean folksong study first and foremost to the development and elaboration of a theory of regional modes. This divides the Korean peninsula into five regions: *Sŏdo* north of Seoul, *Kyŏnggi* around Seoul, *Namdo* in the southwest, the east coast, and *Cheju* after the southern island of the same name.

The regional modes are said to comprise, respectively but with the exception of Cheju,[13] *sushimga cho*, *kyŏngjo*, *namdo kyemyŏnjo*, and *menari cho*. Two of these terms actually incorporate the names of characteristic folksongs: *Sushimga* from the north and *Menari* from the east. Hahn Man-young (1991) draws a map and defines regional styles. Vocal characteristics – nasal resonance in the north, clear and lyrical singing in the centre and sad lamenting (*aewan ch'ŏng*) in the southwest – are very relevant. But these are subsumed beneath modal distinctions which give (ignoring "occasional tones," passing tones, and so forth) *sushimga cho* as re, la, do, *kyŏngjo* as so, la, do, re, mi, *namdo kyemyŏnjo* as mi, la, si, and *menari cho* as mi, la, do (Hahn 1991: ch.6).

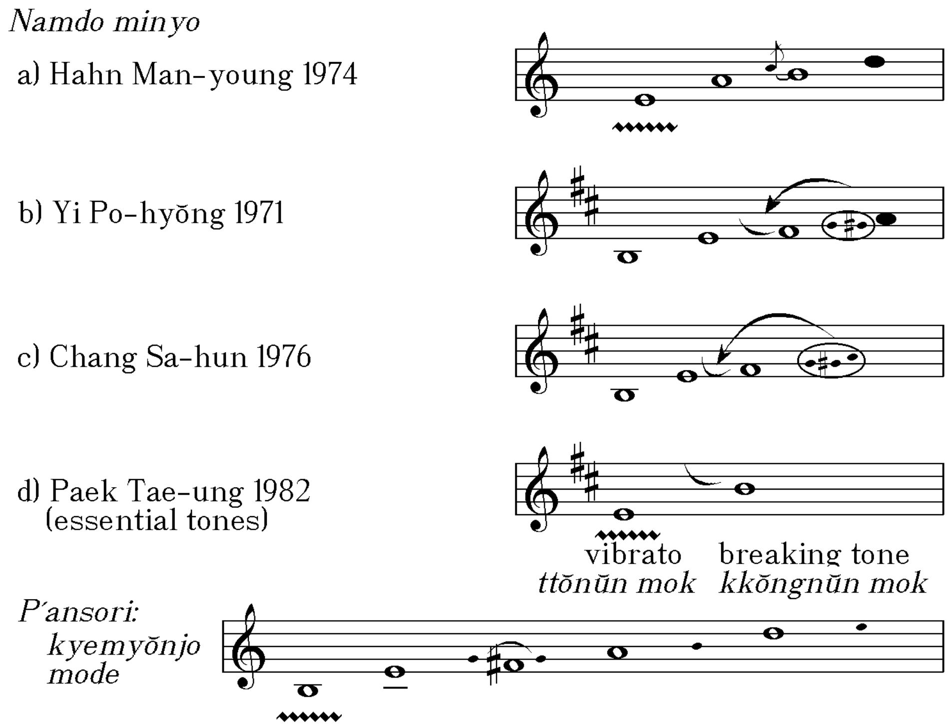
The imposed modal distinctions neither match stylistic features in song texts nor respect context and use. Nonetheless, and surely partly to ensure success, ornamentation and constituent pitches have to be straightened out to fit the theory. An unfortunately blunt reason for discounting apparent aural evidence has been given by Kwŏn Osŏng: "because they were not professional (folk) singers, they sang with undifferentiated ornamentation" (1983: 60). Elsewhere, Hahn Man-young (1973: 141) explained that some tones had to be removed or corrected because there was a wide margin of acceptable pitching. Referring to *Namdo* songs from the southwest, he states they "manifest distinctive functions of microtonal shadings (non-vibrating tones with complex microtonal shadings, widely vibrating tones)..." He defines the mode as mi, la, and si, with an additional minor tone (mi) and a characteristic descent from re to si, but in a further article published in 1974 concludes that "the tonal supply is mi, la, si-re, re, mi, mi-sol, and la" (1974: 311). Related to this, Chang Sahun considers three basic tones form the axis upon which "microtonal shading" occurs over a minor third range (1976: 38-9).

Yi Pohyŏng (1971 and many later articles) and Paek Taeung (1982 and more recent articles) have attempted to reduce this tonal specification. Yi has replaced the court-inspired term for mode, *cho/-jo*, with something more akin to a melodic style, *tŏri*. Paek prefers *kil*, a term denoting a road or path. Paek emphasizes two features of *Namdo* songs, a *kkŏngnŭn mok* "breaking tone" in which a note is approached through a descending appoggiatura and then typically resolves onto the tonic, and a *ttŏnŭn mok* "vibrating tone" which approximates to a dominant below the tonic.

Yi reports:

> In the tone system...the typical characteristics are: the cadence tone is la, a perfect fourth lower than la is mi, and above la is si. The characteristic is of differential variable tones from the upper fourth over a minor third, and from re to do (Yi 1971: 80-81).

Nonetheless, both scholars still simplify their notations and both try to keep the imposed set of pitches.

Fig. 8 - A: The modes of Korean folk songs

B: Weighted scales for *Namdo tullŏrae*

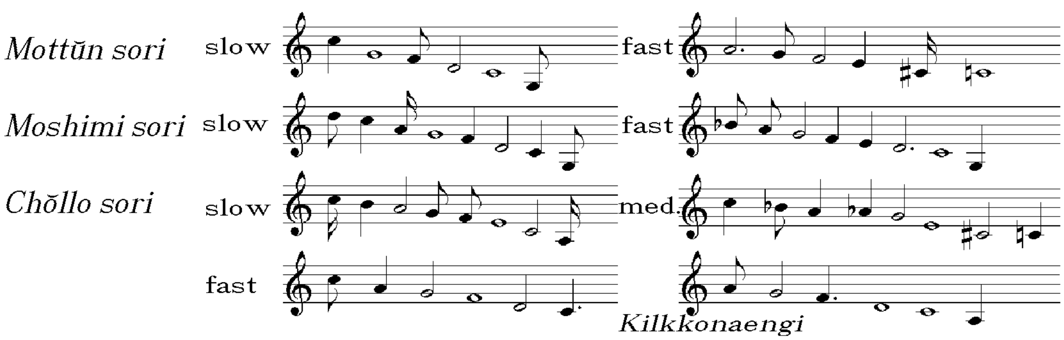


Figure 8 notates these differing modal specifications. The basic tritonic set may well lie underneath many songs from the *Namdo* region, but in itself it is insufficient explanation, for not only is such a set never verbalized, but it also oversimplifies what can clearly be heard.

Two examples from Chindo, an island county off the southwest corner of Korea,[14] demonstrate:

1. For two months, I daily visited Cho Kongnye, a grandmother in Inji village who since 1973 has been appointed a *poyuja* (holder)[15] of *Muhyŏng munhwajae* (Intangible Cultural Asset) 51, *Namdo tŭllorae*, to learn her songs. The set of planting, transplanting, weeding, and harvesting songs were consistently sung with a large pitch palette. Using a weighted scale analysis, based on McAllester and Blacking (Blacking 1967: 183–187; McAllester 1954: facing 46, 50, 54), the tritonic relationships quickly break down (**Figure 8**). Yet behind complex ornamentation, which may vary from stanza to stanza, there is a distinct melodic model. I was never taught the model, and my attempts to sing just this basic form were not tolerated by Cho. Further, experimentation with more "legitimate" pitches from the *Namdo kyemyŏnjo* mode were corrected whenever this meant discarding other pitches. It appears then that a model, more than any concept of mode, defines the songs. This is consistent with Yi's *tŏri* and Paek's *kil*, and is underlined by a Seoul National University MA thesis written in 1984 by Yi Chŏngnan, where versions of one song from the set, *Sangsa sori*, are compared in terms of modal similarities. Yi, like Yi Pohyŏng and Paek, retains, *a priori*, the concept of mode, considering melodic patterns only as a secondary feature. My notation of Cho's *Sangsa sori* is given in **Figure 9** (see texts below).

(i) Refrain: This is the song of love sickness!

Verses: Here we plant, there we plant,
Plant the fields evenly, plant the rice carefully.

This song of love sickness! Where have you been, my lover?
Now is the right time for you to return.

If our human life is lost just once,
There is no way it can come back again.

This love sickness, whose love sickness is it?
It must belong to Mr Kim, the owner of this field.

(ii) Refrain: This is the song of love sickness!

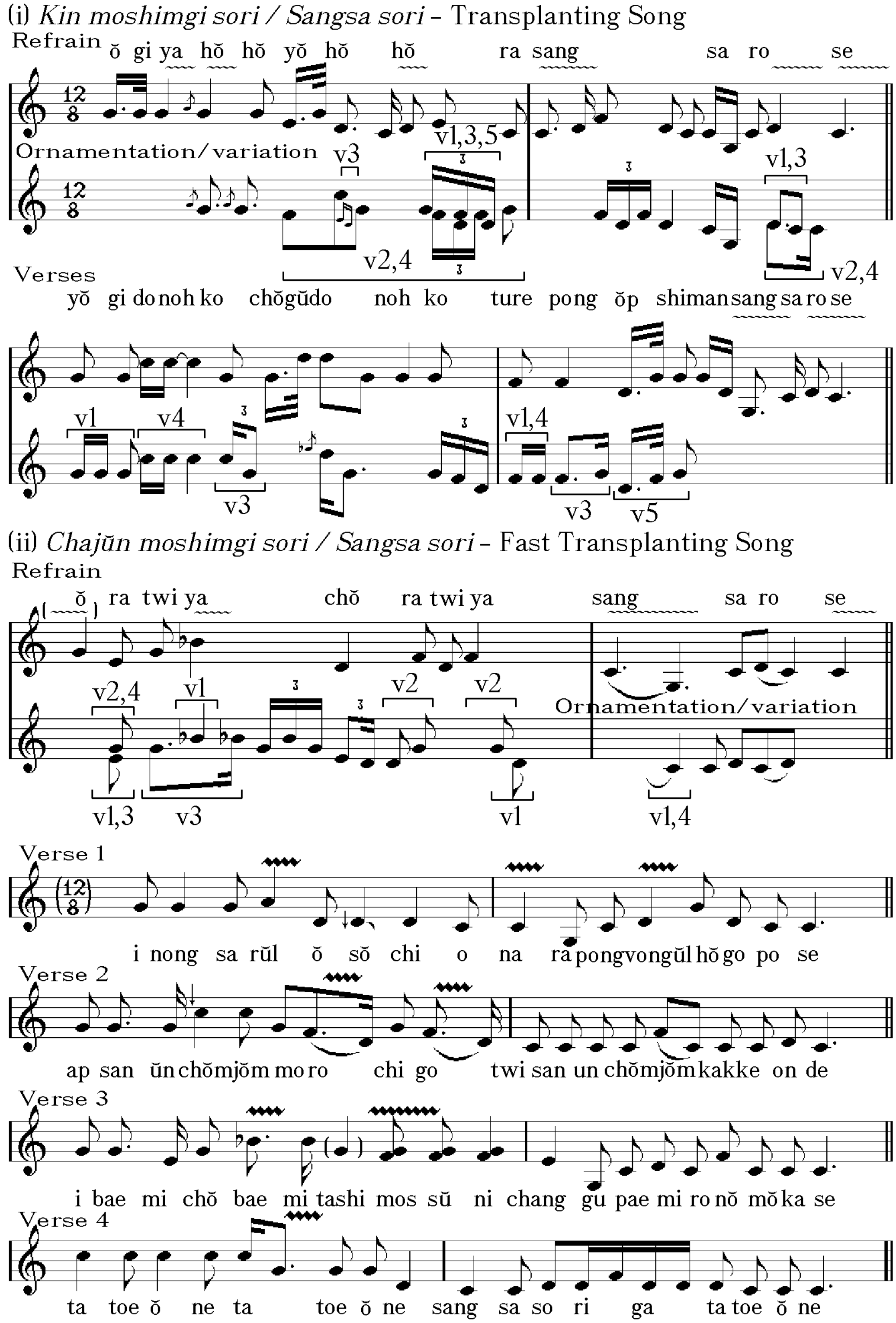
Verses: 1. We should finish our work quickly,
Then we can go to serve our country.

2. Little by little the mountain before us gets further away,
Just as little by little the mountain behind us gets closer.

3. We have finished planting this rice paddy and that rice paddy,
Now we must cross to that paddy over there.

4. All is finished, all is finished;
My love sickness also comes to an end.

Fig.9 – Two *Sangsa sori* with variations ("vN" marks variations in repeats)



2. Kim Kwibong lived in Songjŏng. He made his living as a ritual accompanist (*koin*) to hereditary shamans (*tan'gol*); indeed, his family had belonged to the shaman fraternity for many generations. In the 1970s he had learnt the *p'iri* (oboe; H/S 422.111.2) from Pak Manjun and Kang Hansu, both of whom have now died. In 1983 he agreed to teach me. I was given an instrument made by Kang and arrived for my first lesson.

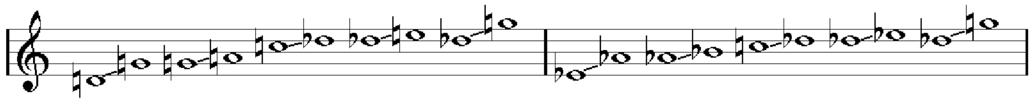
Kim played a seven-note phrase and told me to copy it. Which fingering should I start with? I asked. He responded it didn't matter, so long as I produced the correct pitch. What pitch should be produced when three holes plus the thumb hole are covered? It depends, came the reply. I asked him to repeat the phrase a few times, but still I had no clue how to play it. How about teaching me a scale first? He kept playing phrases, never single notes, and never anything akin to an ascending or descending scale.

Eventually I mastered this simple phrase, but I was immediately thrown by a further shock: he played what he considered the same, yet it was now distinctly different. I tried it, and was told not to copy.

Several things emerge from this. First, Kim had little or no concept of scale beyond melodic passages. Second, fingerings were not associated with precise and constant pitches. Rather, the melodic contour dictated approximate pitches and allowed these to be obtained with a range of timbral shadings determined by the player, his skill, and the mood he hoped to create. Third, the oboe normally has seven finger holes and a thumb hole, but Kang made some instruments with only four or five finger holes.

In most rituals, Kang and Kim both played with just one hand, using the other hand to simultaneously give a rhythmic foundation on the gong. This reflected that clients lacked sufficient money to hire many musicians, but it also had the direct result of requiring a fairly broad pitch range to be produced with a restricted number of finger positions. This was made possible by breath adjustments and through the use of an oversize reed, so Kang obtained a range of an 11th (D-g) with just his thumb and three fingers, Kim a 10th (E♭-g) (**Figure 10**).[16]

Fig.10 – Fingering charts for the *píri* in Chindo shinawi

Kang Hansu: Chinyangjo — Kim Kwibong: Kutkŏri

Thumb	●	●	●	●	●	○	●	●	●	●	●	○
1st hole	●	●	●	●	○	○	●	●	●	●	○	○
2nd	●	●	●	○	●	○	●	●	●	○	●	○
3rd	○	●	○	○	○	○	○	●	○	○	○	○
(etc.)	●						●					
	●	(open except for fine tuning – below 4th hole)					●					

Fourth, the melodic phrases were based on models. The oboe was taught through these models, and was a vehicle for melodic patterns considered to imitate the human voice. In this perception, the development of fluency in playing ascending or descending scalic passages had no place. Again, as in *Sangsa sori*, the model itself was hardly ever performed. Musicians added ornamentation, extension, and elaboration.

In one performance in the rhythmic cycle *kutkŏri* , I have identified six phrases in a single performance by Kim (Howard 1988: 75–77). In other parts of Korea, *kutkŏri*, played as an instrumental piece, sounds quite different yet is based on similar models. Elsewhere I have juxtaposed Kim's performance with other versions played by ritual accompanists in Seoul, notated for a literati ensemble known as *Chul p'ungnyu* in the North Chŏlla provincial town of Iri, and sung as a processional along with percussion bands. I am not able to identify precise archetypes for models, perhaps reflecting that considerable time has passed since common melodies were played, but nonetheless feel there is too much similarity to suggest different roots.

To reiterate: mode has very little concept in the reality of what musicians do. Modes may be there in books, and maybe can be heard in a performance merely because a scholar said they should be used. Musicians, moreover, are creative beings, and prescriptions have a habit of being abandoned.

1 Korean terms are romanised according to the McCune-Reischauer system, Chinese terms according to pinyin.

2 Eg, F (Amiot), E (Mahillon, Courant), D (van Aalst).

3 Even this *qin* soon fell into disuse. Koreans lost the playing technique and, although always placing alongside other zithers in the orchestra for Confucian rites, restored it only after an article on tuning systems by Yi Hyegu was published in 1957 (1957: 379-80).

4 Pian 1967: 52-3 gives a chart of Cai's modes.

5 The fourth originally had six verses, but verses four, five, and six were sufficiently brief to be condensed into one. See Provine 1988: 157; Pian 1967: 161.

6 The changes are also apparent if the Chinese melodies (transcribed in Pian 1967 and Picken 1956) are compared to the Korean, transcribed in Provine 1988.

7 Provine 1992 gives a much more complete history of the ritual orchestra than I can do here.

8 They comprise I and XIII in Provine 1974 and I and IX in Provine 1988.

9 Here I am only concerned with the court instrument. Folk instruments, most commonly today played in sanjo ("scattered melodies" with drum accompaniment), are 10cm or more shorter, have an even larger blowing hole, and are often played without using the bottom one or two finger holes (see Howard 1988: 99-113). The pitch produced with a given fingering is some 15% higher than comparable fingerings on court instruments.

10 To make matters confusing, in Pak's 1990 article two blowing instruments appear which are dated to the end of Koryŏ (late 14th century) and early Chosŏn (15th century) times. These seem to suggest pitches roughly a perfect fifth higher.

11 Until 1988 glossed in English as the National Classical Music Institute.

12 The phonetic theory of solfege offered by Hughes (1989) suggests that some verbal notations I recorded (in Howard 1988) were incorrect. But I simply recorded what Korean musicians, not aware of any inconsistency, related. Some verbal notations for wind instruments, incidentally, actually descend from zither notations (eg, Kim Mugyu 1980).

13 Cheju is recognized as having two distinct folksong styles, with additional complications caused by earlier waves of migration from both the southeast and from central Kyŏnggi.

14 Howard 1990 is based on my doctoral fieldwork on this island. In the early 1980s the population stood at about 82,000, but this declined to around 56,000 by 1990.

15 The popular term for this, coined by the journalist Ye Yŏnghae in the mid-60s, is *In'gan munhwajae* (Human Cultural Asset)

16 Howard 1988: 49-77 provides an account of the *p'iri* in both court and folk use.

Habib Hassan Touma

Basics of Ratio Wrapped in Space, Time and Timbre: On the Structure and Semantics of Arabian Music

Ever since ancient times philosophers and scholars have been often occupied in examining numerical behaviour in music. As early as the third millennium B.C., thoughtful men and women in ancient Mesopotamia contemplated the interdependency of musical structure (particularly pitch scales and rhythmic organization) and numbers. They concluded that music was indeed based on tone combinations and rhythmic structures revealing a rational organization based on ratios, numbers and fractions. The beauty of sound structure was thus devised through organized basics of ratio wrapped in space and time.

Verbal articulations and philosophical–mathematical treatises on music continue to exist in manifold cultures of the Earth: in Asia, Africa, the Pacific Islands, South America and Europe. Music, "an arithmetic exercise of the soul, unaware of its counting" (Leibniz 1712), is borne out repeatedly all over the globe. However, at the beginning there was music; only thereafter followed the rational description of its mysterious structure. The tremendous power of music on human beings and its intense emotional content, especially in social contexts and in religious ceremonies, urged some thinkers to put forth philosophical and mathematical analyses of the phenomenon music, aiming at unravelling its mystery and its overwhelming power on its listeners. However, the question as to why a musical idiom in a specific cultural area is structured as such and not otherwise, remains unanswered in most cases.

In contemporary Western music, however, the case is different! Composers seem to be aware, at least during a particular phase of their creative life, of why their music is structured as it is and not otherwise. They are even prone to disclose techniques concealed in their work. This may perhaps clarify the difference between an Asian or African traditional composer and a Western composer. While the traditional Arabian, Indian or Turkish musician is overwhelmed by his or her tradition, and blindly respects laws of musical composition orally transmitted by past generations, we observe that the Western composer historicizes his/her musical culture through a continuous innovative act of compositional technique and in some cases, through the rational metamorphosis of tonal structures, compositional laws, rhythmic and metric organization of music, particularly in today's computerized music. The traditional non-Western musician/composer on the other hand lives in an eternal yet slightly changing cultural context, abiding by a tradition orally passed down by the masters of bygone ages. In spite of these basically contrary traits, we can detect a common denominator to both Western and non-Western musicians, viz. basics of ratio wrapped in space (pitch), time (metre) and timbre (colour), common to almost all musical cultures of the world.

The beauty of sound structure has been often judged through the organized ratio basics wrapped in space and time. Numbers and ratios have thus helped us to define pitch, rhythm and colour: pitch has been described as a number of vibrations in time, the beat as an impulse in relation to other beats, likewise in time, and the spectrum of sound colour has been fixed on sonographs to explain the characteristics of a specific sound. It is hardly possible to describe a tonal system of a people who had not yet invented their own instruments. Only after the invention of musical instruments were scholars capable of establishing the rational organization of musical tones. The history of the Arabian tonal system, for example, can be traced back to the VIIIth century A.D., a history of the way in which scholars fixed the frets on the neck of a lute.

It is the main object of this paper to concentrate on the basics of the Arabian musical system by displaying at length the rational organization of its tonal scales and perhaps rhythmic patterns. The interrelationship between the mathematical organization of scales and emotional content latent in the music based thereon, i.e. on the maqam, is the second objective of this paper.

In Arabian music, ratio wrapped in space might be approached from three different perspectives, all of which lead to a logical description of the mathematical ratios its tonal system is based on:
- the octave is the sum of 1200 cents,
- the octave is the sum of 53 equal commas and
- the octave corresponds to the whole number 2.

Thus a tone can be defined in relationship to either 1200 cents, to 53 commas or to the whole number 2. If in the first case a tone is at e.g. 355 cents, in the second case it will be at 16 commas and in the third case its pitch will be expressable as the ratio 22:27 in relation to the first tone of the octave. While the prime, fourth, fifth and octave maintain constant values in all scales, we shall see that the values for the seconds, thirds, sixths and sevenths fluctuate, which, as a consequence, is responsible, among other factors, for the intensification or mellowing of emotional contents latent in the repertory of the different maqams of Arabian music.

On Listening to, Understanding and Making Music - The Metrics of Musical Cultures?

In this symposium, speakers talked during the last two days about music they are familiar with. In most cases they were discussing their own "mother tongue music". When Jim Tenney talked about music in fact he was talking about Western music. We very often take for granted that the music we are talking about is Western music. Though music is a universal phenomenon it is hardly a universal language. There are as many musical languages as there are musical cultures in the world. Therefore to understand music demands more effort than merely listening to its structure, and to make music presupposes a perfect command of its syntactic and semantic structures. Yet, listening, understanding and making music are not limited to members of a musical culture alone, but can be learnt and mastered by those alien to that culture. It is the familiarity with a musical culture, with a musical genre or with a compositional style which fosters the understanding of a music and provides the means, perhaps the right, to talk about a music.

We could describe music in any culture by observing it through three dimensions: space, time and timbre. It is the degree of rigid or loose organization of any one of these three dimensions which characterizes a musical culture and stamps it as such. The <u>spatial</u> dimension might exhibit either a rich or a poor tonal organization, so that its scales may include a number of notes gleaned from a tonal pool of 5, 12, 17, 24, 53 etc. equal or unequal tones. <u>Temporal</u> organization may exhibit simple or complex relationships between short and long notes. Such relationships may be confined to combinations of the three prime numbers 1, 2 and 3 (so ratios of short:long can appear e.g. as 1:2, 2:3, 2:4, 4:6, and can be reduced to these three prime numbers), or extend the values of these ratios to higher prime numbers such as 5, 7, 11, 13, 17, 19 etc. – here the relations short:long or vice versa would appear as 5:7, 7:13, 11:17 etc. Similarly we find some East Asian cultures dwelling on a minimum number of pitches for a long time so as to enrich the minimally conceived tonal-spatial dimension of the music. Some of you may disagree with me in considering in addition to space and time a combination of these two – timbre – as a third music dimension.

To summarize, specific cultures in the world give priority to spatial organization following a specific law. In some cultures spatial tonal organization is so organized and predetermined that it is of high priority and functions as an identifying factor of this music. Other cultures stress temporal organization and the division of time. There are also cultures which give main priority to timbre: Ann La Berge's piece which she played for us yesterday stressed timbre, neglecting intricate time structures, which most of us noticed as a clear decision. Therefore how a culture divides time or organizes tones in space and selects timbres for tones identifies the culture.

Methodologically speaking, this could in fact be a possible way of measuring musical cultures of the world. Let us take a specific example. Arabian, Indian, Turkish and Persian music give priority to their tonal spatial organization. They derive heptatonic scales from divisions of the octave into 17 or 53 tones or more. In such scales they give special priority to the melodic aspect of their music, to specific tones in space, meaning that this pool of tones in space is governed by a hierarchy of tones, specifically the maqam.

When a culture gives priority to one dimension one expects that the other two are less projected. Chinese, Japanese, Vietnamese or Korean music give more priority to the dimension timbre than to those of space and time. The Korean flute *taegum*, for example, has an extra built-in membrane which distorts the purity of its pitch and adds a nasal buzzing to the blown notes. Why is this? I believe it agrees with the music mentality of East Asians, who attend more to timbre than to space or time. Of course this does not mean the elimination of spatial or temporal dimensions; these are always present and discernable, yet pushed aside – the timbre of each note catches the listener's main attention and forms the foreground.

Temporal division in almost all musical cultures south of the Sahara shows an intricate structure in which tonal space plays a lesser role. A xylophone player from Ghana, for example, would include a piece of wood in his instrument with an unidentified pitch called the dead note. This dead note purposely metamorphoses the pitch of that specific point in his xylophone. It is not the number of different tones in the scale under consideration that counts for the musician or listener, it is rather time and the way it is divided. It is not enough to know that in the Arabian scale there are 17 or 53 tones. More crucial is to find out what categories of scales can be constructed out of this pool of tones – here we could glean ten or eleven tones to make a row, which I will call a maqam-row, with a modal hierarchy defining the personality of the maqam.

Aesthetic Knowledge

Discussing musicological problems implies dealing with an æsthetic knowledge, which signifies scientific and assumptive knowledge. When I say the fifth is the equivalent of the ratio 2:3 and the fourth of 3:4, I am dealing with a scientific knowledge valid for Arabs, Turks, British, Chinese – for anybody. When I, on the other hand, say that the voice of this or that singer from Upper Egypt sounds like a bell, praising his or her voice, then I am dealing with an assumptive knowledge valid in the society in question. Similarly a Muslim would not eat pork because it is against Islamic religious rules. It is also not permissible for a Jew to eat meat and milk from the one and the same plate at the same time.

Now, in dealing with music we deal with æsthetic knowledge which by itself includes scientific and assumptive knowledge. In trying to understand cultures other than our own, we are guided factually by our own æsthetic knowledge as a point of reference, which tends to "correct", subtract or reduce what is alien to our own music, especially in the values of pitch, time and timbre. What is beautiful and serene in a Chinese opera for a Chinese listener might be ruled ugly and unmusical by a European ear untrained in Chinese music. A Verdi opera or Beethoven symphony might seem chaotic noise to an Arab. The Arabian third, the *sīkāh*[1], [e𝄳], would be found false and out-of-tune by a European violinist and would be "corrected" and reduced to a major third. Responsible for this "correction" is the æsthetic knowledge and the musical mentality of the listener.

Each people on this globe has its own musical mentality, describable as practised æsthetic knowledge in culture. Music mentality is undoubtedly governed by culture itself and is further responsible for the plurality of musical cultures in the world.

I shall try to define culture empirically, historically and scientifically. Empirically, it is the culture which people accept and identify as their culture, and their neighbours would also agree that it is the culture of their neighbours. Historically it is that culture which exhibits a written or orally transmitted history. Scientifically it is that culture which should be described by applying scientific knowledge yet without ignoring assumptive knowledge. Culture is a set of behavioural rules which are governed by three decisive factors: belief (religion), language and tradition. Arabian culture is defined as governed by Islam, the Arabic language and tradition. Islam is the religion which governs all aspects of life in Arab society. Arabic is the medium in which an Arab thinks, expresses his thoughts, feelings, rituals and ideas. Tradition, the third factor, is based mainly on assumptive knowledge, which has been transmitted orally and also in written form from one generation to another and has thus shaped what we know now as tradition in an Arabian society.

The Arabian tonal system

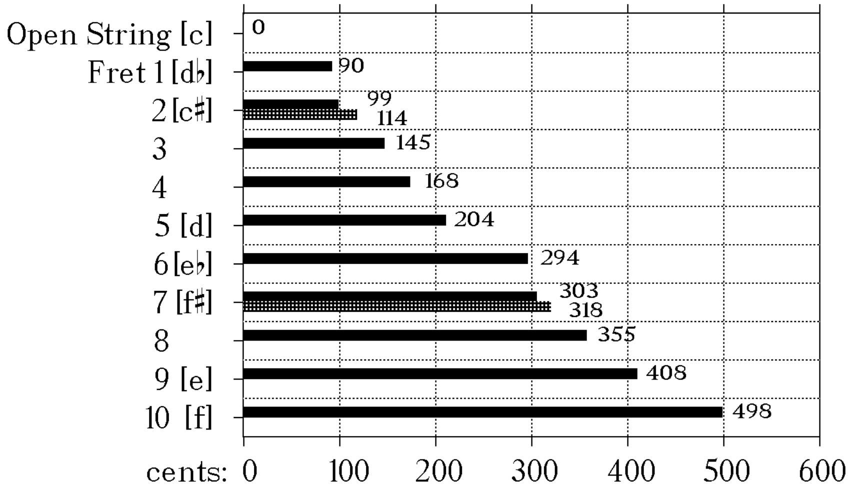
I shall limit myself to only three, at the most four scholars who have dealt with the Arabian tonal system during the last twelve centuries. Their contributions are considered original and form milestones in the history of Arabian music. In fact there are too many scholars dealing with the Arabian tonal system during this period: al-Kindī was the first important scholar of the VIIIth century followed by the great al-Fārābī of the Xth century (d.950), and thereafter by Ibn Sīnā, or as you know him, Avicenna of the XIth century (980-1037). During the XIIIth century the great Ṣafiyyuddīn al-Urmawī (1216-1293) offered original contributions to the subject followed by many scholars who based their thoughts on his treatises. Only during the XIXth century do we find another original contribution; it came from the Syrian Mīkhā'īl Mīshāqā. It seems that at different periods of history whenever something went wrong with music or culture some intelligent scholar or thinker was asked to intervene and help to correct the case.

And I believe that was often the case with the tonal system. Zalzal was a great lute player who lived in the IXth century in Baghdad and used to perform for the Caliph Hārūn ar-Rashīd. His name is associated ever since the IXth century with the pitch of the third tone of the Arabian scale, so that this pitch became known as his third. The value of the Zalzal pitch is somewhere between [e] and [e♭]. Several scholars of that period tried to fix this value, and as we shall see, have calculated various possibilities for this tone. It was given the value of 22:27 by al-Fārābī, Ibn Sīnā gave it 32:39. Both of these fractions cannot be reduced to 2:3, i.e. they are not Pythagorean tones. Ṣafiyyuddīn who lived in Baghdad during the XIIIth century calculated the fraction of Zazlal's third in a unique way worth displaying. He bases this third specifically, and the Arabian tonal system in general, by applying the Pythagorean method of calculating pitch. The virtue of his method is that he explained an Arabian tone, foreign to the Pythagorean system, through that very system, in which the scale is a sum of natural fifths. He gave this third the pitch value [f♭] ($3^8:2^{13} = 6561:8192$).

The history of the Arabian tonal system is the history of calculating the fret distances on the neck of the short-necked lute. Since the strings of the lute are tuned in fourths[2], this means the descriptions of the tonal system guided the lute player on how and where to stop a note on the neck of the lute and consequently the way the tetrachord was divided. Al-Fārābī divided it into ten different tones, Mīshāqā also gave it ten, Ibn Sīnā gave it seven tones – the difference between Mīshāqā's and al-Fārābī's tones lies in the fact that Fārābī's are ten unequal quarter-tones, while those of Mīshāqā are inclined to be ten equal intervals. The octave was attained by putting two tetrachords together and adding another whole tone – as you may imagine there are several ways of doing this.

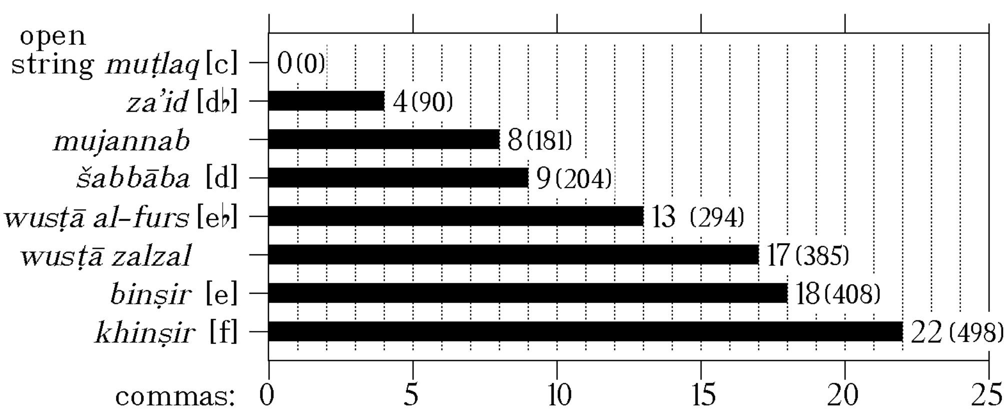
Look at the tetrachord [c–f] in the Middle Ages as given in **Ex.1**. There are ten frets here. While – based on an open string [c] –the first [d♭], second [c♯], fifth [d], sixth [e♭], seventh [d♯], ninth [e] and tenth [f] frets represent tones known to most of us, we see that the third, fourth and eighth frets do not match nameable tones of classical Western music or the Pythagorean tonal system; these latter pitches are at 145 cents for the third fret, 168 for the fourth and 355 for the eighth.

Ex.1 – The Arabian Scale: the tetrachord [c–f] in the Middle Ages



Each tone in the Arabian tonal system has a name, which can be seen in **Ex.2**: the first fret [d♭] gives the tone *zā'id*, the second *mujannab*, the third [d] *sabbāba*, the fourth *wusṭā al-furs*, the fifth *wusṭā zalzal*, the sixth [e] *binṣir* and the seventh [f] *khinṣir*[3]. As can also be seen, their pitch is expressable as whole-numbered Arabian commas – *zā'id* is at 4 commas, *mujannab* 8, *sabbāba* 9, *wusṭā al-furs* 13, *wusṭā zalzal* 17, *binṣir* 18, *khinṣir* 22. The whole octave contains 53 commas. Therefore if we multiply each value by 22.64 (=1200/53) we get the value of the tone in cents.

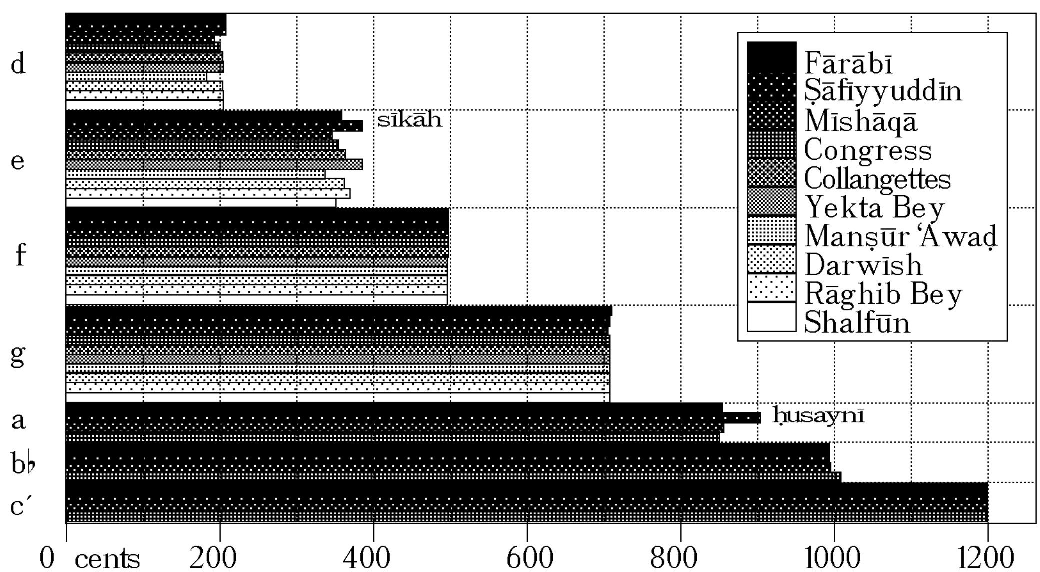
Ex.2 – The tetrachord [c–f] in names and commas (cent values in brackets)



The Arabian comma is a tiny tempered interval, first discovered by Ching Fang, a Chinese scholar who lived around the year 145 A.D. He added 53 fifths in a circle of fifths, and then transposed the top note 31 octaves down, arriving only 3.6 cents from his starting point. As already said, dividing 1200 by 53 you get 22.6415 cents, the Arabian or Holdrian comma – the perfect fifth contains almost precisely 31 of these. Now, the Pythagorean comma has 23.46 cents (twelve fifths minus seven octaves). The Syntonic comma (four fifths minus two octaves and a third) has 21.506 cents. Some scholars in discussing tonal systems say "comma" without differentiating between these three. We usually use the term to mean the Pythagorean comma and falsely say it has 24 cents, because in fact it is smaller than that. 53 Arabian commas add up to an octave. Thus an interval of nine Arabian commas, e.g. [c–d], is 9 x 22.6415 = 203.77 cents. Some Turkish scholars falsely equate the Arabian with the Pythagorean comma – multiplying 23.46 by 53 we get 1243.38 cents for the octave, 43.38 cents too high.

Ex.3 shows a diatonic scale with pitch distances in cents from the tonic [c] as established upto one octave by Fārābī, Ṣafiyyuddīn, Mīshāqā and the Congress of Cairo in 1932, furthermore upto the fifth by the scholars Collangettes, Yekta Bey, Manṣūr 'Awaḍ, Darwīsh, Rāghib Bey and Shalfūn – notice the marked fluctuation in the values for the third (*sīkāh*) and sixth (*ḥusaynī*).

Ex.3 – A comparison of scale degrees measured by different sources



The placement of the frets in the Middle Ages.

Ex.4 shows detailed fret names (with Western equivalents where applicable) as well as interval ratios and cent values and stopped string lengths as fixed by al-Fārābī, Ibn Sīnā and Ṣafiyyuddīn.

Ex.4 – A comparative description of fret placement in the Middle Ages

Fret	Name/descriptor	interval ratio (cents), string length* al-Fārābī	Ibn Sīnā	Ṣafiyyuddīn
	Open String *muṭlaq*	[c] 1:1 (0), 20736	[c] 1:1 (0), 20736	[c] 1:1 (0), 20736
1	Neighbour of the forefinger fret (Pythagorean limma)	[d♭] 243:256 (90), 19683	256:273 (111), *19444.75*	[d♭] 243:256 (90), 19683
2	Neighbour of the forefinger fret (halfway between *muṭlaq* & forefinger)	17:18 (99), 19584	12:13 (139), *19140.92*	[e𝄫] 59049:65536 (180), *18683.47*
		[c♯] 2048:2187 (114), *19418.07*		
3	Neighbour of the forefinger fret (halfway between *muṭlaq* & Persian middle finger)	149:162 (145), 19072	[d] 8:9 (204), 18432	[d] 8:9 (204), 18432
4	Neighbour of the forefinger fret (halfway between *muṭlaq* & Zalzal's middle finger)	49:54 (168), 18816	[e♭] 27:32 (294), 17496	[e♭] 27:32 (294), 17496
5	Forefinger fret *sabbāba*	[d] 8:9 (204), 18432	32:39 (342), *17014.15*	6561:8192 (384), *16607.53*
6	Neighbour of the middle finger fret	[e♭] 27:32 (294), 17496	[e] 64:81 (408), 16384	[e] 64:81 (408), 16384
7	Persian middle finger fret	68:81 (303), 17408	[f] 3:4 (498), 15552	[f] 3:4 (498), 15552
		[d♯] 16384:19683 (318), *17260.51*		
8	Zalzal's middle finger fret	22:27 (355), 16896		
9	ring finger fret *binṣir*	[e] 64:81 (408), 16384		
10	little finger fret *khinṣir*	[f] 3:4 (498), 15552		

* all string lengths except those in *italics* scaled so as to bear mutual whole-numbered relations

The tonal system of Ṣafiyyuddīn al-Urmawī has been discussed widely by well-known European music theoreticians, among them the French Villoteau and Fetis, the Germans Kiesewetter, Ambros and Helmholtz. In his book *Die Lehre von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik* ("On the Sensation of Tone as Physiological Basis for the Theory of Music")[4] Helmholtz based his research on the work of Kiesewetter, the author of *Musik der Araber, nach Originalquellen dargestellt* ("Music of the Arabs, Presented after Original Sources")[5]. These theoreticians helped establish a theory of an Arabian tonal system incorporating "third-tones", which falsely assumes that a whole tone in Arabian music is a tripartite interval. This conclusion was occasioned by Ṣafiyyuddīn's own treatises – in his *Kitāb al-Adwār* and *ar-Risāla ash-Sharafiyya* he divides the octave into seventeen unequal tones, viz. a combination of limma and comma, a fact which misled European scholars of the XIXth century into overlooking the fact that if a whole tone is splittable into three intervallic units, one has eighteen <u>equal</u>, not seventeen <u>unequal</u> pitches in the octave, as in Ṣafiyyuddīn's theoretical discourse. Ṣafiyyuddīn's theory would need one more tone to form eighteen tones in the octave. It was the Briton Ellis who corrected this error, which lay in the misinterpretation of the value of the comma as applied by Ṣafiyyuddīn in his XIIIth century treatises.

Ṣafiyyuddīn's row of seventeen tones to the octave is based on a succession of limmas (90 cents) and commas (24 cents):

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
L	L	C	L	L	C	L	L	L	C	L	L	C	L	L	L	C,

where L means "limma" and C means "comma".

His tetrachord was structured thus (refer back to Ex.4):

Frets:		1	2	3	4	5	6	7
Ratio:	1:1	243:256	59049:65536	8:9	27:32	6561:8192	64:81	3:4
cents	0	90	180	204	294	384	408	498
	[c]	[d♭]	[e𝄫]	[d]	[e♭]	[f♭]	[e]	[f]

His tonal system he based on an application of the Arabic alphabet to name each tone of the scale, using the characters seen in **Ex.5**.

1:

Ex.5 – Ṣafiyyuddīn’s seventeen-tone system

Note no.	Arabic letter(s)	pronunciation[3]	Latin equivalent	Note-name	Interval in cents	Tuning plan in terms of relative string lengths
1	ا	alif	a	c		open string
2	ب	bā’	b	d♭	90 (limma)	9/8 of Note 5 [e♭]
3	ج	jim	j	e𝄫	90 (limma)	9/8 of Note 6 [f♭]
4	د	dāl	d	d	24 (comma)	8/9 of open string [c]
5	ه	hā’	h	e♭	90 (limma)	9/8 of Note 8 [f]
6	و	waw	w	f♭	90 (limma)	3/2 of Note 16 [c♭′]
7	ز	zayn	z	e	24 (comma)	8/9 of Note 4 [d]
8	ح	ḥā’	ḥ	f	90 (limma)	3/4 of open string [c]
9	ط	ṭāh	ṭ	g♭	90 (limma)	3/4 of Note 2 [d♭]
10	ي	yā’	y	a𝄫	90 (limma)	3/4 of Note 3 [e𝄫]
11	يا	yā’alif	ya	g	24 (comma)	2/3 of open string [c]
12	يب	yā’bā’	yb	a♭	90 (limma)	2/3 of Note 2 [d♭]
13	يج	yā’jim	yj	b𝄫	90 (limma)	3/4 of Note 6 [f♭]
14	يد	yā’dāl	yd	a	24 (comma)	3/4 of Note 7 [e]
15	يه	yā’hā’	yh	b♭	90 (limma)	3/4 of Note 8 [f]
16	يو	yā’waw	yw	c♭′	90 (limma)	3/4 of Note 9 [g♭]
17	يز	yā’zayn	yz	d𝄫′	90 (limma)	3/4 of Note 10 [a𝄫]
18	يح	yā’ḥā’	yḥ	c′	24 (comma)	1/2 of open string [c]

Ṣafiyyuddīn’s method for establishing the seventeen tones in the octave is characterized by his calculation of non-Pythagorean tones such as the third (*sīkāh*) and the seventh (*awj*) by employing Pythagorean values and thus differing from that of al-Fārābī or Ibn Sīnā whose calculations of the third, for example, do not refer to Pythagoras – al-Fārābī’s third is set at 22:27 i.e. 355 cents whereas in Ṣafiyyuddīn’s system its value is 6561:8192, i.e. 384 cents. Therefore in constituting his tonal system, Ṣafiyyuddīn limited himself to combinations of Pythagorean intervals, e.g. octave 1:2, fifth 2:3, fourth 3:4 and major second 8:9. He further conceived his system on the monochord by dividing the string into various numbers of halves, thirds, quarters, eighths and ninths (actually in the ratios 1:2, 2:3, 3:4, 8:9, 9:8 and 3:2), thus determining the seventeen tones in the octave. His plan of tuning can be seen in the rightmost column of Ex.5.

Of special importance for us are the tones [e𝄫] and [f♭], for which Ṣafiyyuddīn has also assigned two frets on the neck of the lute, viz. frets 2 [e𝄫] and 5 [f♭], without however reporting why he has done this, although both frets are his own creation and were not known before he wrote down his treatises. Ṣafiyyuddīn names the tone [f♭] *wusṭā zalzal*, a tone to which al-Fārābī assigns the value 22:27 and Ibn Sīnā 32:39. The difference between *wusṭā zalzal* of Ibn Sīnā and al-Fārābī and that of Ṣafiyyuddīn is unambiguous – Ṣafiyyuddīn's *wusṭā zalzal* is a Pythagorean tone which, curiously enough, does not appear in the Pythagorean tonal system; the *wusṭā zalzal* of al-Fārābī and Ibn Sīnā are not Pythagorean tones at all. Yet all three tones are significant in the Arabian tonal system.

We have seen above that Ṣafiyyuddīn's tone [f♭] or *wusṭā zalzal* is set at 384 cents, and we also know that Didymus and Ptolemy calculated the interval [c–e] assigning for it the value 4:5 which is 386 cents. The *diatonon syntonon* of Ptolemy assigns for [c–d] the frequency ratio 8:9 (204 cents), for [d–e] 9:10 (182 cents) and for [e–f] 15:16 (112 cents). Ṣafiyyuddīn, on the other hand, assigns for [c–d] 204 cents, for [d–f♭] 180 cents and for [f♭–f] 114 cents; he also assigns for [c–e𝄫] 180 cents, for [e𝄫–f♭] 204 cents and for [f♭–f] 114 cents. In fact this tiny difference between Ptolemy's and Ṣafiyyuddīn's intervals is the difference between the Pythagorean comma [e𝄫–d] of 524288:531441 (24 cents) and the Didymian comma [d̲–d] of 80:81 (22 cents): 32768:32805 (2 cents). This tiny interval is known to musicology as a "schisma", and was first referred to by G. M. Artusi in 1600 in Venice in his treatise *Imperfettione della musica moderna*.

The permutation of [e𝄫]–[d], or [e]–[f♭] is known as "schismatic permutation". It is the merit of Ṣafiyyuddīn al-Urmawī to be the first scholar ever to apply this mechanism in practice; it was Helmholtz who drew our attention already in 1862 to Ṣafiyyuddīn's schismatic permutation. Its application in the Arabian tonal system is discussed by Ṣafiyyuddīn when he describes the structure of the different maqams, e.g. *Rāst* as [c d f♭ f g b𝄫 b♭ c′] – see **Ex.6a+b**.

Ex.6a – three renditions of the maqam-scale *Rāst*

al-Fārābī		Ibn sīnā		Ṣafīyyudīn	
c	0	c	0	c	0
d	204	d	204	d	204
e𝄳	**355**	*e𝄳*	**342**	f♭	**384**
f	498	f	498	f	498
g	702	g	702	g	702
a𝄳	**853**	*a𝄳*	**840**	b𝄫	**882**
b♭	996	b♭	996	b♭	996
c′	1200	c′	1200	c′	1200

Non-Pythagorean tones *italicized* in both tables

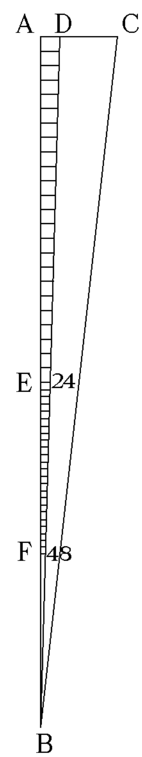
Ex.6b – An example of Ṣafīyyuddīn's schismatic permutation vis-a-vis Ptolemy

Ptolemy			Safīyyudīn		
Interval	ratio	cents	Interval	ratio	cents
c–d	8:9	204	c–d	8:9	204
			e𝄫–f♭ (=*d*–*e*)	comma +limma +limma	204
c–*d*	9:10	182			
d–*e*	9:10	182	d–f♭ (≈d–*e*)	limma +limma	180
			c–e𝄫 (≈c–*d*)	limma +limma	180
e–f	15:16	112	f♭–f (≈*e*–f)	comma +limma	114

The tonal system of Mīshāqā

XIXth century musicians in Syria discussed whether the third tone of the Arabian scale, *sīkāh*, [e𝄳], coincides with *ḥijāz*, [f𝄲], the third tone from [d], when the music is transposed up a tone – some Arabian flutes are in D, some in C or G. For musicians things were unclear especially when having to perform *Rāst* on a D flute. Their question: is *ḥijāz* here a *sīkāh* on [d] or is it the independent *ḥijāz* as applied in another maqam? Yet all agreed that *ḥijāz* cannot be *sīkāh* at all! The latter exists only as the third tone of a scale on [c], for *sīkāh* and *ḥijāz* each has its own personality. To resolve this dilemma the mathematician Mīshāqā was approached; he devised a diagram geometrically dividing the octave into 24 tones and fixing the fret distance for each quarter-tone on the long necked lute, the tambour. His division is mathematically based on the 24th root of 2. See the diagram in **Ex.7**: AB is the string length; AC=AB/9; AE=EB=AB/2; EF=FB=EB/2; AD=AC/4=AB/36; BAC=90°. Divide AE and EF each into 24 equal parts; connect DB. Each horizontal line joining AB and DB sets the gap between two consecutive frets on the neck of the lute, whereby the topmost one is for the first quarter-tone, the next down for the second etc.

Ex.7 – Fret distances set by Mīshāqā



The maqam

The term "maqam" designates a modal framework in the music of several peoples living in North Africa and Asia. It denotes not just the intervallic distances between tones of specific order, but rather the mood created through realization and presentation of the modal infrastructure based on such an order of intervallic distances, which themselves make up what I call the "maqam-row" or the "maqam-mode". The maqam phenomenon characterizes the music of a vast geo-cultural region which includes the Arab countries, Iran, Turkey, Uzbekistan, Tadzhikistan and Xinjiang in mainland China. From a historical point of view, the term "maqam" became the common property of Arabic-Islamic musical scholars in the XIVth century and it is still in use, embedded in musical cultures along the Silk Road from the Atlantic Ocean in the West up to Xinjiang in the East. The maqam phenomenon is a monodic musical conceptualization, the core of which is predetermined tonal-spatial infrastructure. It disposes of a repertory of instrumental and vocal pieces firmly established in an æsthetic musical mentality proper of the musical cultures of the region. The æsthetic mentalities in this large geographical area have been responsible for moulding the framework of this musical phenomenon. There is the Arabian maqam, the Turkish makam, the Iranian dastgah, the Azerbaijani mugam, the Tadzhik and Uzbek maqam, and the Uigur maqam. Most of these terms have been known ever since the XIVth century in the legendary cultural centres of Ürümqi, Kashgar, Dushanbe, Tashkent, Samarqand, Bukhara, Tabris, Teheran, Baghdad, Istanbul, Cairo, Tunis, Algiers and Fez. It is the æsthetic entity of the maqam phenomenon that has determined the form-building elements of the composed and improvised forms of the maqam, instrumental as well as vocal, secular or religious. Yet, the ideals of this musical phenomenon are determined in the firm union of poetry and music on the one hand, and in the incorporation of a monodic melodic line with a recurrent rhythmic pattern called the *uṣūl*, *mīzān*, *zarb* or *iqa'* which appears in the composed form of the maqam. The maqam phenomenon represents a unique improvisatory process in the art music of Arabs, Turks, Iranians, Uigurs, Tadzhiks, Uzbeks and Azerbaijanis, all of whom have been cultivating the maqam for many centuries and are proud to point out the names of their many legendary maqam masters.

We must differentiate between 1) the systematic realization of a maqam as a unique improvisatory process which aims at creating a specific feeling, and 2) the accomplished composed form of a maqam based on a selective choice of latent elements for its systematic realization. To unravel the infrastructure of the maqam phenomenon we have to first examine the immediate improvisatory process. Only then can we understand the accomplished composed form of a specific maqam.

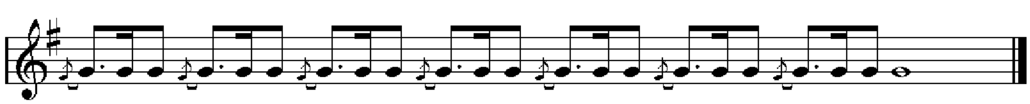
The development of the maqam in its authentic vocal and instrumental form, i.e. in its unique improvisatory process, is determined by two primary factors: space (tonal) and time (temporal). The structure of the maqam thus depends on the extent to which these two factors exhibit the fixed complex of the tonal parameter and the free manner of running the rhythmic-temporal flow of the monodic melodic line. The tonal-spatial component is organized, moulded and emphasized to such a degree that it represents the essential and decisive factor in the maqam, whereas the temporal-rhythmic aspect in the authentic maqam form is not subject to a definite form of organization. In this very circumstance lies the most essential feature of the maqam phenomenon: a free organization of the rhythmic-temporal and an obligatory and fixed organization of the tonal-spatial aspect.

It is in this tonal-spatial organization that the structural and semantic characteristics of the maqam are displayed. The singular feature of this form is one which is not built upon motifs, their elaboration, variation and development, but through a number of melodic passages of varying length which realize one or more tone-levels in space and thus establish the various phases in the development of the maqam. In its authentic improvisatory form, the maqam is thus based on a systematic realization of tone-levels which gradually move up from lower to higher registers, or down from higher to lower registers, but gradually ascending to the higher registers until a climax is reached, at which point the perfect form of the maqam is completed.

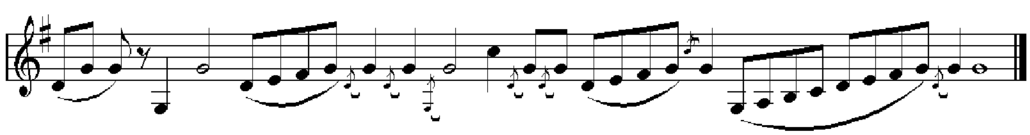
The maqam is thus not subject to specific rules of organization in its temporal parameter, i.e. it has neither a regularly recurring and established bar scheme nor an unchanging beat. The rhythm characterizes the performer's style and is dependent on his manner and technique of playing or singing but is never characteristic of the maqam as such. This is one reason why, from a Western point of view, the maqam has sometimes been regarded as improvisation without form – particularly since clear and fixed themes, together with their subsequent elaboration and variation, are absent. The absence of a fixed rhythmic-temporal organization has hampered and still hampers some musicologists, who have drawn astonishing conclusions which have unfortunately been accepted and repeated as self-evident – certain temporal features have been unjustly attributed to the maqam, viz. "motivic groups", "definite tempi", "definite variations", "melodic pattern", "melodic models" or "tono-melo-syndrome". These designations do not correspond to the actual and latent structural elements of this phenomenon, because the maqam is a form represented by fixed tonal-spatial organization peculiar to the respective maqam-row.

Tone levels

A tone-level can be realized by constant tone repetition (**Ex.8**),

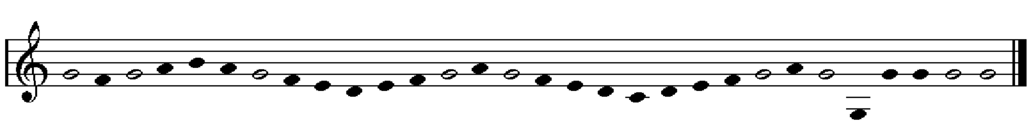
Ex.8 – a tone-level on [g] for repetition

or through an emphasis of a tone by leaping into it or filling a certain interval leading to that tone (**Ex.9**),

Ex.9 – a tone-level on [g] for leaping and filling



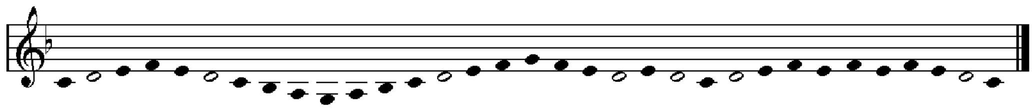
or through building up a melodic axis around that tone (**Ex.10**).

Ex.10 – tone-level on [g] as musical axis



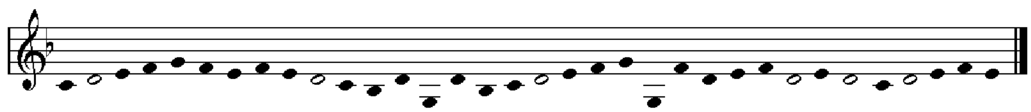
A tone-level can for instance be set up around the note [d] and extend over the octave it is centred in, where [d] becomes a pivotal point encircled and emphasized by its neighbouring tones (**Ex.11**).

Ex.11 – a tone-level on [d] as central tone



It is not unusual, however, for a tone-level to have more than one tonal centre; for example, one of the tones of the said octavic range (here [f]) can form a secondary centre functioning as a kind of satellite to the central tone [d] – the intervallic relationship between the primary and secondary centres gives the entire tone-level a characteristic colour (**Ex.12**).

Ex.12 – a tone-level around [d] with a secondary centre on [f]



The full exploration of the possibilities of such tone-levels represents a new phase – with its characteristic central tone – in the build-up of the maqam. Some musicians develop a particular phase at length, others do so quite briefly; some extend the range of the tone-level and move quite a distance away from the central note, others restrict themselves to a narrow range around the centre. But in all cases the central tone of a tone-level is of the utmost importance for the musicians, because it is the nucleus of the entire phase.

The aggregate of the phases determines the form of the maqam, a form which is shaped by the succession of the central tones of the tone-levels. Each central tone is encircled by neighbouring tones and is sustained for a duration determined by the musician. One musician may take seven seconds to present a tone-level, another forty seconds.

The phase

In every maqam the central tones stand in different relationships to one another and always produce at least two different intervals: for example, a third plus a second, a fourth plus a second, a third plus a fourth or a third. These intervals are dependent upon the structure of the maqam-row and this upon the tonal system of Arabian music. They determine the mood and the nuclear structure of the maqam. The nucleus consists of the sum of all central tones which can be produced to three or more notes.

The first and last tone-level of a maqam are centred on the first degree of the maqam-row. The maqam is divided into melodic passages, the number and length of which are not predetermined. In each melodic passage, one or more tone-levels are combined and contrasted, and they can also replace one another. The number of tone-levels, without repetitions, is predetermined in every maqam and can be reduced to a nucleus. Native audiences recognize the standard of the originality and ability of a musician in the way he or she illustrates, combines and contrasts the tone-levels or phases. Therefore, all possible combinations and repetitions of the tone-levels, as well as their departure from and their return to the first tone-level, proceeding to the highest tone-level (the climax of the maqam) are regarded as standards by which the performer's creative originality, ability and musicianship are judged. The realization of a truly convincing and original maqam requires a creative faculty like that of a composer of genius. Nevertheless, this phenomenon can only in part be considered a composed form because no maqam can be identical with any other: each time it is recreated as a new composition. The compositional factor shows itself on the predetermined tonal-spatial organization of the fixed number of unrepeated tone-levels, while the improvisational aspect freely unfolds in the rhythmic-temporal layout. The interplay of composition and improvisation is one of the most distinctive features of the maqam phenomenon in Arabian music.

It is in this tonal-spatial organization that the structural and semantic characteristics of the maqam are displayed. In accordance with the predetermined tonal-spatial model of the maqam, a mosaic-like structure of musical form evolves. It is made up of a sequence of melodic elements which are repeated, combined and permuted in the course of the presentation of the maqam. The presence or absence of an identifying element and the place or order in which it appears is prescribed by the semantics of the tonal-spatial structure of that maqam. Let us listen to a Koran recitation which should elucidate the tonal-spatial structure of the maqam *Bayātī*.

(Tape example)

I planned to play other, measured music. But I think we don't have the time for that. Thank you very much.

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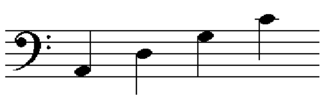
1 Approximate guide to the pronunciation of Arabic words in this text: [']: glottal stop (*hamzah*), as in the initial vowel of "absolutely"; [ʻ]: very strong guttural (*ʻayn*) by breath expulsion through compressed throat; [a, ā]: short, long "ah" / [aw]: as in "ouch" / [ḥ]: as "h" but strongly aspirated and velarized, i.e. articulated deep in the throat / [i, ī] as in English "pill","peel" / [kh]: as in German "Bach" / [q]: velarized "k" / [r]: rolled "r" / [u, ū] as in English "pull","pool" / [y] as in English "yellow" / [ḍ, ṣ, ṭ] as in English but with flattened, broadened tongue / [b, d, f, h, j, k, l, m, n, s, sh, z] as in English.

2



3 The terms *zā'id*, *mujannab*, *sabbāba* etc. were used in the Middle Ages; one now employs *sīkāh*, *ḥijāz*, *ḥusaynī*, *awj* etc. *Muṭlaq* is still in use.

4 Braunschweig 1863, 1865, 1870, 1877, 1896 and 1913

5 Leipzig 1842

Stan Tempelaars

Unheard Sounds

This text is intended as a tutorial on psycho-acoustics, so let us go back to the basics. I fully agree with remarks that have already been made by other speakers about the fact that our hearing organ is, from its origin, a warning system. The requirements of a good warning system are:

- it should be active day and night,
- it should be omnidirectional and very sensitive,
- it should be able to discriminate between simultaneous sounds and to localize these sounds as well as possible.

The ear does all these things quite well. It is always ready. Even when you sleep, it still picks up sounds that maybe will wake you up. It is omnidirectional. The sensitivity of the hearing organ is well known. It has an enormous dynamic range of about 120 dB. The vibration amplitude inside the ear is incredibly small. It is able, indeed, to discriminate between sounds because it has a filter system in the form of the basilar membrane, which is capable of splitting frequency components, and thus sounds. Each of these sounds can be localized quite accurately by measuring time differences (especially between sound envelopes), level differences, and spectral changes in the sounds. In this way the direction from which the sound is coming is determined. It is important to realize what kind of sounds such a warning system should react to. These sounds (wind, water etc.) are always irregular sounds, noise-like, pulse-like, in general aperiodic. Such sounds always have a complicated envelope structure, which means that the determination of time delays between signals is done very accurately.

We thus have a good warning system. So good that in the period between the World Wars the Dutch Army experimented in order to develop a system for the early detection of incoming airplanes. It came up with something like what you see here in Figure 1 (a+b: the smaller model of 1932 never went into production):

Communication by means of acoustics came of course at a later evolutionary stage. When that development started, a system to receive air vibrations was already in existence. But these vibrations had also to be produced. And here

Fig.1a - An Dutch Army acoustic airplane detection system (see also Fig.1b)

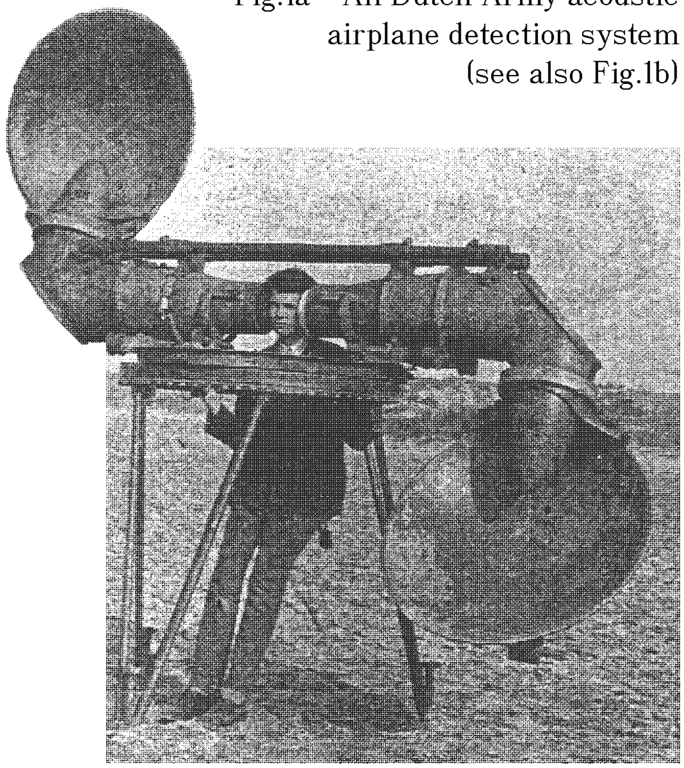


Fig.1b - A smaller model

we have a strange physical problem. If you use air waves for acoustic communication, you have to set air into vibration with your muscles. The problem is simply that the maximum speed at which we can move our muscles corresponds to a frequency of 10-20 Hz, or a wave length of about 30 meters or more. There is a physical law that states that for an efficient radiation of a signal the source dimension should be of the same order of magnitude as the wave length of the signal. The human body is thus simply too small for that task. The efficiency of the radiation would be so low that no true communication system could be based upon it. This problem was solved in a wonderful way: the voice was developed.

The voice is a kind of modulation system. When the vocal chords are brought into vibration more or less periodic vibrations are produced with frequencies in the range of 60–300 Hz with a correspondingly small wave length. Such signals can be radiated much better than low frequency signals from direct muscle action. This more or less periodic signal is generated by the vocal chords and acts as a carrier wave on which information is put by three simultaneous processes:

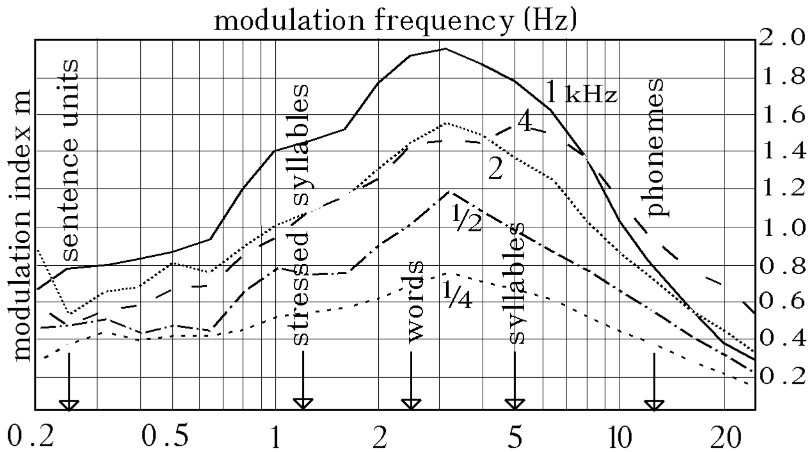
- by varying the tension of the vocal chords, the frequency is changed,
- by changing the energy used to drive the system the amplitude of the vibration is changed,
- by changing the shape of the vocal tract, the position of the tongue etc., the wave form is changed.

In technical terms we have a carrier wave of which the amplitude, the frequency and the spectrum is modulated. Due to the different types of modulations going on simultaneously, we have a much more complicated system than the technical modulation used for radio and TV broadcasts, but there is a correspondence which was recognized only afterwards. The result is not only an improvement of the radiation efficiency, but also all other benefits of a system of modulation such as a better protection against interference. The price is the need for a demodulator at the receiver end.

The idea that speech (and also music signals) are modulated signals is now generally accepted, at least in speech research. The well-known RASTI-index for speech transmission is based on it. It expresses how well the modulation parameters are preserved during transmission. A set condition with modulation is that the carrier frequency should be well above the modulating frequencies. That explains why a frequency of at least about 20 Hz is required to hear a tone and why beats (= amplitude modulation) only can be heard up to 16 Hz. The ear is not capable of following faster beats as natural modulation is restricted to this upper frequency.

Figure 2 shows a graph showing the strength of the amplitude modulation in speech as function of the frequency (ranging from 0.2 to about 20 Hz); the maximum modulation is around 4 Hz, the average frequency at which words are pronounced. Syllables and other speech elements are found at other places on this scale.

Fig.2 – Average temporal envelope spectra in terms of the modulation index for one-minute connected discourse from ten male speakers



James Tenney: A modulation index, I can't remember what that is.

ST: It's the amplitude of the modulating signal. In the mathematical expression of an AM, i.e. amplitude modulated signal

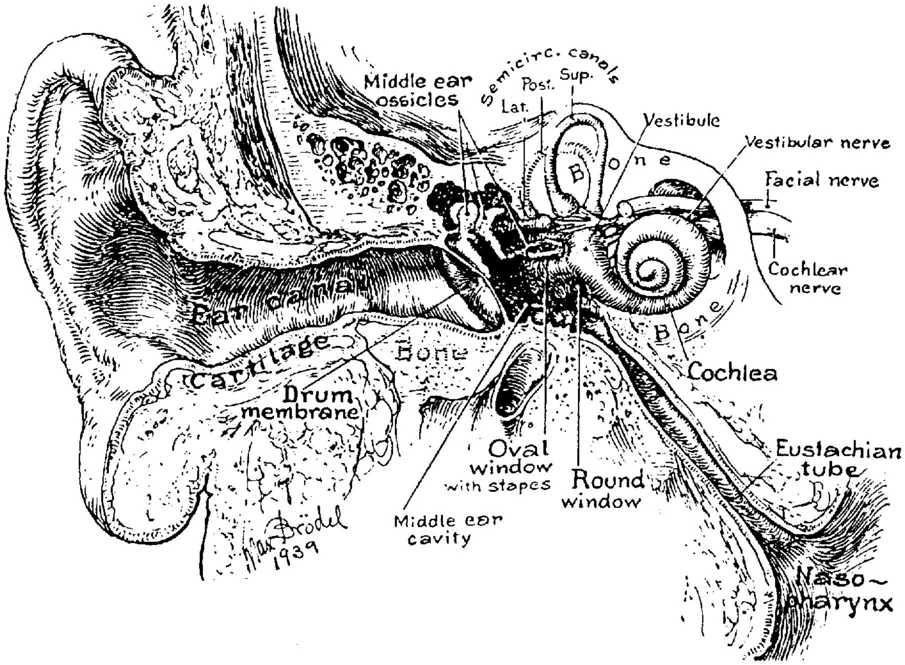
$$\sin 2\pi f_c t(1+m \cos 2\pi f_m t)]$$

it is the parameter [m].

In my view we should approach the phenomenon of perception of music and speech signals as a demodulation process. My proposal for this introduction is that we follow the sound signals on their way, from the outside to the inside. That is the normal approach, but in this way we also will make the transition from a warning system to a communication system. We shall consider the ear as a "living microphone system" whereby the emphasis will shift from "microphone" to "living".

Look at Figure 3, a well known picture of the hearing organ:

Fig.3 - Cross section of the human ear - a classical drawing by Max Brödel



On the outside we have the shell-shaped "pinna" or ear conch and the ear canal. Some people think the pinna is just an ornament. This is not true. We now know that the acoustical function of the pinna is very important and strongly related to the warning function we discussed already. I mentioned time differences and level differences. To detect these you need two ears because you need two signals to be able to tell a difference. But spectral changes can also be detected with a single receiver, with a single ear. The pinna is a linear filter with a complicated direction- dependent frequency response due to the way the resonances are provoked. The amount of spectral "colouration" thus depends on the direction of the sound source. We can recognize these changes and interpret them as directional information, which normally is mainly used to check elevation, while we use time and level differences to determine directions on the horizontal plane.

Perhaps you wonder about the title of my talk "Unheard Sounds". You haven't heard anything about that yet. I must say I used a provocative title like Jim did, but I promise you I will play some of these sounds. As I wrote in my short summary I will give examples of sounds not being produced by physical vibrations, and of physical vibrations not leading to sound impressions.

We continue our trip to the inside of the ear. There's the ear canal, which can be easily physically described by talking about frequency responses, about sound transmission in a tube – or in a set of tubes with different areas. Even the ear drum, which we reach here, can still be considered a microphone membrane. Determining the acoustic impedance of the ear drum is nowadays a common diagnostic tool. If something is wrong with your ears it sometimes can be discovered by measuring how that membrane reacts to pressure fluctuations.

Then we reach the middle ear section of the ear, with that wonderful construction of the three small bones or "ossicles" that form the connection between the ear drum and the oval window, that is the entrance to the inner ear, to the cochlea. This system can still be described in more or less physical terms. We know that the main function of this system is to act as an acoustic impedance transformer to guide the arriving air vibrations into the fluid that is contained in the inner ear by functioning as a system of levers. But there are in the middle ear section not only ossicles – here you see on the left the hammer or malleus that is normally in contact with the ear drum, followed by the anvil (incus) and stirrup (stapes) – but also a few muscles, two in particular: the tensor tympani and the stapedius. The stapedius has an important acoustic function: when this muscle contracts, the stirrup changes its way of vibration and the sensitivity (especially for low frequencies) is reduced. This has always been interpreted as a protection mechanism comparable to that of the pupil reflex. That is only partly correct; we now know that its main task lies elsewhere. Why should we have a protection mechanism against an unlikely risk? Our ancestors lived in a very quiet world. Loud sound levels, like those we have to endure continuously nowadays, occurred very rarely. Perhaps now and then a loud thunderstorm or the sound of the sea. But really loud sounds were very exceptional. And it is not likely that evolution would provide us with a protection system against something that very rarely happens. We now know that the muscle connected with the stapes has a main function of improving acoustic communication. By contracting, this muscle attenuates the low frequencies, especially of your own voice, and reduces in this way the masking effect on higher frequency components (I will speak about masking in a few minutes).

So it is actually anti-masking that is taking place here. And the best proof of that is that the stapedius action starts before you start to speak, while normally a reflex follows the stimulus. In this way the sensitivity to your own voice is reduced. This is already clearly the function of a living organism, it is a feedback system taking a path via the brain. And it is no longer valid to describe it in terms of a passive microphone-like system.

I should like to discuss another subject in relationship with the middle ear: combination tones. We have talked about that phenomenon a few times during the past days. The reason to mention it here is that Helmholtz assumed the combination tones (as they are named nowadays) to have their origin in the middle ear section. We know that this is not true – although the exact origin of the combination tones is unknown.

I think everybody knows the most common manifestation of a combination tone, the difference tone. We talked about it yesterday. Let us now listen to the first sound example. You will hear two signals, one from the left speaker and one from the right. The tape has to be played loud, please accept that – I will make it as short as possible. You will first hear a random series of high pitches on one channel, then another series of high pitches (a short one) on the other channel. And then both at the same time.

(Tape example)

It's not surprising that these difference tones were discovered by musicians. They are sometimes called "Tartini-tones" and it is indeed likely that Tartini was one of the first to have heard and studied them. Helmholtz was the first to explain them by assuming a nonlinear relationship between the acoustic input signal [x] and the reaction of the hearing organ [y]:

$$y = a_1x + a_2x^2 + a_3x^3 + \ldots$$

When the input signal x consists of the sum of two frequency components, you will find of course the same two components in the output signal, but the output also contains all kinds of sums and differences of (multiples of) the two frequencies. The theory predicts that the squared term generates the sum and difference tone and the cubic term frequencies like $2f_1 \pm f_2$ and $f_1 \pm 2f_2$.

The theory thus predicts which frequency components will be found in the signal. Experimental verification shows that the theory is right in the sense that only combination tones with frequencies below those of the primary tones are found.

This can be easily explained by assuming that the higher components are masked by the primary tones. The fact that only difference tones are found is in itself not in contradiction with this theory. Helmholtz himself by the way claimed to have heard the sum tones as well. The problem, however, is that the theory not only predicts which frequency components you will hear, but also what their amplitude is. And here the theory fails. If you take the prediction from this theory, and you measure the strength of the cubic combination tone you will find complete disagreement. Once more we have to leave the simple physical model. We have to assume a different kind of non-linearity to account for this fact.

How important are combination tones? Very important, because several properties of the ear like certain kinds of phase sensitivity can be explained on the basis of difference tones. Although we don't hear them as clearly as in the sound example, they are always present and they always play a certain role. Perhaps also in music theory. In his *Unterweisung im Tonsatz*, Hindemith based his theory of harmony on the fact that each time that two tones sound together, a third tone is introduced. It is strange that he used only the quadratic difference tone and not the cubic one.

Dimitrios Lekkas: There are two of them aren't there? There is also a $2f_2-f_1$.

ST: Yes, but this one's much stronger. I think the $2f_2-f_1$ is above the primary tone. So you won't hear it; it is masked.

Another way to show that the physical description is no longer valid is by measuring the strength of the distortion products. Like with an amplifier the quality of the system can be expressed as a distortion figure. When you calculate this distortion figure from traditional measurements, you come up with something like 20%. Such a high value is utterly unacceptable in any electro-acoustic device. How could it be acceptable in the human ear? The point is that common measuring methods lead to wrong results. So the figure itself should be questioned

Let us continue our trip, arriving at the inner ear, at the spiral-shaped cochlea. An important part of this is the basilar membrane that divides the cochlea (which for simplicity can be imagined as a straight tube) into two parts. On the basilar membrane rests the organ of Corti in which hair cells are located that play a central role in the mechanism converting vibrations into nerve pulses.

This part of the ear is where the frequency selective mechanism is located. Helmholtz tried to explain our ability to discriminate between simultaneous sounds by assuming the basilar membrane to consist of little fibres, resonators tuned to different frequencies. This hypothesis was rejected by Georg von BŬkŬsy who gave the correct description, leading once more to a fascinating physical problem.

Trying to describe mathematically what happens when a narrow, tapered membrane in a fluid is subjected to vibrations is not easy. Von BŬkŬsy not only gave a theoretical analysis, he also confirmed it by observing with a microscope the vibrations in the ears of deceased people. What he saw was a pattern that can best be described as a “running wave”. Due to differences in elasticity and dimensions the different parts of the basilar membrane have a delayed reaction to the pressure. The delay increases with distance to the pressure source, the oval window. This means that when the system is driven with a sine wave, we get a running wave which sweeps up to a maximum and then dies out very rapidly. The place of maximum deviation depends on the frequency of the sine wave. The higher the frequency, the more the maximum moves towards the oval window. The up-and-down motion of the basilar membrane leads to a to-and-fro movement of the hairs protruding from the hair cells. When this movement exceeds a certain threshold the nerve is triggered. This process is an all-or-none process, which means that when it happens, it happens completely. The fact that triggering takes place at a certain moment and then takes place completely, explains the mechanism of masking. Each tone generates an activity or excitation pattern along the basilar membrane with a strong asymmetrical shape. If there are two tones, a strong low tone and a weak high tone, the excitation pattern of the weak tone “drowns” within that of the strong one. No extra nerve activity is initiated, the weak tone is not heard. I have a sound example in which the "masker" is a noise band (to avoid sine tone interaction) and the masked tone is a sine tone that sweeps from low to high and back. When the sine tone approaches the noise band, you will hear it disappear. You will also hear that masking is far more pronounced towards the higher frequencies.

(Tape example)

This behaviour can be measured, giving the well known masking curve with its characteristic asymmetrical shape. Masking is an important phenomenon with consequences in communication processes in speech and music. New digital recording techniques employ it: by not storing those frequency components which are inaudible due to masking, the amount of information can be reduced by a factor of four to five. Furthermore, the masking curve gives us an image of the excitation pattern.

This pattern can also be gained by a non-simultaneous technique (avoiding interaction between the masking and the masked tone) called the pulsation threshold technique. After the combination tone and the masked tone this will be the third example of an unheard sound. It is important, for it shows that under certain circumstances the ear can "fill in" a sound that is not physically present. You will hear two alternating tones, a strong and a weak one. If the weak tone is in the region of the strong one and sounds simultaneously, it is inaudible due to masking. The hearing organ then cannot decide whether the weak tone is there or not. The fact that it is there before and after the strong tone makes it likely that it is also present during the strong tone. It is filled in and we hear a continuous tone, instead of an interrupted one.

(Tape example)

This is a first demonstration of the ability of our ears to restore a signal that contextually should be there, but can't be heard. It is as such the first proof of a much higher order of organization. We should consider the hearing organ not simply as a microphone, but as an information processing system with unexpected qualities like just demonstrated. When our ear receives a complex tone, we get a complex vibration, a series of (partly overlapping) excitation patterns, from which all information about the tone is extracted.

So the peripheral part of the hearing organ is still mainly determined by its task as a warning system. When we consider the central part of the system we recognize the specialization for dealing with sounds of speech and music. From the complicated excitation pattern with its peaks our information processing unit extracts the pitch, loudness and timbre information. This process is reasonably well understood. It is possible on the basis of the physical properties of the signal function to predict what pitch, what timbre and what loudness will be heard.

Loudness is derived from the total neural activity. It is the total number of neural pulses reaching the brain, that determines the perceived loudness. By integrating the total excitation pattern, the perceived loudness can be predicted.

Timbre is derived from the global shape of the excitation pattern, the global spectral envelope. Timbre perception is thus based upon a pattern recognition mechanism. In our memory a number of timbre patterns is stored, and we can recognize an incoming pattern by comparing it with the stored patterns. In this way we can recognize vowels and musical sounds.

The term "pattern recognition" also applies to the mechanism of pitch perception. When we listen to two tones, we have two intermingled patterns of peaks. The ear is capable to recognize the two individual patterns and to separate them in such a way that we do hear two tones, not two complexes of harmonics. A simple physical filter without pattern recognition capabilities can never achieve this.

As soon as pattern recognition is involved it is always attractive to try to fool the system, to distort patterns and to try to find out how far you can go with that. This can be done with timbres, e.g. by constructing timbres that change from one class to another. It is very interesting to follow where the transition takes place. It can also be done with pitches by trying to find out the minimum number of harmonics required to hear the correct pitch. The ear always tries to fit the series of peaks in the excitation pattern to a harmonic series. When it succeeds, the pitch is determined by that harmonic series.

It has been found that you can go very far in making the ear try to fit a pattern to a harmonic series. Normally a few harmonics are sufficient to hear a pitch. Even just one harmonic in one ear, and another one in the other ear. Under bad signal–to–noise conditions (that make it easier for the perception system to "fill in" missing components on the basis of contextual evidence) even a single harmonic can be enough. My last tape example, which I made a number of years ago, still surprises me. You will hear a simple melody eight times, first twice in the normal way. Then strongly filtered with a lot of noise – even though most harmonics are now masked and filtered out, we have no problem in following the pitch. Then you will hear it the same way again, but with one tone changed – and I ask you to find out which one. Finally I will play it still with the changed tone but without noise or filtering, in which case the change will be very obvoius.

(Tape example)

In this example I replaced a complex tone by just one harmonic; it was possible to "hear" the low corresponding fundamental on the basis of just this one tone. The hearing organ has astonishing capabilities to restore mutilated or missing information. This justifies the qualification "information processing system". The same mechanism certainly plays an important role when we listen to orchestral music where the interference is caused by other musical voices.

James Tenney: Does it work that way if you present just the noisy distorted version, in other words without hearing the tune over and over several times?

ST: Just the isolated tones? I've never tried. I shall try that but I don't think it will work. There is no reason why it should.

Wouter Swets

Shifting processes in the metric and modal forms of Balkan and Near Eastern Music.

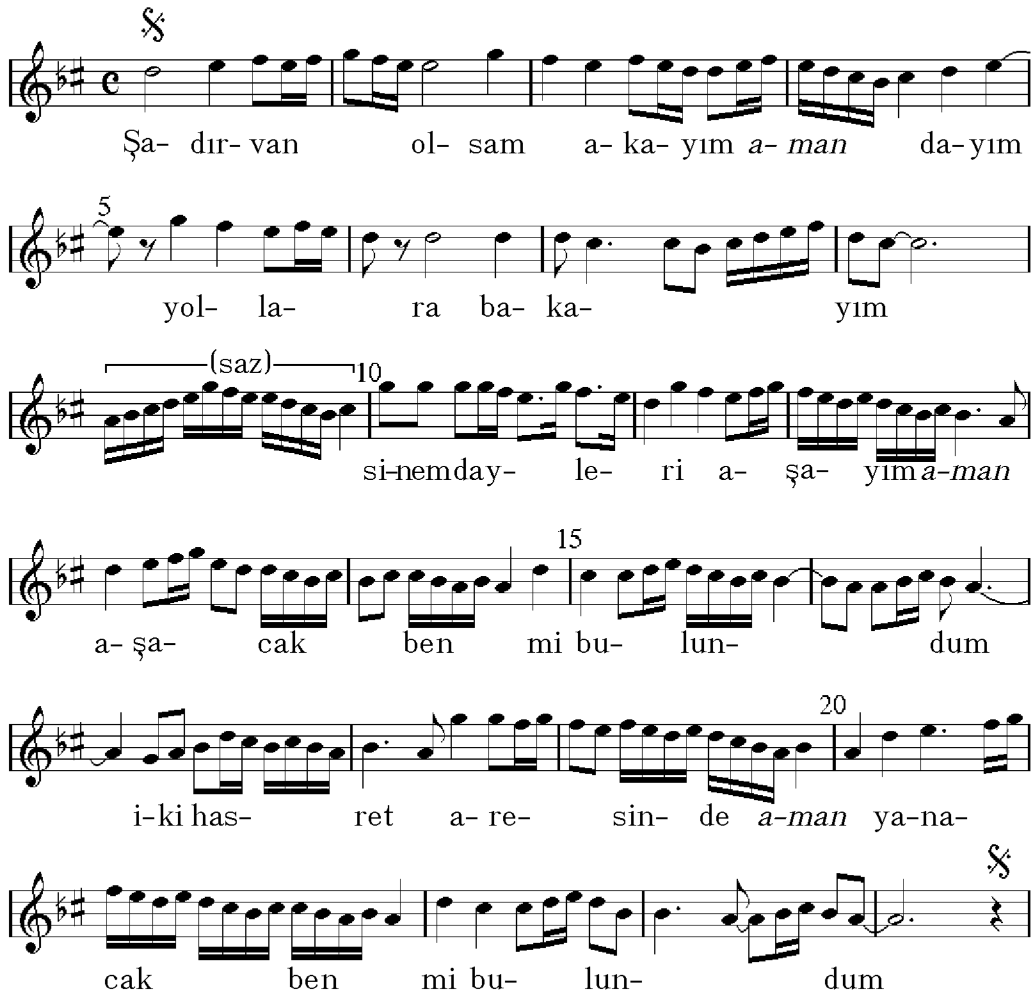
This text gives a general survey of the subject of my symposium paper of 16 December 1992 which could not be treated completely within the available time. Metric and modal shifting processes are especially interesting in music of those regions of the world where many different meters and modes are used alongside each other in folk practice as well as in traditional classical performances. In this respect the Balkans and the Near East show an exceptional musical richness. The following text will give you an idea of the different ways in which I am involved in questions rising from the measuring of time values and tone pitches as far as concerns the mentioned shifting processes such as they may appear from time to time, place to place, performance to performance or even within a performance. When I delivered my paper, performances and notations were supplied to the symposium participants. Some of the latter will be discussed now more fully and in detail.

Metric and modal shifting processes are often the result of creative contributions of members of a society who try to preserve and develop consciously or unconsciously the musical heritage of their culture. Nevertheless misunderstandings in the world of oral tradition appearing among less gifted local musicians and music lovers and even among collecting and transcribing musicologists may have a very damaging effect on the possibility of future survival of the musical culture concerned. In cases where the damage has already been done, the reconstruction of corrupted performances and notations becomes therefore very important. In this respect I offer a folksong (to be found in a collection of folksongs of the Balkan Turks[1]) which I reconstructed, a very interesting case, because apparently both its performance, collected and recorded by M. Ramiz, and his transcription of it are corrupted, but can nevertheless be reconstructed.

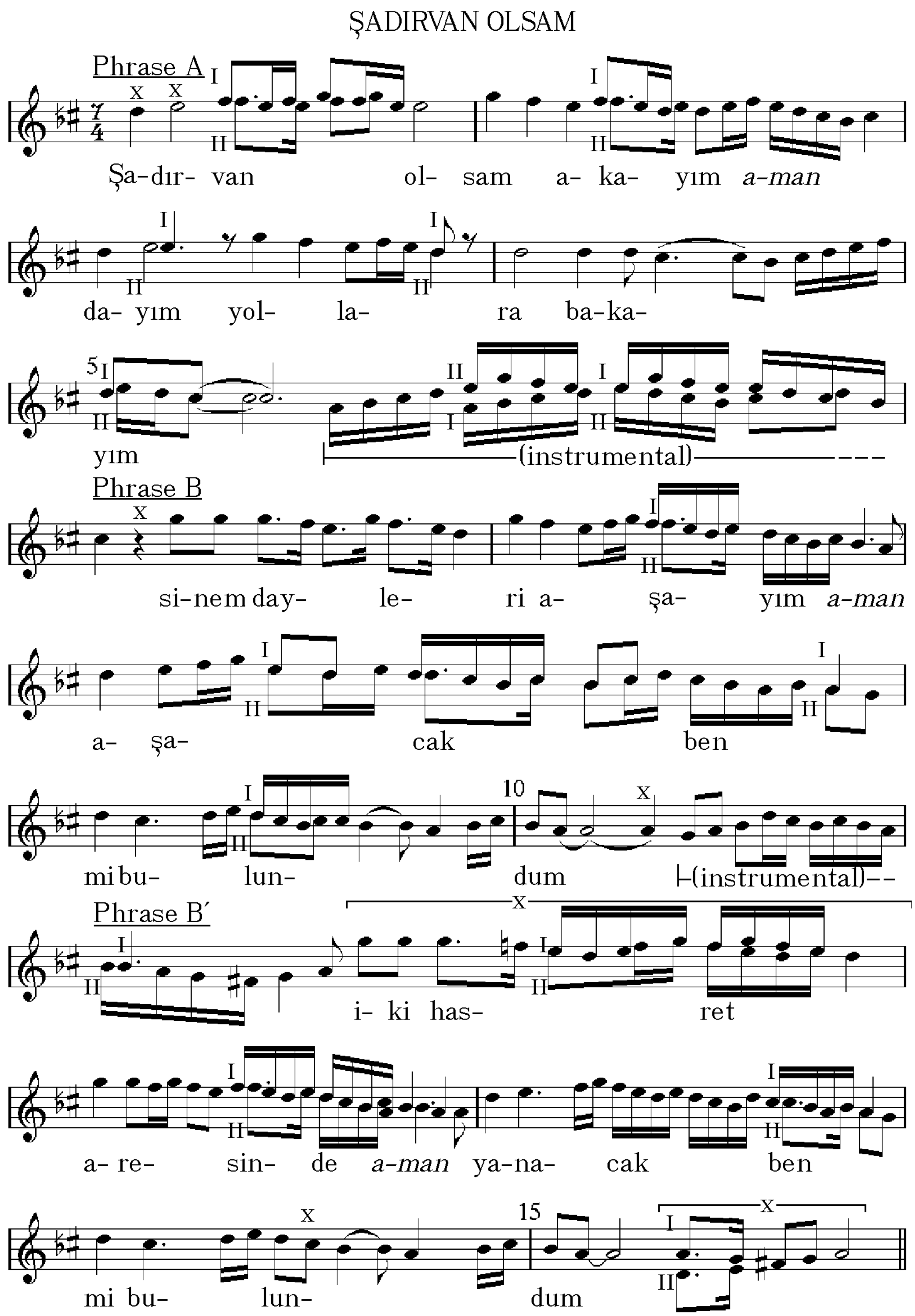
Ex.1 gives the song as transcribed by M. Ramiz; **Ex.2** gives my reconstruction of it (I) and by way of comparison my final arrangement as performed by my ensemble *Čalgija* (II). On analysing the transcription it seems unavoidable to conclude that Ramiz himself must have felt either that his transcription of the song in $4/4$ meter was wrong, or that his recorded version of it was hopelessly and irreparably corrupt. Most probably his informant was a singer accompanying himself on a plucked instrument (*saz* or *sharki*) but a wrong accompaniment on percussion in $4/4$, though improbable, cannot be excluded totally: in Istanbul I once heard two non-professional gypsy musicians performing a well known classical Turkish piece in $10/8$ meter[2] (3+2+2+3). The violinist played in $10/8$ but the percussionist accompanied him persistently in $4/4$, so their performance became an unexpected polymetric happening. Ramiz' transcription in $4/4$ results in a totally idiotic syncopated placing of the word syllables. The placing alone of the words *mi bulundum* – which appear twice in the first stanza, take an identical position in verse lines 4 and 6 and moreover cover both times the identical musical phrase – is different in relation to the metric frame. Ramiz must have seen this but was unable to find a metric alternative, most probably due to a lack of knowledge of syllable placing in the case of anacruses[3]. This lack was apparently shared by his informant musician.

For an explanation, let us turn to my reconstruction of the song in $7/4$ meter. The song's build becomes as surveyable as the placing of the verse lines and syllables are logical. The song consists of three musical five-bar phrases ABB′, each covering two verse lines of two and three bars, respectively. Each stanza consists of 4+2 verse lines with rhyme scheme [aaaxbx]. The verse lines with [ax] and [bx] rhyme cover musical phrase B and its modified repetition B′. In the song a pair of verse lines of eight syllables each is divided into four groups of four syllables which are distributed over the the musical five-bar phrase so: (4+ 4)+ [4+ (3+ 1)]. Each group of two verse lines is separated from the next one by a short dance-like instrumental interjection which is contained in the fifth bar. Only at the end of the song is this interlude omitted. The separation between the two verse lines of each group is effected by the insertion of the word *aman*, an emotional exclamation, at the end of the second bar of each musical phrase. Usually each group of four syllables gets the beat values 1+2+2+2 or 2+1+2+2.

Ex.1 – Old Turkish urban folk song from Skopje, transcribed and arranged by M.Ramiz

ŞADIRVAN OLSAM

I. Şadırvan olsam akayım *aman*
Dayım yollara bakayım
Sinem dayleri aşayım *aman*
Aşacak ben mi bulundum
İki hasret aresinde *aman*
Yanacak ben mi bulundum

II. Bak şu feleğin oynuna *aman*
Ak gül daldırmış koynuna
Menekşe takmış boynuna *aman*
Korkacak ben mi bulundum
Eşim dostun aresinde *aman*
Yanacak ben mi bulundum

Ex.2 – Reconstruction (I) of song on left and arrangement for performance (II), both by W. Swets, shown separately only where divergent

There are exceptions to this:

(1) in the second bar of each phrase where *aman* is inserted the beat structure becomes 2+1 (or 1+2)+1+$\frac{3}{4}$+[aman:]$\frac{1}{4}$+2,

(2) in bars 4 and 5 it becomes 1+2 (or 2+1)+4+3+[instrumental:]4,

(3) in the first bar of phrases B and B′ where the first two beats hold the end of the previous instrumental interlude thus creating a vocal anacrusis in which the time value of the two first syllables of the group are squeezed to the value of a half beat each, thus: 2[instrumental]+$\frac{1}{2}$+$\frac{1}{2}$+2+2.

Had Ramiz recognised the shortening of the first two syllables as pointing to an anacrusis of 5 beats he could have discovered the 7/4 meter as fitting the song. But besides transcribers, also the local performers of folksongs often have difficulties with anacruses, more especially when they sing solo without instrumental accompaniment or when they themselves accompany their singing.

For instance in Balkan and Turkish folksongs in 9/8 meter with pattern 2+2+2+3 beats at the beginning of a verse line anacruses of 7 beats (2+2+3) often appear. The four syllable setting 2+2+2+3 then becomes 1+1+2+3. Now solo performing village musicians sometimes tend to “forget” the previous 2 beats as a rest or instrumental filling, with the result that in their 9/8 meter song performances there suddenly appear isolated bars of 7/8. Even when such musicians do have some notion of a “break” which should precede anacruses they usually give it an arbitrary duration, for instance one or three beats instead of two. This can happen in this way because at such breaks the singer cannot avail of metrically abstract feeling and becomes disoriented as soon as his concrete metric feeling is not reflected in the portioning off of time in sung syllables or dance-steps. In a positive sense such arbitrary breaks might even give the musician a feeling of ad libitum freedom. During one of my field recording trips a Macedonian singer once asked me ‘How shall I sing my song for you, as a dance song or “just free”?’ As a dance song it had a 7/16 (3+2+2) meter, whereas as a “free” song it showed a far more complicated, apparently locally undanceable 19/16! Of course in the Balkans and Anatolia there are many really free, i.e. ametric songs in which the sung words and verses structure the rubato melody.

To end this discourse on anacrusis practice it should however be stressed that the better professional Turkish and Balkan folk musicians are and the more they follow the example of Turkish art musicians the better they will treat anacruses. They are very popular especially at the beginning of vocal-instrumental songs, because participants do not have to start together. The percussionist usually plays the first beat. In any case one can now understand why the recording of our Turkish song as rendered by Ramiz shows a metrical performance with free breaks even without having actually heard the original. Ramiz appears to be a very reliable transcriber as far as the duration of the notes is concerned. Though he was aware of the nonsensical result of his transcription he never was driven to changing the note values and the place of the syllables according to what the singer must have "meant" in order to fit the song better to the supposed $^4/_4$ meter. This is proved by the fact that when I fitted the song to the true $^7/_4$ (with the exception of two places), I nowhere had to change or "adapt" a note duration – and just these two places marked "x" in bars 6 and 10, where I had to add a quaver, are situated in the above mentioned free break in relation to a following anacrusis. I did this, of course, to maintain the $^7/_4$ meter during the breaks.

Qualitatively the performance of the song on tape of Mr Ramiz cannot be described else than as mediocre and corrupted. I have reversed the durations of the two first notes of the song as transcribed by Ramiz and performed by his informant; from a metric point of view there was no need for this, but this was recommended by the mode of the song, makam *Uzzal*. Thus the [e] is emphasized as required in this makam, which has the fifth as dominant. The marked [c♯] in bar 14 was changed from the original [b♭] to improve the melodic flow. As many other so-called *Rumeli türküleri*, folksongs of the Balkan Turks, this song too shows by its melodic shape a pretty strong approach to the classical makam conception of traditional Turkish art music. The key signature of the song has been adopted from that music: the crossed flat [♭] lowers the [b] by a Pythagorean limma of 90 cents, the sharp raises the [c] according to the Turkish system by a limma, too. All other notes without accidentals represent the Pythagorean diatonic scale. Consequently the [c♯] of 384 cents sounds just a little lower than our equal-tempered one of 400 cents while the [b♭] of 114 cents is somewhat higher than the equal-tempered 100 cents.

According to the transcription of Ramiz the performance of the song on tape shows typical oriental melodic embellishments, which are, however, at some places too abundant and at other ones too rare. That is why I arranged the song by changing some embellishments in order to be performed thus by my ensemble *Čalgija*. The music example gives an opportunity to compare my reconstruction with my arrangement of the song. In my reconstruction one may see, marked with an [┌—x—┐], a melodic fragment of the song in bar 11 which is not present in the tape recording of Ramiz. In his transcribed version only after the words *iki hasret* the melody to which verse lines 5 and 6 are sung is a modified repetition of that of verse lines 3 and 4 (compare Ramiz bars 11–16 with bars 18–24). Moreover the "new" melodic beginning covering the words *iki hasret* (bars 16 and 17) is in contrast with the "old" one on the syllables *sinem dayle* (bars 10 and 11), connected to the repeated melodic section by a totally ridiculous anti-traditional jump of a minor seventh. This melodic fragment clearly belongs to the preceding and not to the following melodic section. Besides, the expected instrumental interjection at the end of verse line 4 is lacking in the version transcribed by Ramiz.

After all this it is not difficult to conclude that the melodic fragment covering the words *iki hasret* should be reserved for the instrumental interjection at the end of verse line 4 and further connected with the repetition in bar 11 covering the mentioned words of the melodic fragment to which in bar 6 the syllables *sinem dayle* were sung, modified similar to the way the continued melody in bars 12–14 shows a modified repetition of its counterpart in bars 7–9. This I did in my reconstruction, and as a result the three phrases of the song get an equal length of five $7/4$ bars each (see bars 6, 10 and 11 of my reconstruction) and moreover a near-identical placing of the syllables. Of course after verse line 6 an instrumental interjection is needed as well when the song is continued with the second stanza but it should, according to custom, be omitted at the end of the song. Because this interjection was absent in the performance transcribed by Ramiz I simply had to add it myself in the traditional style. The $7/4$ meter is not a frequent feature in folksongs of the Balkan Turks and may possibly be considered as a local Macedonian or Albanian influence, not improbable at all in the Macedonian city of Skopje – the home of this song – which houses a considerable Albanian minority.

So much for this reconstruction. I have made a large number of such reconstructions in the course of my life. By giving this special example I wanted to show how even far from ideal musical performances and in some respect wrong transcriptions can contribute to successful repair work. Therefore transcribing of folks songs and orally transmitted traditional art music should be continued wherever it exists and be undertaken wherever it is not yet present. There lie the hearts of musicians serving an ethnomusicology unenslaved by anthropology, thus not becoming a breeding place of articles producing articles written by musically less involved, less gifted scientists describing thoughts about music they understand more often by reading or talking words and by watching musicians perform than by analytically listening to the music itself. Where necessarily locally adapted, our Western musical notation offers probably the best equipment for excellent prescriptive transcriptions much more detailed as concerns the embellishments than the schematic, sloppily printed one of Ramiz in which even ties were forgotten (but included here).

Both studying music from transcriptions and teaching by or learning from an Indian guru have their limits. But undoubtedly recordings of good raga performances and their transcriptions, combined with methodical exercises in oral tradition and – as far as they exist – good instruction books on Indian musical practice could speed up the learning process considerably, compared with the many years spent with a guru for which one may have no time. Before I made my first fieldwork trip to Yugoslav Macedonia in 1961, I had by way of preparation and in order to develop a critical musical taste already collected many recordings, studied thoroughly many folk-song and dance-tune collections of the region, and learned the language in a basic form. I have always persisted without any regret in this method which enabled me to discover really good folk and art musicians. Our first music examples show how important the build of verse lines and the grouping of words and syllables are for the shifting process of correcting a wrong meter into a right one. But they are even more important in so far as they set out the course of factual and possible but as yet undiscovered metric shifting in different versions of one song with the same text and the same melody.

If for example a song exists in meters A, B and C, and a second song with the same verse type in meters C, D and E, and many other songs in meters A, B, C, D and E sharing the same verse type and syllable grouping show an identical syllable placing in the melody, it is safe to say that this verse type creates a path of shifting musical meters in which the meters A, B, C, D and E each occupy a special position. Thus for example the eight-syllable verse grouped as 4+4 can be found in Macedonia and Bulgaria in

4/4	(1+1+1+1)+(1+1+1+1),	9/8	(2+2+2+3)+(2+2+2+3),
5/8	(1+1+1+2)+(1+1+1+2),	11/8	(2+2+3+4)+(2+2+3+4),
7/8	(2+2+1+2)+(2+2+1+2),	11/8	(3+3+2+3)+(3+3+2+3),
13/16	(4+4+2+3)+(4+4+2+3),	12/8	(1+1+1+2)+(2+2+1+2) etc.,

whereas the eight-syllable verse with subdivision 5+3 can be met in the same countries for instance in

8/8	(1+1+1+1+1)+(1+1+1),	4/4	$(\frac{1}{2}+1+\frac{1}{2}+1+1)+(1+1+2)$,
5/16	(2+2+1+2+3)+(2+3+5),	7/16	(3+2+2+3+4)+(3+4+7),
9/8	(2+2+1+2+2)+(2+3+4),	7/8	(2+1+1+2+1)+(2+2+3),
11/8	(3+2+2+2+2)+(3+4+4),	12/8	(3+2+2+3+2)+(3+4+5),
16/8	(2+2+1+2+2)+(2+1+4),	22/16	(2+2+2+3+4)+(2+3+4) etc.

In order to get an idea of how such metric shifting processes actually feel in speech one may try them out on two English sentences: “Never wake up sleeping persons” (4+4) and “Grandfather used to sleep so long” (5+3 syllables). By doing so it will become moreover evident that the English language – as many others – fits complicated meters like the above mentioned very well. The duration of the syllables can apparently be prolonged or shortened without a damaging effect on the diction if only the fixed grouping of the syllables as marked by the accented ones is respected. However in Turkish traditional art music which knows some seventy different musical meters called *usul*, the setting of poetry to music is decided by the difference between short and long syllables. In Turkish-Ottoman poetry the verse lines show predominantly fixed prosodic types. As in the above mentioned folk music it happens in Turkish traditional art music that the same text is set to different *usul*, but at the same time to different compositions. The word *usul* covers more than our Western concept of musical meter. It is a schematic rhythmic periodic type in which each period shows the same fixed order of time segments of different duration, limited by heavy and/or light beats.

An *usul* can vary from 2 short to 88 long time units; its concept mediates between a musical meter (short *usul*) or a group of musical meters (long *usul*) on the one hand and a rhythm worked out in detail on the other as performed during a composition or melodic improvisation. Both composed melody and sung prosody have to manifest the *usul* in their macro- and micro proportions, the former by means of the melodic course as prescribed by the makam (mode), the latter by way of syllable placing in the music.

There are many prosodic types, all of which the Turks adopted from classical Arab poetry. Each type consists of a fixed number of selected prosodic meters in a fixed order. Each meter consists of two to five syllables, long and short, which get a fixed position and order. When in Turkish traditional art music a poem is set to music, it is the prosodic type of its verse lines which determines the musical meters out of which the composer has to make his choice. Each prosodic type can be set to one or more musical meters and vice versa, each musical meter can be used for one or more prosodical types. Thus many combinations are possible, but limitations do exist: a prosodic type cannot be (or till now has not been) set in every musical meter and usually has a more or less fixed setting in a chosen musical meter. Vice versa, a musical meter cannot use (or has till now not used) all prosodic types. In the musical settings of the prosodic types the short syllables get a recognizable, usually strictly respected short duration while the duration of the long syllables may vary from "shortish" (i.e. longer than short) to long or very long. A more detailed article about prosody in traditional Turkish art music is in preparation.

Returning to folk music, one special type of metric shifting should still be mentioned, i.e. the creation of a "new" meter because of the misunderstanding of an anacrusis. For example in songs with a 7/8 (2+2+3) or 9/8 meter (2+2+2+3) and with eight-syllable verses grouped in 4+4 syllables in which every odd-numbered bar is an anacrusis one gets for each pair of bars the syllable placing

(a) in 7/8: (2[rest]+1+1+1+2)+(2+2+1+2) and

(b) in 9/8: (2[rest]+1+1+2+3)+(2+2+2+3).

If in this case singers not understanding anacruses omit the rests, they unconsciously create two new metres, as has in fact happened:

12/8 (2+3)+(2+2+3) and 16/8 (2+2+3)+(2+2+2+3).

Generally spoken, shifting processes are guided by dance steps in instrumentally performed dance music in a similar way to the syllable placing in songs, but indirectly here too the syllable placing often forms the background as the example shows, because many dance tunes are instrumental performances of songs of which everybody knows the words. So in most Balkan and Anatolian dances there is a close relationship between text setting and dance steps.

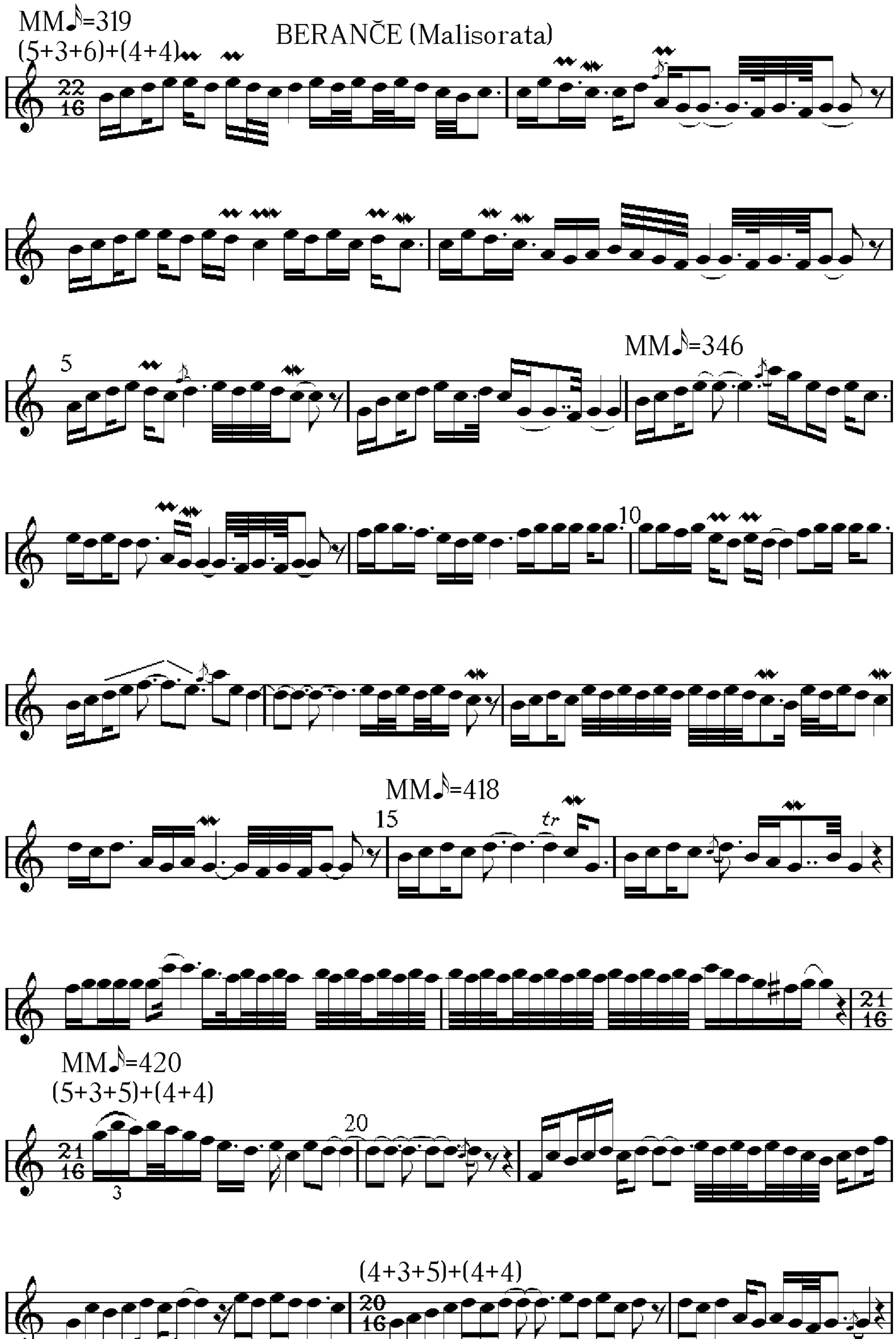
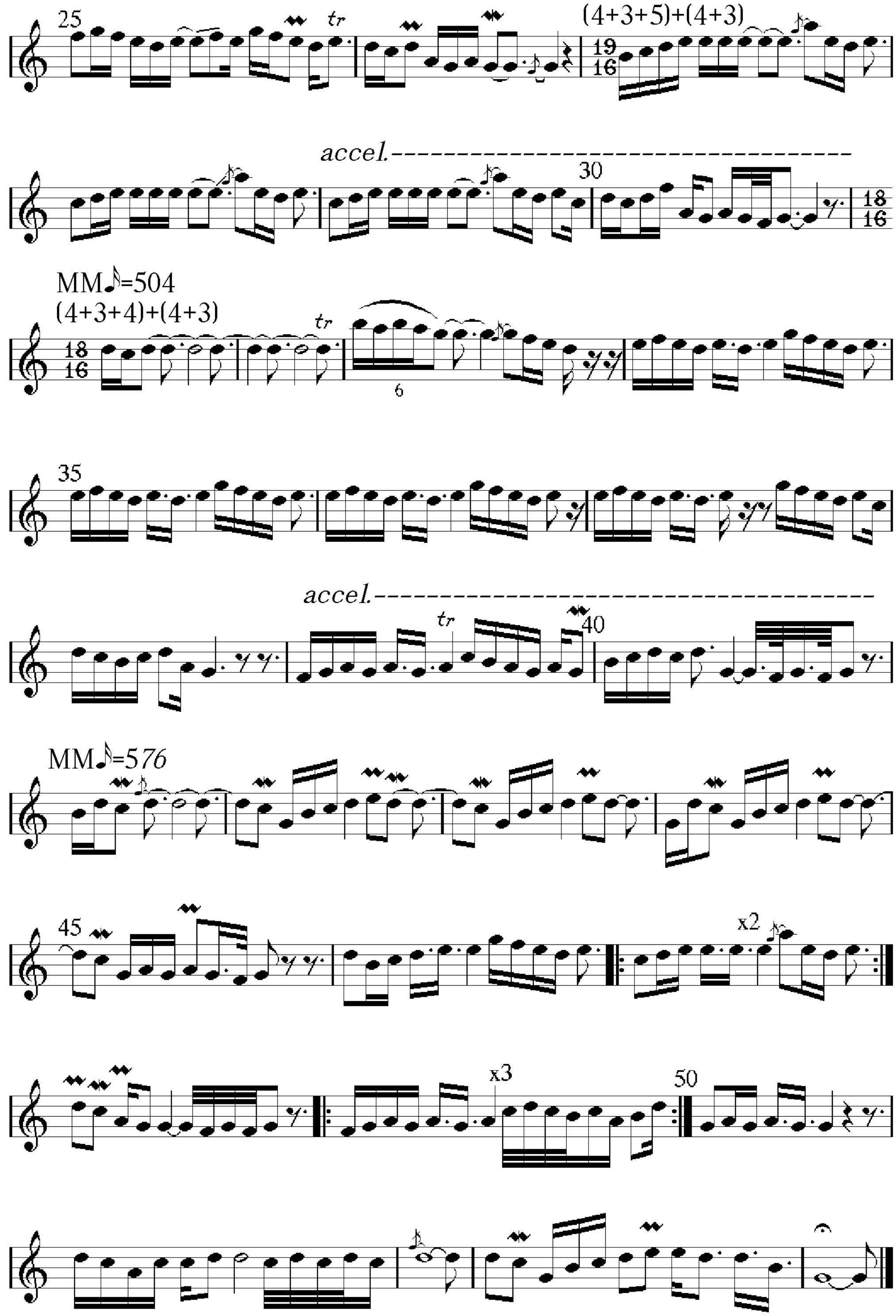
Shifting processes within one piece of music where the same melody later gets a different meter are usually more isolated phenomena, occurring for example in Transylvania, where for instance the slow part of a dance may be performed in $^{10}/_{16}$ (2+2+3+3) and the fast part in $^{4}/_{8}$ or $^{8}/_{16}$ (2+2+2+2) and also in Eastern Turkey where some dances may start in a slow $^{4}/_{4}$ meter and finish in a fast $^{6}/_{8}$, $^{6}/_{16}$ (2+1+1+2) or $^{10}/_{16}$ meter (3+2+2+3). However as an extremely well developed tricky heroic attribute of male dancing, such shifting processes are a characteristic and rich phenomenon in the Western part of Macedonia of former Yugoslavia and Greece. Dances of this type are characterized by the fact that they begin slowly and gradually build up to a speedy conclusion.

There are two possible ways to achieve this acceleration: (a) the meter of the slow beginning is maintained until the fast conclusion or (b) the initial meter, seemingly bred from an ametric chaos, changes by gradually diminishing the number of time units of the metric pattern – which in itself gives an accelerating effect and is used alongside the actual acceleration by shortening the above mentioned time units – only to be stabilized at the fast conclusion. Because the technique of metric shortening is a matter of oral tradition, which includes at least partly unconscious proceedings, local folk musicians using this technique cannot explain what they are actually doing in symbols adopted from occidental musical notation. Moreover when and how exactly the meter of a Macedonian dance is shortened differs from time to time and place to place and depends mainly on the spontaneous interaction between musicians and dancers where both may take the initiative. Professional analysis by experienced ethnomusicologists is in this case indispensable.

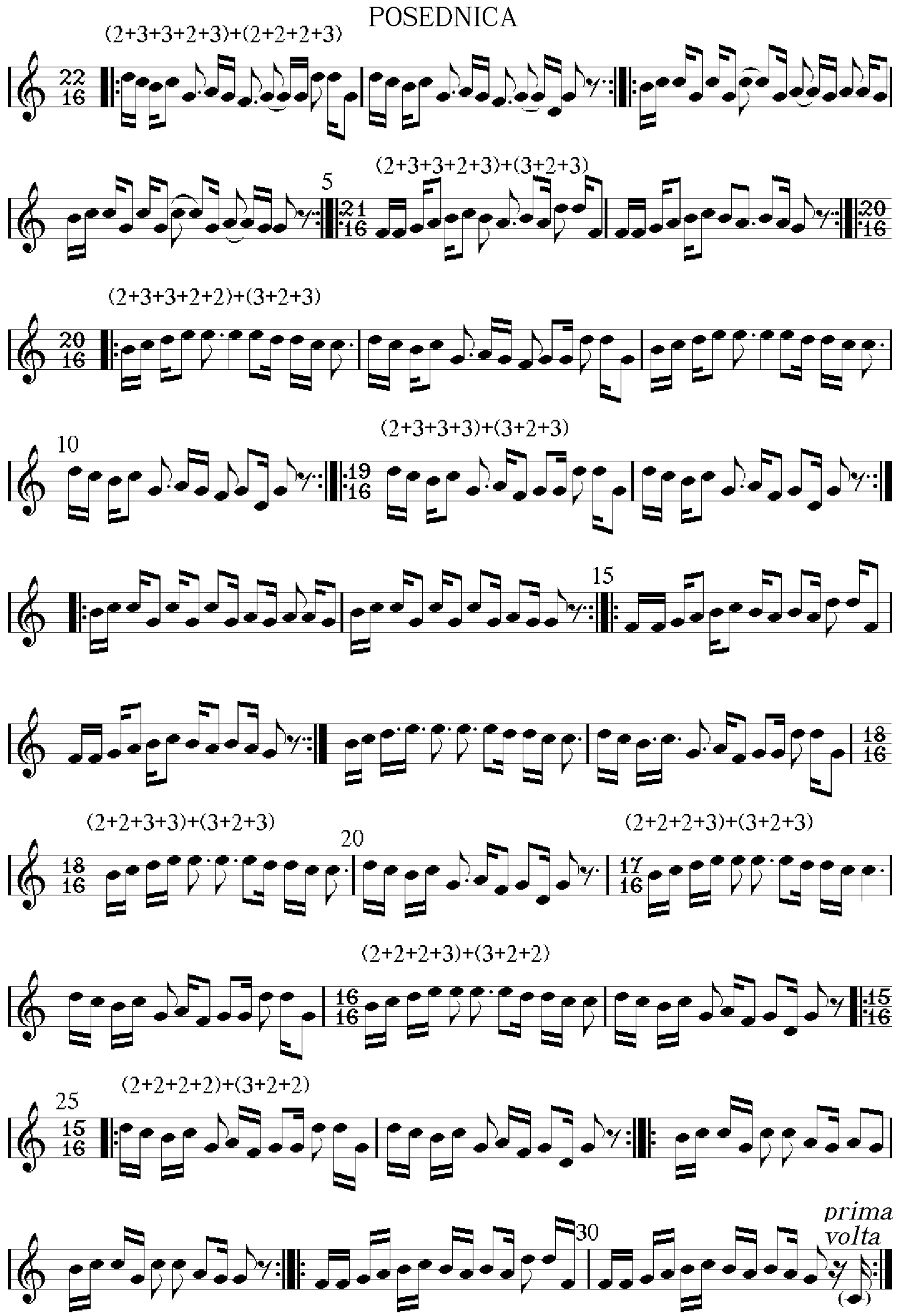
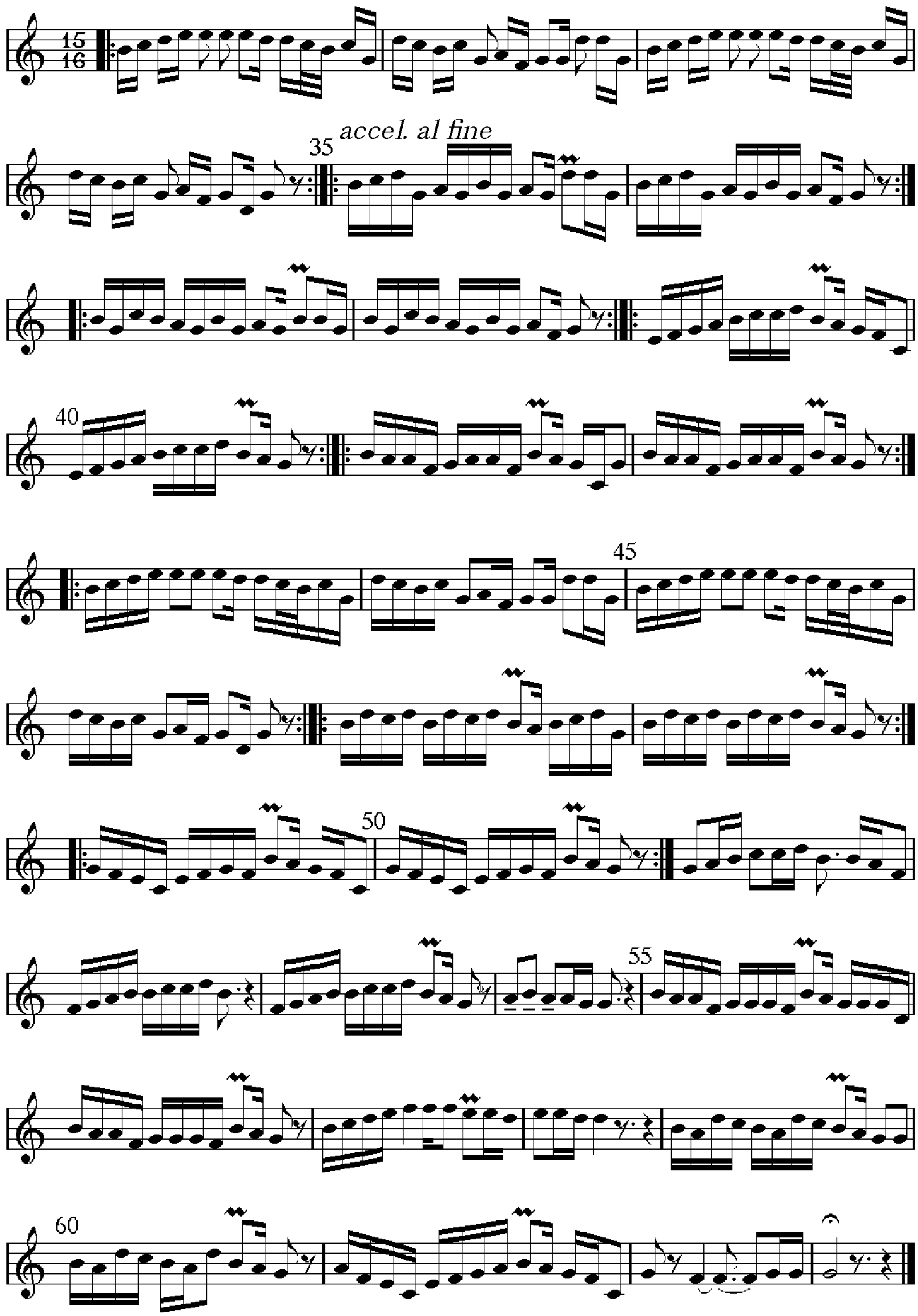
It is my personal discovery that Macedonian heroic male dances which seem to develop from a chaotic rubato beginning to a metric conclusion often employ a consequent structuring of time which may be very complicated but is in any case remote from the voluntary character of a rubato. This may be seen in **Ex. 3** (next page), showing my transcription of the Macedonian folk dance melody *Berančе*, performed on two shawms (*zurna*) and a large drum (*tapan*) and as recorded on a Yugoslav LP, Radiotelevizija Beograd (RTB – LP 1360 side B, track 4) and containing a gradual shrinking from ^{22}/16 to ^{18}/16 meter: 5+3+6+4+4 ➛ 5+3+$\underline{5}$+4+4 ➛ $\underline{4}$+3+5+4+4 ➛ 4+3+5+4+$\underline{3}$ ➛ 4+3+$\underline{4}$+4+3 (see bars 1, 19, 23, 27 and 31). A further shrinking to ^{17}/16 (4+3+$\underline{3}$+4+3) is conceivable but does not take place here. **Ex. 4** (three pages on) shows a Slavic Macedonian dance from Greece named *Posednica* to which I myself applied – with good reason – the metric shrinking procedure as may be heard in a performance by my ensemble *Čalgija* on a recently released CD (PAN 2007 CD, track 20). The main reason is that several other dances of the region sometimes show metric shrinking and sometimes do not, while furthermore phrases A, B and D of the main melody of *Posednica* show a close relationship with the melody of *Berančе*. For more detailed information about shrinking meters see the booklet of the mentioned CD; for recorded shifting processes see an article I wrote in 1988[4].

As with metric shifting processes, modal shifts also appear from time to time and place to place. For example in the Balkan and Near Eastern modes using the scale [d e– f g a b–/b♭ c d] (in Turkey transposed up to [a b– c d e f♯–/f g a]), the lowering of the [e–] and [b–] in the Balkans and in Western Turkey is generally spoken less than in Eastern Turkey, Egypt, Syria, Iraq and finally in Iran where it is most prominent. For centuries there has been much dispute among theorists and musicians about the exact and "right" pitches. Intervals to which one is locally accustomed seem to settle the matter. On the other hand, traditional pitches must be as precisely reproduceable and reperformable as possible in a musical culture, for which theory can give a useful handhold. Moreover if a musical culture, as for example that of Turkish traditional art music, avails of more than thirty pitches used in practice within the central octave and all these pitches have a meaningful function in the development of melody, it is far less important if one of the intervals possible within these pitches has

Ex.3 – Shrinking metres: a Macedonian Folk Dance, transcribed by W. Swets




25
(4+3+5)+(4+3)
accel.
30
MM♪=504
(4+3+4)+(4+3)
35
accel.
40
MM♪=576
45
x2
x3
50

Ex.4 – More metric shrinking: a Slavic Macedonian song from Greece


15
16
35
accel. al fine
40
45
50
55
60

a frequency ratio of 2048:2187 (114 cents) instead of 15:16 (112 cents) – only a very slight difference – than when Westernization in the Balkans forces Turkish melodies into the frame of the only twelve tones of our equal temperament and at the same time annihilates intervals used in the local and regional folk music of the Balkan countries.

For the continuation of Near Eastern musical culture the growing popularity of equal-tempered occidental musical instruments like the accordeon and the conventional synthesizer constitutes a great danger. On the other hand even for well trained Western singers and performers of a fretless string instrument like the violin, who are fans of Near Eastern music, it is nearly impossible to get a hold on its intervals and to develop a reliable self-control for a proper intonation without years of previous analytical listening to recordings of that music and learning to recognize its modes, unless they are able and have time to study on location. Moreover, even performing on such instruments like the fretted Turkish *tanbur* and the string-retunable Turkish *kanun* which have all needed Turkish intervals as “preset” tones (provided of course that they are tuned well) is not something which can be learned soon and easily. The Japanese firm Yamaha has built a playable synthesizer “Arabic style” which combines in the octave ten equal-tempered tones with an [e] and a [b] which can – only simultaneously – be lowered ad libitum. Such a device is hardly workable for the performance of very simple oriental popular and folk-tunes and not at all sufficient for a good performance of refined Turkish and Arabian art music. The only synthesizers which offer conditions for programming microtunings, enabling us to perform Turkish, Arabic and Persian art music is the Yamaha DX7-II and the module Yamaha TX802 in combination for example with the Yamaha synthesizer DS55[5].

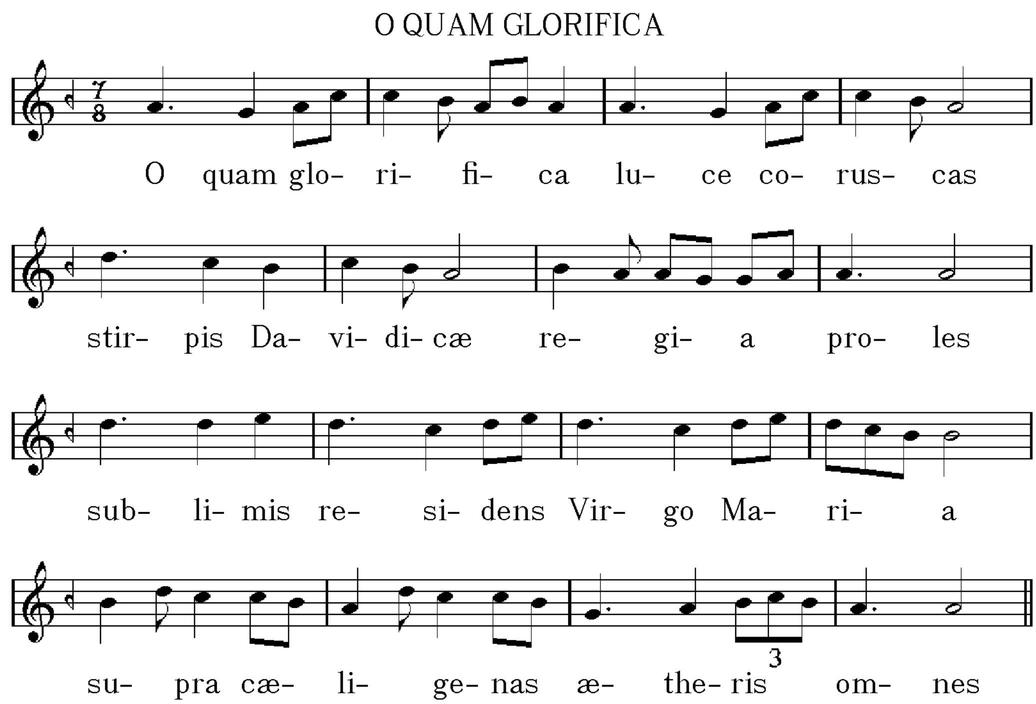
Thanks to the possibility of combining several microtunings one can produce – by strictly monophonic playing on this synthesizer – the double-stop bowing technique of the *kemenŎe* or *Pondiaki lyra*, a fiddle of the Eastern Black Sea region. This technique, difficult for fiddlers, is relatively easy on the synthesizer as demonstrated during the symposium when I accompanied the Dutch singer Roel Sluis in a Pontic Greek folk song.

During recent years I have developed several tuning systems. In order to make them functional I had not only to take care of the presence of all the pitches needed, but also to take into account the modal theory of oriental makams and its application in the performance of compositions and improvisation, in short, instrumental behaviour in oriental music. I designed the mentioned tuning systems in order (a) to provide the occidental music student with an easy way to get systematically acquainted with and accustomed to all Near-Eastern pitches and intervals, (b) to provide him at the same time with an instrument of which the monophonic use, though here and there very uncommon, strange and at first seemingly illogical, poses little difficulty as far as concerns virtuosity, (c) to supply an example to oriental musicians who destroy their own traditional musical culture with their equal-tempered Western instruments and (d) to add where possible, meaningful and desirable extra instrumental timbres to the already existing beautiful timbres of traditional oriental instruments. The DS55[6] ranges five octaves from [c1] to [c6], whereby [a3] has a frequency of 440 Hertz. By means of the TX802 all 61 keys of the DS55 can be tuned individually to any desired pitch via microtuning in micro-units of a 1024th of an octave (1.171875 cents). A designed tuning system of keys can be shifted as a whole to any desired pitch via transposition in half-tones and mastertuning in micro-units. This is very important because in this way the performer does not need to effect the transposition himself and does not need to add extra pitches to the tonal system he has designed in order to make transposition possible.

All tuning systems which I designed – theoretical and practical – have in common that the keyboard is divided into three sections. The theoretical systems allow playing and modulating to all makams but have more auxiliary keys and a smaller main section which is, however, sufficient for strictly monophonic playing. Some of the makams have a more peculiar fingering. The practical tuning systems are oriented towards special makams and make possible local modulations from these makams to other ones but do not allow playing in all makams. They have however a wider main section in which playing heterophonically in octaves is possible.

While keeping a tuning system intact it is possible to move tones from auxiliary keys to keys of the main section and to store the replaced tones of the middle section in the auxiliary keys concerned in order to facilitate the playing in a makam with a difficult fingering. But one should keep in mind that when one performs a makam in a thus adapted key setting, playing in another formerly easy makam now becomes more difficult. Also while keeping a tuning system intact it is possible to change in detail the tone frequency of the present and needed pitches according to some theory or to one's own taste. Thus my tuning systems do not interfere in the discussion about "right" or "wrong" intervals, but simply give a frame in which the desired number of tones within the octave get a placing which enables their maximally comfortable practical use in performance. In any case many modal shifting processes have now been made comparably audible by means of these tuning systems.

Metric and modal shifting processes have also taken place during the long period between antiquity and modern times. Nowadays we hear so-called Gregorian Plainchant of the Roman Catholic Church performed in equal temperament which certainly did not exist in antiquity. Christian Plainchant had its cradle of course in the Near East. Though composing of new sacred music went on during the first thousand years after Christ and much of what we now know of Gregorian chant stems from after the year 800, it is clear that since the beginnings of Christianity a need was felt for preserving the "identity", the old style of Christian singing, the more so, because of its function in validating the celebration of a mass. So there is, in my opinion, nothing strange in the fact that in many Gregorian songs the melodic course is much related to that of oriental makams. A characteristic occidental type of melodic architecture only came to existence when polyphony, homophony and harmony became deeply rooted in European music. At that time the European tonal systems also emerged. If, however, the intervals of oriental makams are applied to Gregorian chant – Byzantine Greek ecclesiastical song still preserves similar intervals – depending on its melodic course and its final tone both Turks and Arabs will immediately recognize that chant if so performed as related to their own music. This certainly would not be the case with a typical European song like *Silent Night*.

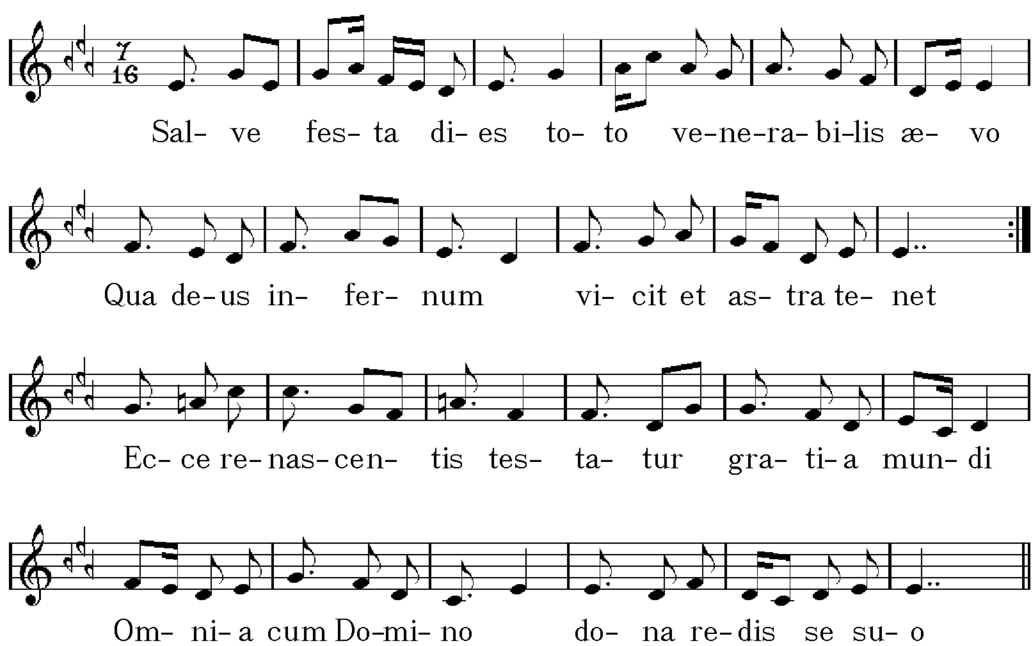
Ex.5 – A *Liber Usualis* hymn set in 7/8 and quasi in makam *Uşşak* by W. Swets

Ex.5 shows an ancient hymn *O quam glorifica* in the second ecclesiastical mode (*Liber Usualis* p. 1864) notated with a major second lowered by two commas[7] as if it were in the Turkish makam *Uşşak* (pronounced "ush-shak") and in 7/8 meter as it was performed during the symposium. The Greek scholar Thrasyboulos Georgiades has very convincingly made clear that the classical hexameters of Homer must have been sung in a meter of seven beats (3+2+2). The Greek theorist Aristoxenos described a special verse meter "long, short, short" with time relation 3:2:2, named *alogos pous*, six of which were arranged to form a Homeric hexameter of six bars of 7/8. This meter must have been very popular because elsewhere it was called *kyklios alogos*, meaning *alogos* of the circle dance. Georgiades states that nowadays in the region of Greece which has remained most purely Greek, viz. the Peloponesian peninsula, a dance in 7/8 meter (3+2+2) of high status still survives. It always opens village feasts and evokes feelings of national pride. Its movements are of an archaic nature as seen from classical vase paintings. About one-tenth of the song melodies to this dance still appear to have six-bar melodic phrases. The tempo, however, is too slow for

singing Homeric verses to. Georgiades believes that the slowing down of the tempo comes from the Greeks' centuries-long sufferings under Turkish occupation. This is however highly improbable because for example the Bulgarians lived even longer under Turkish domination but yet kept their fast dancing. Whatever may be the case, in Slavic Macedonia songs survive in 7/16 meter with six-bar phrases. Even if this was an originally Greek phenomenon it is not unusual that it was forgotten in Greece and lived on elsewhere. The fez, originally a Christian hat, now survives as a typical Muslim hat.

I conclude this survey of shifting processes with the Gregorian hymn *Salve festa dies*, remetricised in 7/16. In its text, written by the VIth century poet-bishop Venantius Fortunatus of Poitiers, all odd-numbered first lines are in hexameter, whereas the even ones represent the related pentameter [–⏑⏑–⏑⏑–/–⏑⏑–⏑⏑–]. In order to show the affinity of the fourth ecclesiastical mode with the Turkish makam *segah* I gave my notation of this hymn the key-signature of that makam (see **Ex.6** – [♮]=here a lowering by one comma[7]).

Ex.6 - Another remetricisation of a Gregorian hymn by W. Swets

SALVE FESTA DIES (beginning)



1 Aluş Nuş: Rumeli türküleri. Priştine (Priština, Kosovo, Yugoslavia) 1988; this collection of folk songs by Turks formerly and still living in the Balkans contains, like many other collections of Balkan and Turkish folk songs numerous especially metrically erroneous transcriptions, which I had to correct or reconstruct as in the example given here.

2 My metric nomenclature usually employs /4 for MM♩=75-150, /8 for ♪=150-300, /16 for 𝅘𝅥𝅯=300-600 etc.

3 The word "anacrusis" is here used to mean syllables following an initial rest in a bar and leading up to the first beat of the next bar.

4 Shifting processes between the metrical patterns of folkdance songs and tunes in the Balkans and Asia Minor - In: *Harmonie en perspectief* p. 333, Deventer 1988.

5 I now use (1996) a Roland A30 synthesizer

6 The Roland A30 (see [5] here) ranges six-and-a-half octaves [c0] to [g6], vastly widening the scope of microtonal usage.

7 The 53-tone-tempered comma, 22.6 cents

Programme of the Ratio Festival 1993

Saturday, April 3

18:30 Opening Concert
Nine Bells [1979] by Tom Johnson — Tom Johnson (walk, bells)
Il rei de spagna (The king of Spain) –
Improvisation on an anonymous cantus firmus [XVth Century]
Crawford Young (lute)
Randall Cook (vielle/gamba)
Madhyalay and *Drut Gat* in Raga Yaman (Tintal) Improvisation
Nandkishore Muley (santoor)
Debendra K. Chakraborty (tabla)
Maqam Nahawand – Improvisation — Omar Bashir (ud)
Ch'imhyangmu
(Dance in the Perfume of the Aloes) [1974] by Hwang Byung-ki
Inok Paek (kayagum)
...until... No.7 [1972/80] by Clarence Barlow
Ireen Thomas (lute)
Pingsha Luoyan (Wild Geese descending on the Sandbank) [1634]
Chen Leiji (qin)
Bandesh in Ragas Kamod and Desh [ca.1960] –
Improvisation on compositions of Radhika Mohan Maitra
Buddhadev Dasgupta (sarod)
Debendra K. Chakraborty (tabla)
Wasla Baghdadia (Baghdad Suite) [1986] by Julien Weiss
Julien Weiss (qanun)
Ma fin est mon commencement (My end is my beginning) –
Rondeau no.14 by Guillaume de Machaut [XIVth century]
Omnes

Sunday, April 4

11:00 Lecture by David Osbon (London/The Hague) –
A Resumé of the Ratio Symposium of December 1992
13:00 Workshop with Crawford Young (Basle), lute,
and Randall Cook (Basle), vielle and gamba
15:30 Workshop with Volker Abel (Darmstadt) –
Synthesis Performance and Analysis of Microtonal Structures
18:30 Concert by Ensemble *Sine Nomine* (The Hague): Early Music
20:00 Concert by Crawford Young (Basle), lute,
and Wendell Cook (Basle), vielle and gamba: Early Music

Monday, April 5

13:00 Workshop with Buddhadev Dasgupta (Calcutta), sarod
15:30 Workshop with Omar Bashir (Budapest), ud
18:30 Concert by Chen Leiji (Lyon), qin
20:00 Concert by Inok Paek (London), kayagum

Tuesday, April 6

11 00 Lecture by Trevor Wishart (York) –
Spectral transformation and rhythm
13:00 Workshop with Julien Weiss (Paris), qanun
15:30 Workshop with Nandkishore Muley (Beilm), santoor
18:30 Concert by Ananda Sukarlan (The Hague), piano,
Anne La Berge (Amsterdam), flute,
Gerard Bouwhuis (The Hague), piano,
Marantz Pianocorder, Stereo Tape: Contemporary Music
20:00 Concert by Kudsi Erguner (Paris), nay and
Nezih Uzel (Istanbul), voice and percussion

Wednesday, April 7

13:00 Workshop with Chen Leiji (Lyon), qin
15:30 Workshop with Inok Paek (London), kayagum
18:30 Concert by Julien Weiss (Paris), qanun
20:00 Concert by Omar Bashir (Budapest), ud

Thursday, April 8

11:00 Lecture-Demonstration by Debendra K. Chakraborty (Calcutta), tabla
Rhythmic Structures in North Indian Tabla Composition
13:00 Workshops with Anne LaBerge (Amsterdam), flute:
Playing in Microtonal Equal and Mixed Temperaments
and Howard Cohen (Herne, Westphalia), flute:
Playing in Integrated Just Intonation
15:30 Workshop with Kudsi Erguner (Paris), nay,
and Nezih Uzel (Istanbul), voice and percussion
18:30 Concert by Nandkishore Muley (Berlin), santoor,
and Debendra K. Chakraborty (Calcutta), tabla
20:00 Concert by Buddhadev Dasgupta (Calcutta), sarod,
and Debendra K. Chakraborty (Calcutta), tabla