THIRTY-ONE

The Journal of the Huygens-Fokker Foundation

Volume 1 | Summer 2009

Thirty-One

The Journal of the Huygens-Fokker Foundation

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EDITORIAL

Bob Gilmore

Welcome to the first issue of *Thirty-One: the Journal of the Huygens-Fokker Foundation.* In its new form this journal continues the work done by *Thirty One: a Microtonal Series*, edited by Ned McGowan, and, stretching further back, the Huygens-Fokker Yearbooks, which appeared irregularly every few years in the 1980s and 1990s and provide documentation of the activities and ideas of those working for, or with, the Huygens-Fokker Foundation in The Netherlands.

This journal is intended to be a forum for the Foundation's central aims: to promote interest in and knowledge about microtonality in its broadest sense and in all its aspects. As a particular idiosyncrasy, the journal will contain a greater-than-average focus on the system of 31-note equal temperament as explored in the mid-20th century by the Dutch scientist and musician Adriaan Daniël Fokker (1887-1972), following up the theoretical interests of the great scientist Christiaan Huygens (as described in his *Lettre touchant le cycle harmonique* of 1691 and his *Novus Cyclus Harmonicus* of 1724).

The use of microtonal pitch materials in contemporary composition has expanded enormously in recent decades. This journal welcomes and attempts to respond to that expansion of focus. This issue features texts by and about several composers, few if any of whom would identify themselves as "microtonalists", together with texts by theorists and musicologists who explicitly cite "microtonality" as one of the chief preoccupations of their ongoing research. As such we hope to start a debate into the multiplicity of viewpoints that underlie the usage of microtonality in theory and practice – indeed, even the semantics of the term itself – a debate which, we hope, will resonate through future issues of this journal.

The articles are collected into three main groups. In the Composition Forum, the Dutch composer Peter Adriaansz writes about the intricate processes that led him to begin using an expanded pitch vocabulary in his music in recent years; the English composer Frank Denyer writes about his particular interest in melodic, rather than harmonic, uses of microtonality; and the American composer and musicologist Kyle Gann offers an analysis of the *Suite for Microtonal Piano* by his teacher Ben Johnston. The Theory Forum offers an intriguing investigation into one aspect of 31-note equal temperament, with a paper by Giorgio Dillon and Riccardo Musenich on the Huygens comma; the authors discuss three different methods to select an equal temperament that best approximates meantone temperament, in the last of which (involving chains of pure thirds) they find an analogue of the Pythagorean comma that they propose be named the *Huygens comma*. In the Instrument Forum, Cees van der Poel describes work on the recently renovated Fokker organ, now again fully functional after several years of disuse.

Thirty-One is intended to be a home for interesting and original writing about microtonality in its broadest sense, covering the whole spectrum from detailed issues of theory or of instrumental practice to broad issues of aesthetics and history. We are happy to consider proposals for new articles – please contact the editor at thirty-one@huygens-fokker.org.

Amsterdam
July 2009

MICRO-ACTUALITIES

Sander Germanus

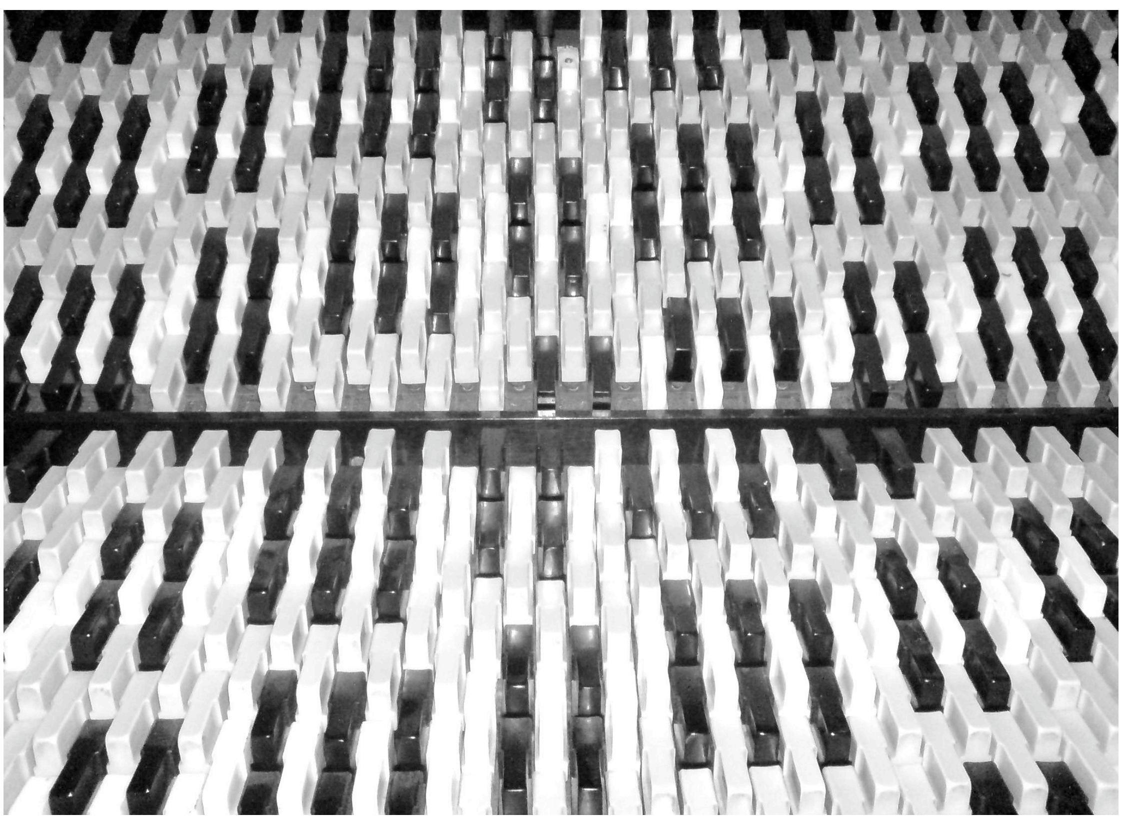
director, Huygens-Fokker Foundation

The year 2009 is a special year for the Huygens-Fokker Foundation. The renovation of the Fokker organ has recently been successfully completed by organ builders Pels & Van Leeuwen. Our unique 31-tone instrument has now a permanent place in the BAM Zaal of the Muziekgebouw aan ’t IJ in Amsterdam, making the return of the Fokker organ to the music world a fact. This memorable event was celebrated with an inaugural concert on May 17th 2009. A cross section of the concert offerings for the season 2009-2010 was performed, including highlights of the repertoire of the Fokker-organ by our own organist Joop van Goozen, improvisations by Guus Janssen, old music from baroque ensemble La Barca Leyden and a new composition by Danny de Graan, in which the newest technical possibilities of the Fokker organ, recently equipped with MIDI-In and MIDI-Out, could be heard.

Another important fact is that the new Huygens-Fokker website was launched on the internet at the beginning of 2009. Our old website was admittedly very extensive but insufficiently inviting to the reader, so it needed a replacement. The website of the Huygens-Fokker Foundation is now, after a complete renewal, even more informative than before. Since 2008 the Foundation has had a new domain name, namely www.huygens-fokker.org. New also is the Bohlen-Pierce site; after the foundation received the whole original Bohlen-Pierce documentation from Heinz Bohlen, we are hosting the new Bohlen-Pierce site on our new website: http://www.huygens-fokker.org/bpsite/index.html

To spread knowledge about microtonality, the Huygens-Fokker Foundation has, in its capacity as a centre for microtonal music, formulated several educational activities over the course of the past year, including study programs, workshops, lectures and educational projects for several age-groups. Also there is, after some time, a new publication of *Thirty-One,* our journal on microtonality, of which this, under editorial supervision of Bob Gilmore, is the first result.

The newly restored Fokker organ in its new location in the BAM-Zaal of the Muziekgebouw aan t'IJ, Amsterdam (above); and a close-up of its keyboard (below). Photos by Maarten Klijn.



MICRO-ACTUALITEITEN
Sander Germanus
directeur Stichting Huygens-Fokker

Het jaar 2009 is voor Stichting Huygens-Fokker een bijzonder jaar. De renovatie van het Fokker-orgel is onlangs door orgelbouwer Pels & Van Leeuwen succesvol voltooid. Ons unieke 31-toonsinstrument heeft vanaf heden een definitieve plaats in de BAM Zaal van het Muziekgebouw aan 't IJ te Amsterdam, waardoor de terugkeer van het Fokker-orgel in de muziekwereld een feit is geworden. Dit heuglijke gegeven is op 17 mei 2009 gevierd met een verrassend inwijdingsconcert. Er is een dwarsdoorsnede van het concertaanbod van seizoen 2009-2010 ten gehore gebracht, waaronder hoogtepunten uit het repertoire van het Fokker-orgel door onze vaste organist Joop van Goozen, improvisaties door Guus Janssen, oude muziek door barokensemble La Barca Leyden en een nieuwe compositie van Danny de Graan, waarin de nieuwste technische mogelijkheden van het Fokker-orgel, dat recentelijk van MIDI In en MIDI Out is voorzien, tot klinken zijn gebracht.

Een ander belangrijk feit dat vermeld dient te worden is dat de nieuwe Huygens-Fokker website begin 2009 gelanceerd is op internet. Onze oude website was weliswaar zeer uitgebreid maar onvoldoende uitnodigend om te lezen, en dus aan vervanging toe. De website van Stichting Huygens-Fokker is nu na een volledige vernieuwing nog informatiever geworden. Sinds 2008 heeft Huygens-Fokker ook een nieuwe domeinnaam, namelijk www.huygens-fokker.org . Nieuw is tevens de Bohlen-Pierce site. Nadat de stichting de gehele originele Bohlen-Pierce documentatie door Heinz Bohlen geschonken heeft gekregen, is ook de Bohlen-Pierce site ondergebracht op onze nieuwe website:
http://www.huygens-fokker.org/bpsite/index.html

Als centrum voor microtonale muziek heeft Stichting Huygens-Fokker verder het afgelopen jaar verscheidene activiteiten geformuleerd om kennis over microtonaliteit op diverse doelgroepen over te brengen, waaronder studieprogramma's, workshops, lezingen en educatieve projecten voor verschillende leeftijdsgroepen. Tevens is er na enige tijd weer een nieuwe uitgave van Thirty-One, ons tijdschrift over microtonaliteit, waarvan dit, onder redactie van Bob Gilmore, het eerste resultaat is.

How I Became a Convert: on the use of microtonality, tuning & overtone systems in my recent work

Peter Adriaansz

Introduction

Before I set out on a discussion of some of the ways microtonality features in my work, a brief, or maybe not so brief, introduction to my training seems to be called for. After all: being trained in the West, one never *automatically* veers in this direction. I would venture to say that it always implies a choice at some point. In my own case, this choice is a relatively recent one – no more than five years at the most. But as is frequently the case with choices of a fundamental nature, it turned out to be one from which there was little turning back once I had decided to cross that particular threshold. There is definitely a 'before' and an 'after'. The choice, moreover, turned out to have implications, which eventually touched on all domains of musical matter. The world of 'micro'-tonality, with its associations of a small, specialized professional field, in reality turned out to be a world of 'macro'-tonality. In this article I thus intend not only to discuss some of my working methods in varying degrees of detail, but to also touch on some of these broader implications, which both sparked it off and came as a result.

As with most composers trained in the West, my initial education was exclusively slanted towards composition with the twelve available pitches neatly formatted between one octave of the piano. For a relatively long time, this was my universe. Although I was aware of the existence of other systems, with two ethnomusicologists for parents and a fairly extensive knowledge of and love for non-western music, the area of further subdivisions however seemed excessively remote to me and essentially alien to the construction of most of the instruments I was asked to write for. Furthermore, I simply couldn't 'hear' it.

It seemed to me at the time that there were basically three approaches towards microtonality that one could choose from:

1) Microtonality in the form of imported oriental modes or scales;
2) Microtonality as a form of inflection;
3) Microtonality as a form of 'serial pitch-expansion'.

Though definitely sympathetic to the first of these directions, none of these possible approaches succeeded in convincing me entirely though, due to the fact that they were either a) entirely out of sync with the nature of the instruments they were mostly transported onto – resulting in a form of musical tourism to my ears; b) no more than a form of embellishment, or gesture – something which was already *non grata* to my compositional concerns; or c) when pasted onto highly expressionistic scores - as most of them were – too reminiscent of a teeth grindingly out-of-tune Schönberg, seemingly devised for no other reason than expansion for expansion's sake, but without any form of true audibility or inner necessity. All three angles, in my mind, basically constituted *horizontal* attitudes towards pitch – something that definitely piqued my interest, but never succeeded in interesting me sufficiently to pursue in my own work.

So, how *did* I become a convert?

Development 1/Renunciation 1

After finishing my studies in the early '90s, I initially embarked on a more-or-less conventional life as a freelance composer: writing on commission for ensembles and orchestras. The pieces from this period, though often deviant in their own particular way, I would still collectively classify as 'Eurocentric' in nature: implying, in this case, a certain emphasis on 'meaning', with pitch as the main vehicle of conveyance. A key element already present in these early works however was a total absence of 'development' in the conventional sense – something which, I had already discovered, was essentially alien to my nature.

Having never wholeheartedly embraced the linear, historical and basically humanist nature of European culture as the sine-qua-non for 'profound' art that it often made itself out to be, the first major crack in this edifice occurred in the mid to late '90s. Two factors were instrumental to this change in perception, of which one can be attributed to the influence of John Cage and the other to my accepting a job as artistic director of Percussion Group The Hague. Where the poetic severity and constant freshness of Cage's music and thought confronted me with certain philosophical choices, the in-depth introduction to the world of alternate sound sources of the latter - combined with a growing ability to analyze and name the many hundreds of different ways of producing sound - sharpened my ears to a world of possibilities outside of conventional instrumental practice. Listening to and working with the many instruments from all parts of the world – new as well as freshly invented - the innate differences among especially the pitched instruments clearly revealed to me how intimately connected sound, tuning and culture actually were. The simple existence of these instruments revealed to me, at the very least, the presence of cultures in which 'the interval' seemed to have a very different meaning than in the West. Unlike Western intervals, these intervals seemed to be authentically 'alive'.

Having been trained as an organist as well, I was naturally aware of the many battles in tuning systems that had occurred in the renaissance and at the time of the North German organ school. Putting the two together at least brought home to me that there were some highly problematic issues involved with the so-called 'progress' of tuning in the West.

Although my compositional concerns at this point mainly pertained to matters of form, several pieces written during this period clearly betray some of these exotic influences in their instrumentation as well (such as the inclusion of detuned porcelain bowls in the second part of *Music of Mercy pt. 3* (1996) and the fake gamelan in *3-pt. (untampered) Product* (1998), just to name two examples).

In essence, the 'development' in this phase - or 'renunciation' as I'd prefer to call it - (assuming that each development in fact consists of a rejection of something else which has become redundant) - could be defined as an overall renunciation of *hierarchy*, be it cultural (the domination of any particular culture over another – although in practice this eventually meant the demise of any Eurocentric allegiances in my own work) or intra-musical (the domination of any particular musical 'form' over another – in practice: the acceptance of any material entity as able to constitute 'music').

Still, none of this really applied to the area of pitch - supposedly, the entire *point* of microtonality after all.

Development 2/Renunciation 2

Somewhere between 2003 and 2005 a decidedly more fundamental change of perception suggested itself, however. This particular change of mind was fuelled to a large extent by circumstantial factors, the main of which was a growing awareness of the degree to which an overall culture actually dictates its own products – in fact, long before they have even been conceived in the makers' mind.

Although ostensibly remote from the present topic of *microtonality*, it became – nearly depressingly – obvious to me that much of our culture not only seemed to generate *itself* (thus enslaving music, as well as musicians, in my opinion) but also suffered from a form of *listening* - and this is where microtonality eventually comes into play - which on the one hand seemed nearly entirely 'event'-based ('value' seemed to a large extent determined by 'activity') and on the other hand, essentially didn't seem to concern itself with much more than relatively banal style-issues.

There seemed to be a great deal of impatience in this music culture, and what it seemed to say about its overall 'function' (the demand to be entertained through unremitting activity change and 'memory games') I began to find both infantile - in its primary emphasis on narrative and dialectics - as well as not conducive to real concentration. Although this may sound like a roundabout way of getting to microtonality, it nonetheless directly lead to it, since it clearly demonstrated to me the extent to which our hearing was intended to be guided by forms of *comparative, referential, listening* - a form of listening which in my view amounted to little more than an act of collective memory, rooted in history, but which essentially had very little to do with actually using one's ears.

Not only did this bring home to me some of the many surreptitious dangers of pragmatism (the various accepted conventions involved with catering to an existing system), but along with that, the need to redefine for myself what exactly I felt the 'function' of music to be and what exactly it was that I really wanted to hear and felt needed saying at this time.

Though all interconnected to greater or lesser degrees, this development eventually resulted in three areas of research:

1) The areas of open, variable, forms; notated in real-time
2) The relationships between 'sound' and 'time' and
3) The areas of resonance and vibration

In practice, it constituted the renunciation of 'events' in favor of the unadorned, straight line as governing musical principle (though this could also be construed as a natural by-product) and the acceptance of music as a physical part of nature, more closely allied to the sciences than to culture. My ideal in this became the image of a tree, a tree of which one could neither say 'this is a bad tree' nor 'this is a good tree', since it simply was 'a tree'; not much happening from the 'event point of view' (and comparing its virtues to any other tree would seem slightly ridiculous), but nonetheless definitely alive and a thing of beauty on its own terms. Akin to this somewhat simplistic image of a tree simply 'being', music, in my opinion, needed also to simply 'be' and to occupy itself more with acts of revealing than of creating.

Although I had always held the belief that music should strive to reflect itself as much as possible, this resulted in a view of music which became more research-bound than pragmatism-bound and also resulted in working in extended series rather than in individual products. As a composer, I also found myself moving away from purely acoustic composition to the area of electro-acoustic composition; using amplification, live-electronics, psychoacoustics and spatial acoustics as vital parameters of my work.

Eventually all of this led to a decision to 'specialize' and a true plethora of resulting works. But it was mostly within the context of investigating relationships between sound and time that microtonality eventually imposed itself naturally.[1]

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[1] A key occurrence, in retrospect, was a meeting in 2004 with the renowned Korean *Kayageum* player Byung-Ki Hwang. Having had the opportunity to immerse myself much more in Far Eastern thought and music in the meantime, Hwang was however the first to draw my attention to an essential difference in approach to sound, between Eastern ears and Western ears. This difference he described in the concept of 'the aftertone': a significantly different approach to the concept of music, where 'the music' doesn't essentially lie in 'the attack' (as is the case in most Western music), but mostly in what happens *after* the attack. The attack itself is viewed as no more than a 'medium' with which to trigger a much more important, often infinitely subtle world of inflections. Considered within a larger context, this concept revealed an immense difference in the respective perceptions between not only sound and time, but also in what seemed to be 'an essence' and what seemed to be merely 'a trigger'.

Discussion of several works 2003 – 2008

In discussing several relevant works from this period – in the form of a kind of chronological progress-report - I have decided to categorize the following paragraphs under two headings: *Sound & Time* and *Vibration, Resonance and Speed*, the two most dominant areas of research in my work over the past few years. I use the term 'research' both literally as well as with caution – and always in the presumption that the reader understands that all research in the area of composition is done with a definite sounding experience in mind, but in many cases is also done for its own sake as well, simply in order to find out how certain phenomena work. In all cases however, this research found its way into the music itself; meaning that 'research' and 'music' are for me one and the same, in the same way that 'notation' and 'music' are one and the same and 'sound' (or 'orchestration') and 'music' are one and the same as well. These three areas are to me the vital cornerstones of composition.

I) Sound & Time (overtone- & ratio-related works)

Relevant works: (No 23) *Serenades II to IV* (2003) (open form; 'live sculpting'); (No 27) *Structures I – XVI* (2005-2006) (chromatic time, variable forms based on overtone series, correlations of time, interval and register, plus size and length); (No 30a) *La Voce di Zarlino* (2006) (vocal form; syntonic comma; modality; ratio rhythms); (No 36) *Concords I – III* (2007) ('irrelevance' of the series; other ways of generating harmony).

<u>Serenades II to IV (No 23)</u>

The first piece worthwhile mentioning in this context is a work called *Serenades II to IV*, written in 2003 for electric guitar quartet *Catch*. Due to the medium's potential for long, sustained sounds, this piece proved something of a breakthrough in several ways, since it forced me to come up with a form of notation which would enable certain 'sound envelopes' to occur. In this way, I would say the work was the first to consciously investigate specific relationships between sound and time.

Having been used to notating 'everything' up to this point, I soon realized that the domain of 'sound', especially sound which required unspecifiable amounts of time for its realization within a live environment, demanded its own form of notation and could never be forced into set time lengths. For a composer who was used to controlling all aspects, determined in no small degree by vital matters of form, this implied a very different approach. Also, bearing in mind that I had been trained as an 'acoustic' composer in the first place, this type of thinking was like skating on thin ice.

In the final section of the *Serenades* (see Figure 1) a procedure was employed for which I coined the term 'live sculpting': a procedure which implied that a) each sound was to be designed 'live' on stage, b) that progress from sound to sound (or from chord to chord) could only occur once each sound or sound shape had been achieved, and c) that all of this had to be done by *ear*. The *musician's* ears, that is. Although never using the term again, this form of music making, through the successive acts of listening, choosing, designing and completing proved not only to be a major ear-opener, but also something I would use extensively in later works.

Also in the area of tuning the piece is worth a brief mention, since it was the first piece to make a tentative, but later rejected, attempt at detuning (arbitrary quarter-tone detuning in this case). Basically consisting of very clear, juxtaposed, chords however, the detuning ended up

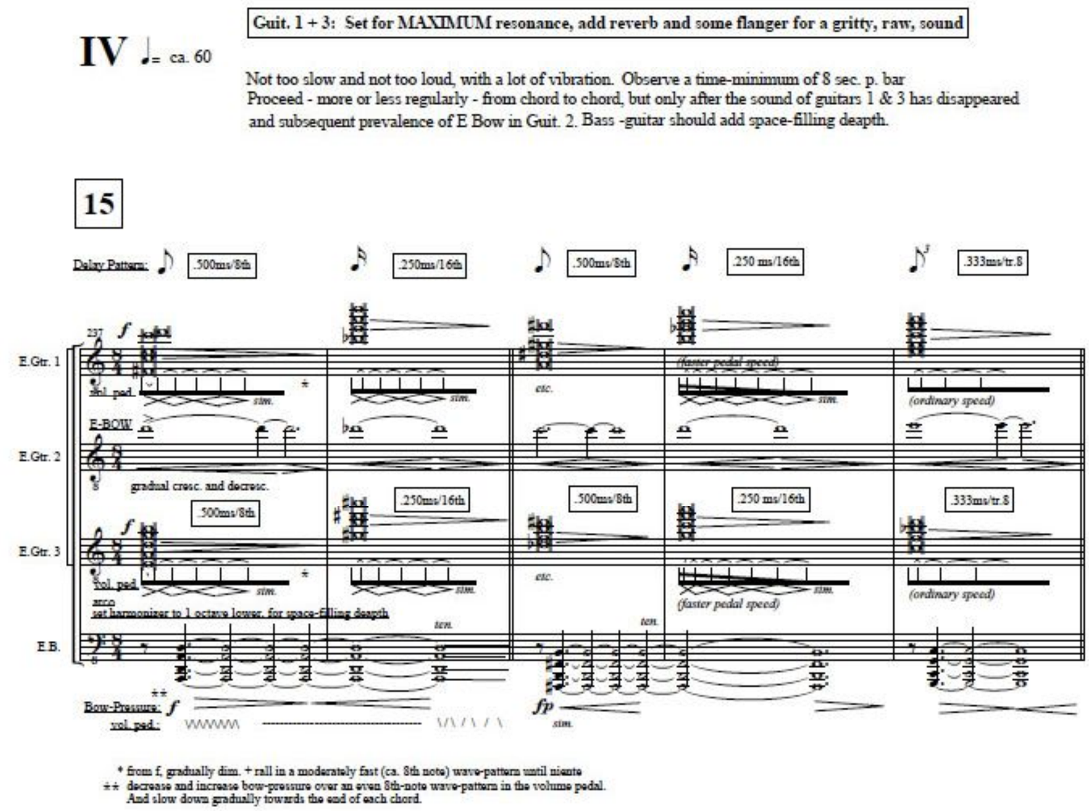

Figure 1: opening of last section of Adriaansz, *Serenades II to IV.* ©AsZoh Press, 2004.

sounding somewhat like the aforementioned example 3 on the first page of this article: 'accidental' – and was thus accordingly rejected.

Structures I – XVI (No 27)

It wasn't until 2005 however that I picked up the thread again. Interspersed by a trio of pieces dealing with 'translations' of mathematical formulas, the first work to continue in this line was a series called *Structures I - XVI:* a collection of sixteen works for unspecified, variable set-ups - from small ensembles to large orchestral forces with or without live delay - lasting well over six hours in total.

All the materials for the individual pieces were derived from the harmonic series and focused strongly on 'time-interval' relationships. The *Structures* were essentially the first to do away with 'events' and to focus entirely on sound production and listening, as well as being the first piece to dispose with individual parts for the players, requiring them to play from the score or from specific group scores instead. The set-up for each of the works was 'variable' (meaning that any collection of instruments could in principle tackle the scores) and was timed by means of a central stopwatch (thereby also disposing of a conductor in the process and restoring much of the responsibility to the musicians themselves). Governed by a painstakingly assembled ground set of 'rules', the players were then left free to enter and choose pitches at their own volition. Inspired by the centenary of Einstein's 'Golden Year' and dedicated to the undeniable pioneer of this form of music making, James Tenney, the works aimed at an essentially 'harmonic' type of music: a type of music in which the perception of Time could be both 'timeless' (through the musicians' free entries) as well as 'tangible' (through a set of measurable interval-durations). In their preoccupation with the act of listening, the works also aimed at creating a situation in which no obstacles could stand between the musicians and their undivided concentration on the sounds they were producing. Needless to mention, in dealing with the harmonic series the whole field of 'pure intervals' came into focus as well.

Divided into five sets (#27a, #27b, #27c, #27d and #27e), the works explored various ways of mapping overtone-derived chords in space. Within this 'mapping', chords could be produced in either 'linear' or 'non-linear' ways, indicating either a) mono-directional forms - ascending, descending, approaching from opposite directions ('Cross'-forms) or diverging from a central point ('Wedge' forms) – or b) multi-directional forms, which constituted the majority of pieces and indicated that chords could be formed from all points in space at any time. All in all, the various works, whether mono-directional or multi-directional, consisted of two 'types' of music: pieces revolving around the eventual formation of a perfect 'harmonic' chord (i.e. according to the series), or entirely static pieces revolving around 'octave replacements' within limited harmonic ranges.

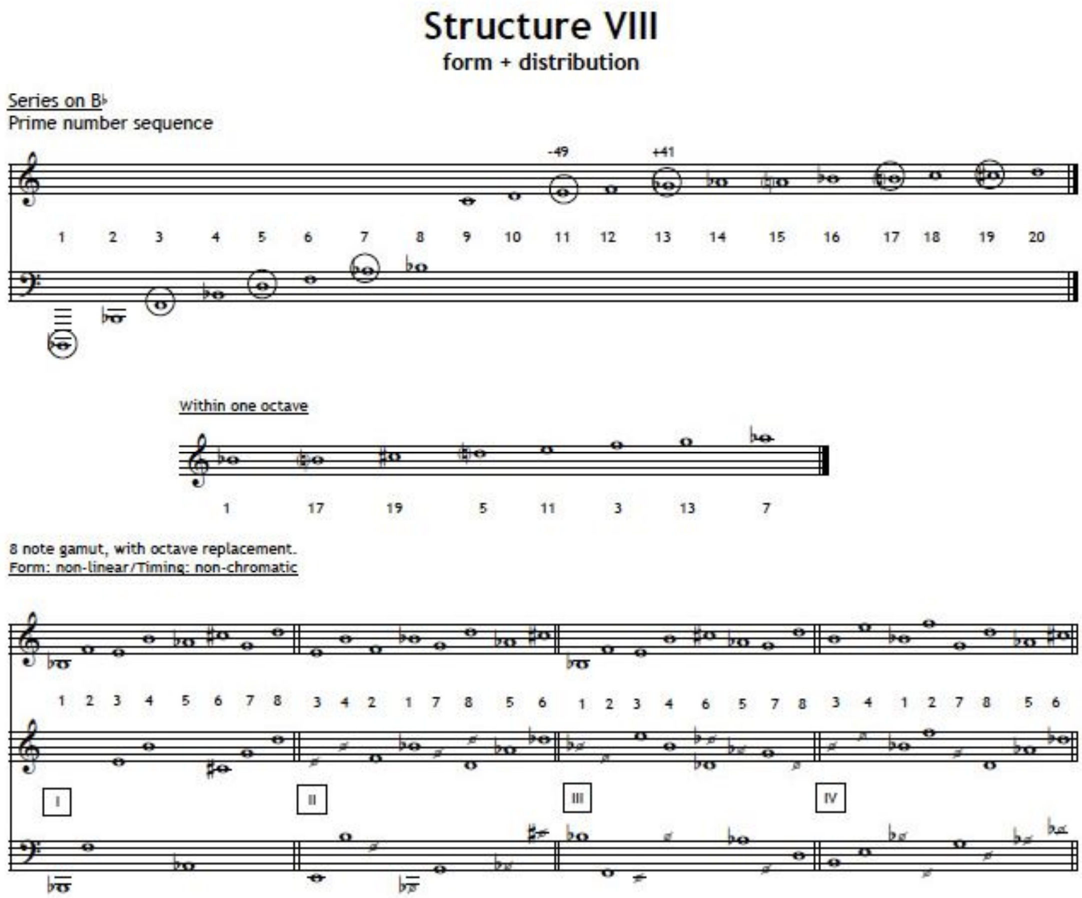

Figure 2.1: form and distribution in Adriaansz, *Structure VIII.* ©AsZoh Press, 2005.

The guiding principle behind all of the works was a 'one-pitch-at-a-time' construction (see Figure 2.1), in which each newly appearing pitch would be linked to the last and, as an interval, would be coupled to set time-lengths. These time-lengths were based on multiplications of the smallest interval (i.e. a minor second interval having a set duration of 20 or 30 seconds, a major second would be twice that length, a minor third three times that length, and so on). When used in this strict sense, I called the division of time 'chromatic' (meaning, augmentation by one degree at a time and thus reflecting the size of each interval accurately in time; see Figure 2.2). When used in a less strict sense (as was sometimes the case when the size of intervals used would simply take 'too long' to approach strictly – the larger the interval, the longer the time between entrances and the longer the entire piece after all), I would use three different durations (basically short, medium and long) to cover the differences in interval. This I then called: 'non chromatic time'.

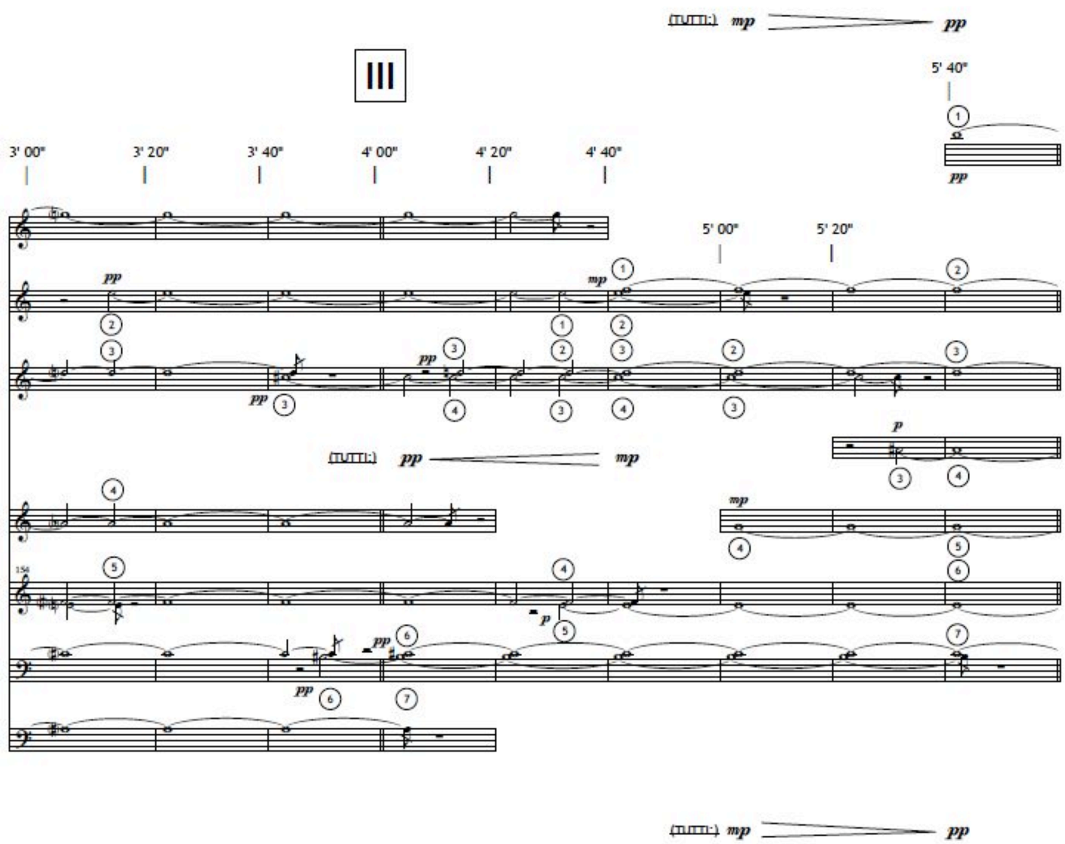

Figure 2.2 extract from Adriaansz, *Structure IX.* ©AsZoh Press, 2005.

The main advantage of this 'time-interval' system was that there existed not only a credible relationship between pitch, interval, register and time (something which was immediately discernable on the page as well – one could actually 'see' the music), but also between the size of the chords used and the overall duration of the piece as a whole (the bigger the chord, the longer the piece obviously). In this way the shortest piece of the collection (*Structure VII,* consisting of no more than 6–voiced chords within a span of an octave-and-a-half) lasts thirteen minutes, while the longest (*Structure X,* with an eventual chord consisting of up to thirty-three voices, spread over a six- to seven-octave span) lasts close to an hour. The 'twenty-second-average' for the smallest interval was based on what seemed to be a 'sufficient' amount of time for a pitched sound to 'sound': less than twenty seconds would reduce a vertical process to a horizontal one, while significantly more would simply be detrimental to one's patience. Even to this, there are limits…

In choosing the actual partials, I eventually found myself departing from only two fundamentals for the entire set of pieces: B flat and E natural (a choice based on the most commonly accessible bass pitches for most instruments). When studying the harmonic properties of either series, I found that both fundamentals more-or-less complemented each other, the higher usable partials of the one being closely linked to the lower ones of the other (not entirely illogical for a tritone relationship). Partials were then subsequently chosen according to either prime numbers or according to uneven numbers, but never exceeding the 24th partial in practice. Within pieces I would then either a) stick to one basic gamut of pitches, b) exchange and alternate between primes and uneven partials, or even – in a few cases – c) 'modulate' between fundamentals.

Partials however, were never notated as microtones, even in the cases where they obviously *were* 'microtonal'. In an effort to not restrict the availability of certain pitches to specific instruments (and thus seriously limit the sounding potential to 'the same instrument always for the same pitch'), I opted to leave this part open, in favor of constantly changing fields of sound. In practice, musicians capable of producing partials as natural overtones were asked to do so, while others were given the freedom to intonate as they were able and as the environment seemed to imply. This somewhat quirky relationship between equal temperament and non-equal temperament, in reality created a vibrant surface, which, in my opinion most benefited the music.

La Voce di Zarlino (No 30)

A work which followed up directly on some of the harmonic concerns of the *Structures*, but combined these with specific tuning concepts and the use of ratio-rhythms (as well as attempting to deal with the 'lost art' of modal singing), was a work for unaccompanied voices called *La Voce di Zarlino*.

Where the *Structures* derived much of their harmonic wealth from a heterogeneous abundance of instrumental color, the particular challenge of *Zarlino* lay in attempting to transport the principles of the *Structures* ('pure', 'harmonic-based' sound) on to the medium of voices – obviously unable to color with the same kind of richness or diversity, or to hold their pitches for significant amounts of time. Another challenge lay in having to come up with a way in which to treat text within the confines of an unemphatic, un-metered kind of music; music which was essentially antipathetic to forms of 'text setting'.

Intended, curiously, for performance during the Holland Festival for *Old* Music (which had furthermore imposed the theme of *Venice* on its programming) there were obviously several obstacles to overcome. Researching 15th and 16th century Venice however, with a specific focus on some of the modal/chromatic 'tuning battles' that had occurred at the time (the debate between Lusitano and Vicentino comes to mind), an interesting figure emerged in the person of theoretician and composer Gioseffo Zarlino. Aware of the fact that Zarlino was not only one of the main instigators of the eventual Western conversion to equal temperament (and thus somewhat rejected by the modal schools of singing), but that he had spent equally much time on attempting to find alternate tuning systems - through his design of the *Archicembalo,* an instrument which would be able to follow the perfect modal intonation of singers - an intriguing figure imposed himself on the scene. Reading through the entire *L'istitutioni Armoniche* (1558) and the later *Dimostrationi Armoniche* (1571) as well as his famous books on counterpoint and composition (an often extremely arduous task, I might add) I started looking for 'speculative' passages, passages in the form of private opinions concerning the nature and function of music. Though these kind of 'private opinions' were far and few between, a handful of useful texts eventually surfaced, describing not only certain aural observations about sound, but also describing his discovery of the *syntonic comma* (a tuning-dichotomy pertaining to the difference between four justly tuned perfect fifths, and two octaves plus a justly tuned major third, a difference equal to the frequency ratio 81:80, or around 21.51 cents). Wanting to paint a representative portrait of his theories, I decided to use this syntonic comma as a basis for the work and to use the ensuing 'ratio rhythms' as a method for dividing the text over the singers.

In the first movement of this work, I decided to take the five available 'just' fifths, as supplied by one of the readings of the syntonic comma (in the order C-G-D-A-E) and to top the sequence off with two 'illegitimate' tritones on either side. A choice which resulted in the sequence: F#-C-G-D-A-E-Bb (see Fig.3a). Placing these pitches, subsequently, within the harmonic series on C gave me the order: C-G-E-Bb-D-F#-A, translating into the ratios 1:3:5:7:9:11:13 while 'raising' partials 7,11 and 13 in the score (i.e. not notated as microtones, but definitely hoping for a pure, 'harmonic' result, due to the potential of unaccompanied voices). From this sequence, the entire work is eventually derived (see Fig.3b). Placing the pitches subsequently into two sets of interlocking triads and using the same 'one-pitch-at-a-time' process used in the *Structures* (and then replacing pitches from the sixth new entry on), the work travels through eight transformations of this basic gamut of seven pitches. Due to the numerical relationship between the basic gamut (7) and the order of pitch replacement (every 5), no single chord is thus ever repeated literally (Fig.3c).

Pitch Distribution La Voce I

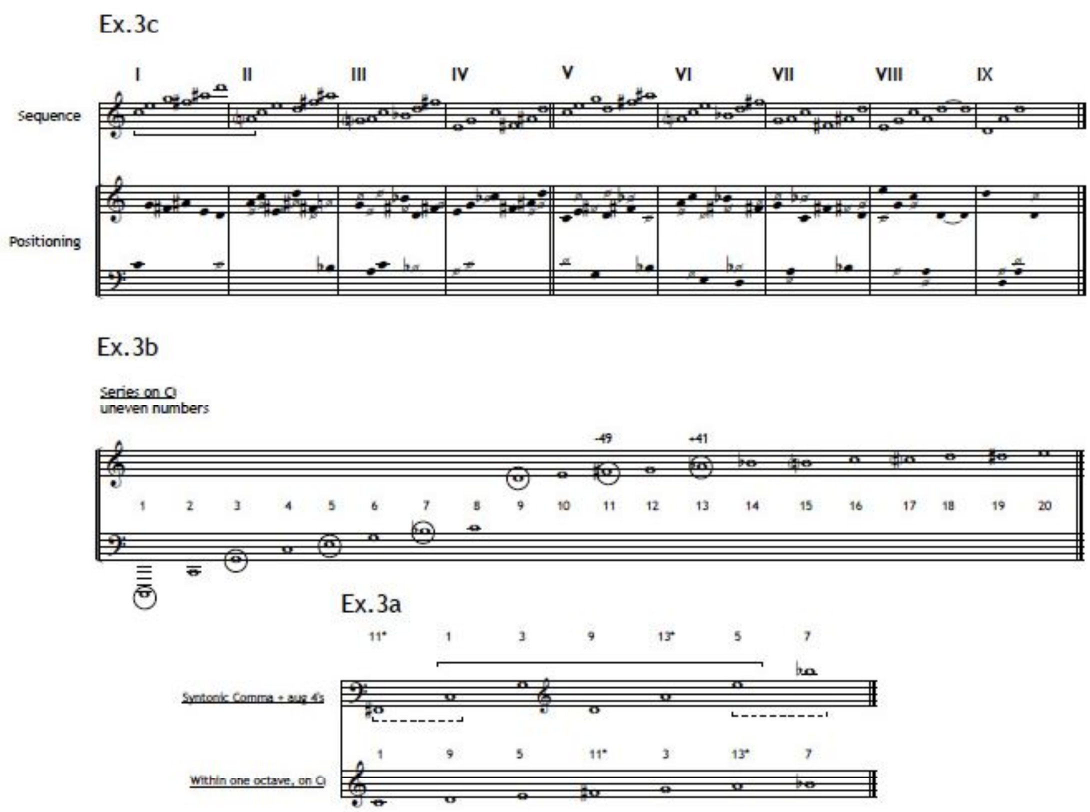

Figure 3 a, b and c: pitch distribution in Adriaansz, *La Voce di Zarlino.* ©AsZoh Press, 2006.

Throughout the first half of the first movement[2] the text is placed as a sort of recitative, in which three different tempi collide with each other, causing the sound to flow incessantly. At the exact half-way mark of the piece, this 'collision' is abandoned however, in favor of simultaneous chord-changes at coinciding points, once every twelve seconds. The text placement for these final six minutes is entirely derived from the harmonic ratios supplied by each pitch. Though often uncharacteristically complicated in its notation - pitting devilish ratios of 11:9:5:4:2 etc. against each other - the use of these ratio rhythms nonetheless cause the music to vibrate according to what one might call its 'natural vibration'. Coinciding with this gradual invasion of staggered homophony, the text - initially slightly out of sync - eventually moves into sync, while emphasizing important communal words in the process. As the

[2] The first movement is based on the perceived 'imperceptibility' of the *Harmony of the Spheres* and several observations about the 'rotation' and 'speed' of the planets.

harmonic gamut is also eventually reduced and more and more of the text starts coinciding, the overall *quality* of sound also becomes more homogeneous, causing the text to 'echo' within itself.

In the third movement of *Zarlino,* this use of ratio-rhythms is taken to an even higher extreme. Based specifically on the 'movimento' (i.e. the 'motion') between 'high' and 'low'[3], the movement literally transcribes harmonic motion in pitch as well as in register, with the faster frequencies consistently on top and the slower ones below (as can be seen from Fig.4, where the numbers above the staff indicate the ratios as they change with each newly appearing pitch).

La Voce di Zarlino thus attempts to paint an entirely 'faithful' portrait of a given topic by deriving all parameters of compositional choice from materials already supplied from the outset; in the process hoping to demonstrate many of the wonderful acoustic qualities which are simply up there 'for grabs'.

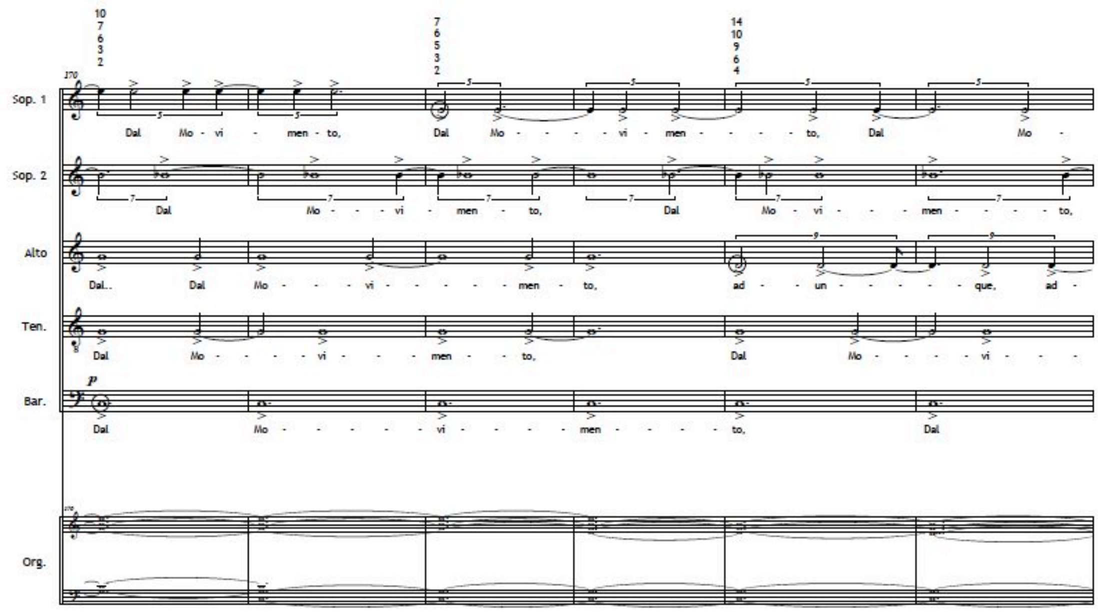

Figure 4: extract from third section of Adriaansz, *La Voce di Zarlino.* ©AsZoh Press, 2006.

<u>*Concords (No 36)*</u>

A final related work, written in 2007 as a kind of afterthought and worthy of a brief mention, is a work called *Concords*. Written initially as a small birthday present, in the form of a 'signature' for the 20th anniversary of the Ives Ensemble, the work later grew out to a full-blown 50-minute work.

Using the same techniques employed in the *Structures*, this work, ironically, proved that one didn't need the harmonic series at all in order to obtain a rich, vibrant surface full of harmonic overtones. In three sections, the work takes the available letters supplied by the name 'Ives Ensemble', and transposes these onto three different harmonic systems: a) chromatic (12 available, equal-tempered, pitches – resulting in a gamut of seven pitches), b) within the series (as many available pitches as are available within the alphabet, resulting in a gamut of

[3] To quote Zarlino: Dal *Movimento adunque nascono I Suoni & le Voci; ma perche della movimenti alcuni sono equali, & alcuni inequali; & di questi alcuni sono tardi & vari; & alcuni veloci & spessi; pero e da sapere, che dalli primi nascono I suoni gravi & dalli secondi gli acuti.* (Zarlino, *Istitutione Armoniche* II, Cap.11.)

ten pitches – with appropriate microtonal notation) and c) according to prime number pitches of a series (however many letters in the sequential order of the alphabet, and supplied by the name 'Ives Ensemble' concur with prime numbers – resulting in a gamut of 6 pitches) (see Figure 5). From any point of view: an entirely arbitrary pitch-choice, ungoverned by any specifically desired outcome.

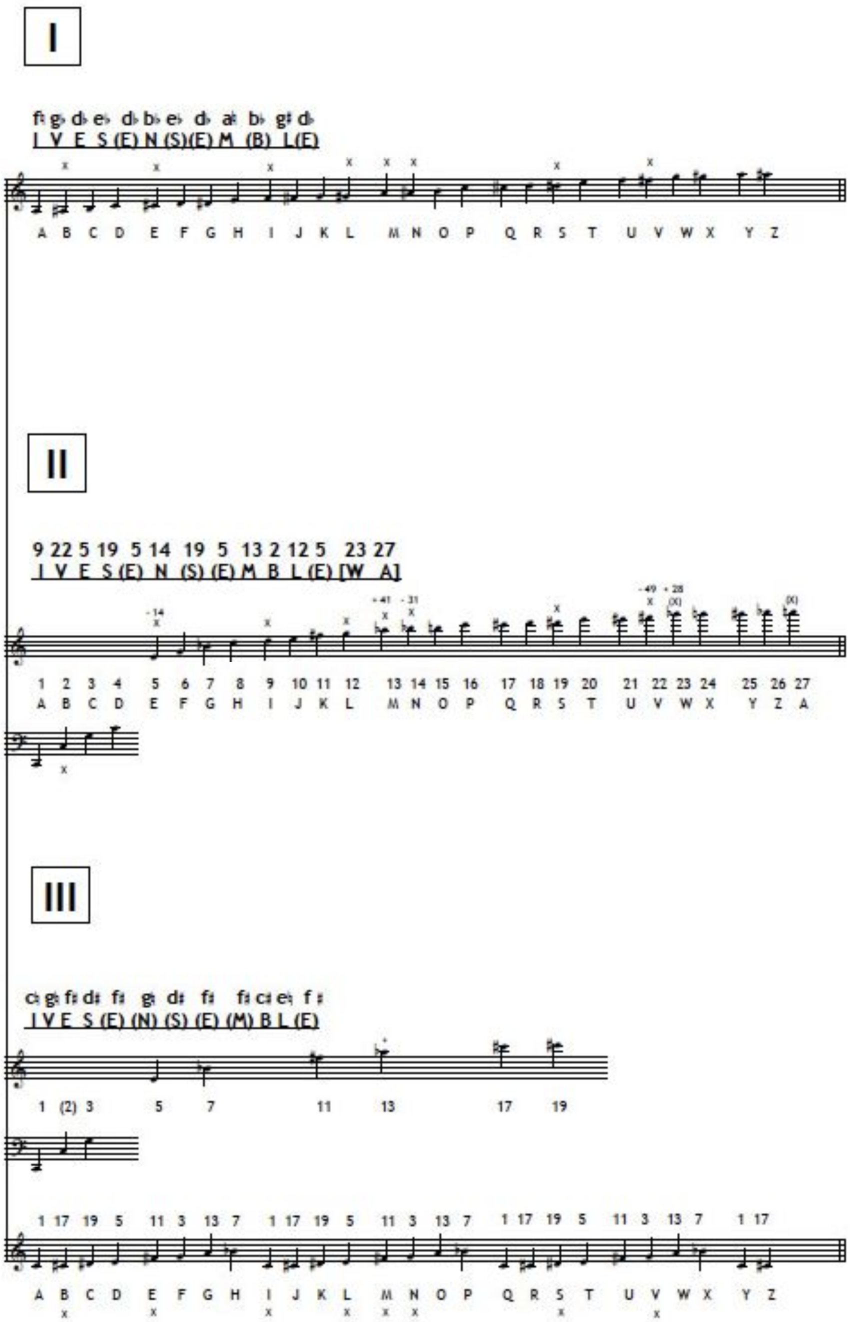

Figure 5: pitch materials in Adriaansz, *Concords.* ©AsZoh Press, 2006.

In practice - though the work was only performed a year-and-half after its composition and my subsequent work had in the meantime already moved away from the series as primary source material - this 'arbitrary' pitch-choice turned out to work just as well as the overtone-related material. Mainly, I guess, because the many pitch-doublings and the emphasis on sound more-or-less naturally veer in that direction, at least when employing this particular kind of technique.

Conclusion 1

Although with the exception of *Concords* none of these works explicitly notated *micro*tones, working within the harmonic series nonetheless 'automatically' produced them and caused the emphasis to lie on many matters associated with their ratios and with forms of 'pure tuning'. More importantly though, the many 'orchestrated unisons', which are characteristic of quite a few of these works, opened up the entire area of *vibration,* making it an important factor in the overall sound world I was striving for. The conjuring up of this *Deus ex Machina*, the 'true music' behind all of our endeavors, eventually made me define my efforts as an attempt at 'creating conditions in which certain things could happen'. Wanting to understand more of this, however, inevitably meant diving into the smallest increments as well.

II) Vibration, Resonance and Speed (tuning- & microtonality-related works)

Relevant works: (No 35) *Prana* (2007) (concept of 'one pitch generating all'; concept of *Deus ex Machina* + manifest/unmanifest; tuning); Actual microtonality: (No 37) *Waves 5-7* (2008) *(*esp. *Wave 6*; ghost harmonies*);* (No 39) *Waves 11-13* (2008) (periodic entries; 'moving tones'; use of sines); (No 41) *Enclosures* (2008) (very small increments; microtonality and speed); (No 42) *Music for Sines, Percussion, eBows & variable Ensemble* (2008) (microtonality and tempo)

Prana (no 35)

One particularly unrelenting idea that kept on resurfacing through some of the aforementioned works was the idea of 'oneness': the concept of whether or not an entire work could be conjured up through the use of nothing but a single fundamental. That is: what would happen if a (pretty large) pool of musicians were only supplied with one fundamental and then left alone initially to double pitches, then pick up on appearing overtones, double those again, transpose downwards, listen, pick up the new overtones etc. - like giving voice to the *God in the Machine*? How long could the piece last? How long would it remain interesting? What would become audible? In other words: how much could actually originate from *one* thing?

These were some of the questions that occupied me while working on a piece called *Prana*, a large-scale work based on texts from the *Bhagavad-Gita* and St. Augustine's *Confessions.* Premiered in the fall of 2007, this sixty-three minute work for the first time brought together several of my favourite media: electric guitars, percussion ensemble, eBow piano[4] and an ensemble of amplified female singers. (Figure 6.1.)

Prana (Sanskrit for 'breath', or 'life') was also the first piece I would now call 'sacred' in its basic intentions. Having been consistently confronted with various metaphysical properties of sound, it seemed unavoidable to deal with this matter at some point.[5]

[4] The eBow (short for 'electric bow') is a small electro-magnet, originally devised for use on electric guitars, but also suitable for pianos when adapted slightly to fit the wider strings. The device basically excites the strings, causing them to sound for as long as the battery holds out. When combining many eBows, the whole area of sympathetic string-vibration comes into play. The eBows are equipped with two settings: one produces fundamentals and the other overtones. When combining these settings in various ways it is possible to produce overtone-rich aggregates of sound and by exerting different forms of pressure on the eBows it is also possible to alter the focus.

[5] Wanting to limit myself to matters of origin and purely technical matters – and wary about delving into potentially pretence-ridden matters of metaphysics or spirituality - I have decided to refrain from any comments pertaining to these more speculative sides of microtonality, even though these 'metaphysical properties' are often in fact very primary motivations.

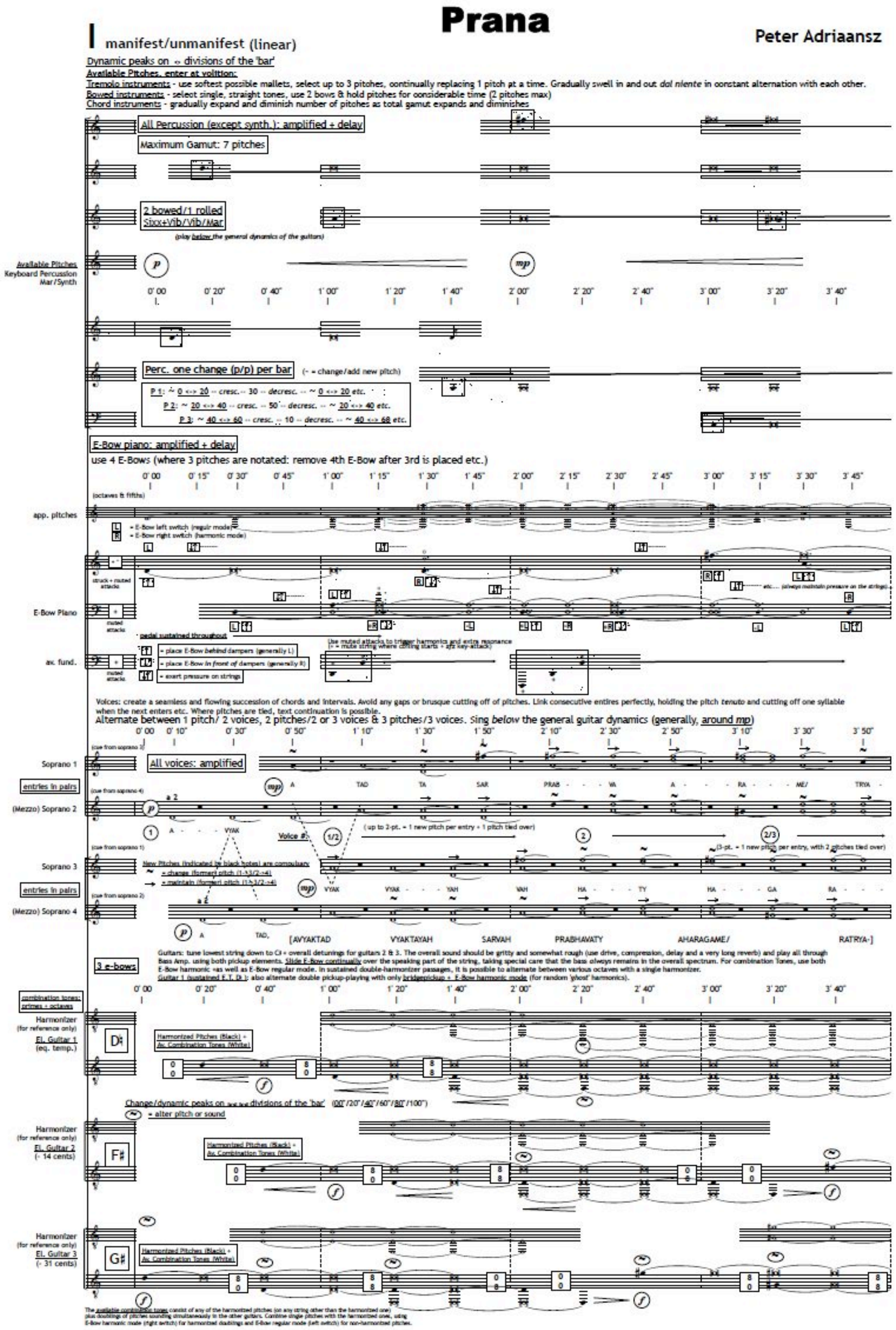

Figure 6.1: opening of Adriaansz, *Prana.* ©AsZoh Press, 2007.

From the outset, two concepts thus dictated the piece:

1) The aforementioned idea of 'unity': a situation in which 'all stems from one';
2) The concept of 'infinity', dealing mainly with Buddhist notions of 'the manifest' and the 'unmanifest' (the 'heard' and the 'unheard', the 'seen' and the 'unseen') as a spiritual parallel to the attempted conjuring up of a *Deus ex Machina.*

In order to achieve this so-called 'unity', the ensemble is – somewhat ironically - *divided* into two different groups, with accordingly different functions. These two groups consist of a *generative* group (consisting of the guitars + eBow piano) and a *responding* group (all others).

Within the so-called *generative* group, the main emphasis lies on the three electric guitars, from which the workings of the entire piece can also be derived. In scoring the parts for the guitars, the *de facto* 'fundamentals' of the piece, two things were very important from the outset: 1) maximum vibration and 2) overtone-rich collections of very deep sounds.

In order to obtain the vibrant sound I was looking for, two of the three guitars were detuned to the 5th and 7th partials (i.e. to the 'flat' major third – minus 14 cents - and the 'flat' minor seventh – minus 31 cents, thus sharing a difference of approximately 15 cents between each of the guitars). This resulted in a collective sound, which not only amplified all natural ratios up to the 7th partial when playing in 'unison', but also guaranteed extremely vibrant beating in the very lowest octaves.

Wanting to also obtain as many overtones as possible, through the use of often extremely low and deep registers, the guitars were subsequently rigged up to a battery of 'harmonizers', special effect-boxes capable of producing multiple intervals when only one would be played (a device comparable to the octave-doubling or mixture stops on an organ and, in fact, used in a similar fashion). In practice, this resulted in not only extending the overall range of the guitars by a good two octaves, but also ended up providing the desired wealth of overtones.

Written in five cyclically connected movements of twelve minutes each – plus an additional three minutes for the central section – each movement of the piece initially 'collects' pitches and then gradually discards them again. Starting from a single guitar pitch, which is then doubled by the other guitars and subsequently 'harmonized', each section gradually splits off into three separate tonal centers, which are then again 'harmonized' before eventually being discarded, one by one, until perfect unison is once again achieved. As each pitch, or pitch doubling, appears, it is linked to a set of gradually notated overtones, which are then distributed over the rest of the ensemble (the so-called *responding* group) in the form of a gamut of available pitches. This distribution is more-or-less governed by the following principles:

- The higher the degree of doubling in the guitars, the wider the amplitude of possible overtones;
- The higher the degree of harmonic variety in the guitars, the wider the overall gamut of possible overtones to choose from.

In choosing their pitches and entries, the percussion is basically 'free' (though gradually accelerating from one entry per minute in Part I to three entries per minute in Part III – and then reversing this process again), while the voices enter and exit - either in pairs or as individuals – according to regular time-intervals. As such, each section of *Prana* – with the exception of the third - gradually builds up sound complexes, which are then deconstructed again, according to a 'natural' appearance of the overtones.

The differences between each section are essentially provided by different interval constellations in the guitars and by gradual changes of register (ascending twice and then descending twice). In this way, the first section creates harmonic gamuts around the
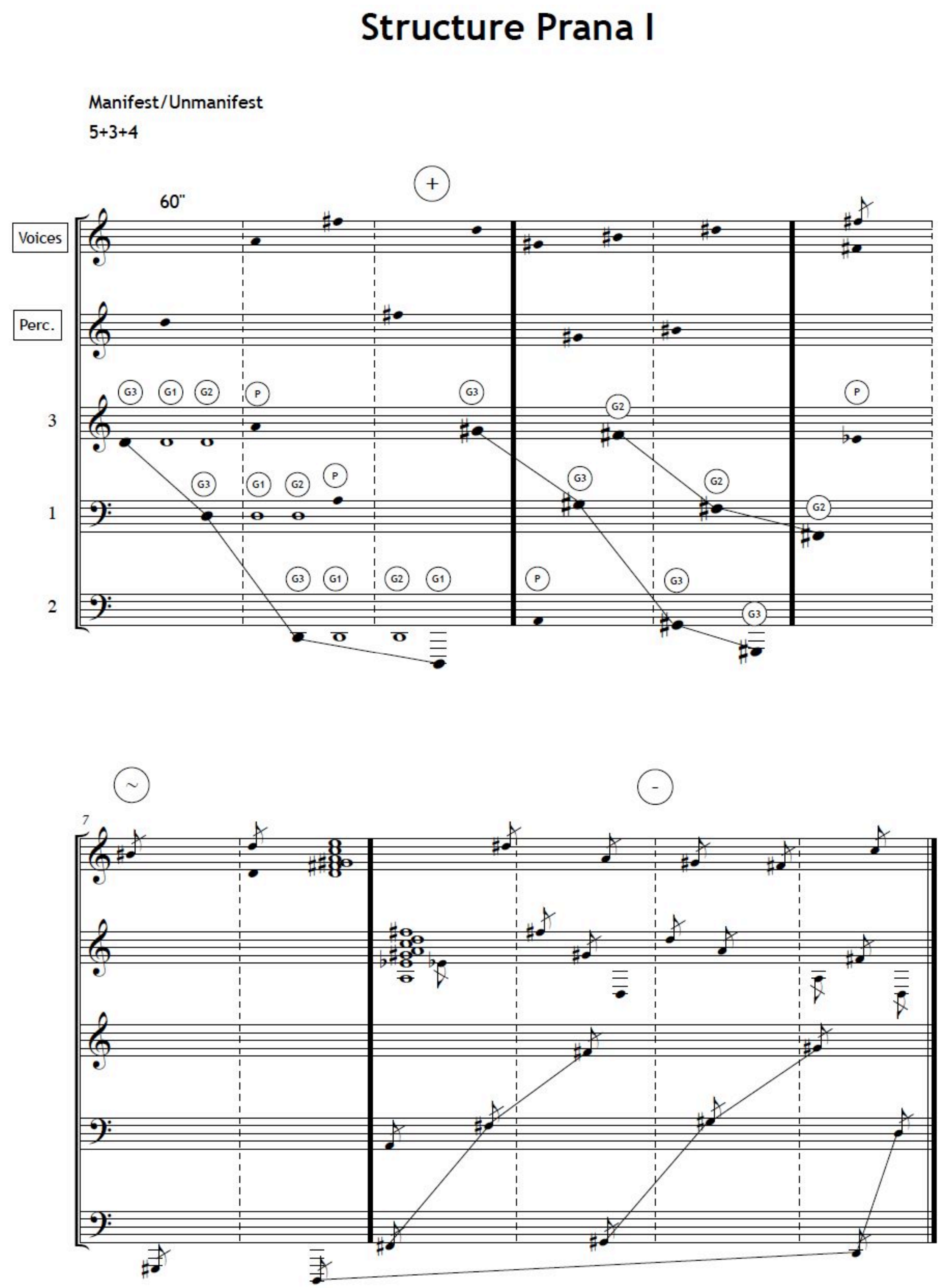
Figure 6.2: representation of the structure of Adriaansz, *Prana I.* ©AsZoh Press, 2007.

fundamentals of D, G# and F# (i.e. major 3rd + major 2nd) (Figure 6.2); the second, gamuts around F#, A# and D (i.e. two major 3rds); the third, gamuts around D, F# and F natural - and eventually Bb (i.e. major 3rd + minor 2nd); the fourth – reversing again – gamuts around F#, A# and D (i.e. two major 3rds again) and the fifth, finally, gamuts around D, F# and C natural (i.e. major 3rd + major 2nd). All in all: six fundamentals for the entire work, linked together via major 3rd relationships. (In the last section, incidentally, the tuning is finally 'correct', with guitars 2 and 3 (-14 and –31 cents respectively) on their appropriate corresponding pitches within the series. An entirely just tuning, resulting, at least to my ears, in a significantly different sensation of groundedness).[6]

As a whole, *Prana* thus seeks to create a vast 'body' of natural sound, through observing and then more-or-less 'transcribing' the workings of the overtones as accurately as possible. In combination with the relatively wide scordatura in the guitars, both factors contribute to an experience, which is often extremely physical in its impact. Also, in the form of the voices' regular alternation of entries and in the uniform lengths of each of the sections, two elements were introduced which were to play an important role in later developments.

Waves 5-7 (No 37)

The next piece in this particular line of works partially carries on with some of the concerns of *Prana* while doing away with some of the others. Where *Prana*, as described, notated all the 'possible overtones', resulting in a powerful vastness of sound, the next, logical, step was to attempt to do away with all of the notated overtones in order to see how much could be conjured up *without* actually notating them – while still obtaining most of the basic power supplied in *Prana*. The first work to do this - and the first work to include an entire section actually *notated* as microtones - was *Waves 5 – 7*, written at the end of 2007 for Ensemble Klang.

This new series of works, generically grouped under the title *Waves,*[7] combines certain features of the *Structures* (most essentially, the concept of chromatic time), but differs from this work in so far as it eventually abandons all forms of overtone-derived harmony and employs both free (variable) as well as fixed (compulsory) elements in the areas of performance as well as orchestration.

Having worked on many amplified pieces by this point, I found that certain elements had become indispensable to the sound I was aiming for. Essentially desiring an environment in which there could always be elements of interplay between electric and acoustic sounds (i.e. between 'eternal' and 'non-eternal' sound), as well as between 'loudspeaker-space' and 'local space', this meant standardizing certain instruments as well, the main ones of which were electric guitar, eBow piano and bowed percussion instruments. But especially the eBow piano had become stock and staple of many of the works discussed so far. To a certain degree this new series sought to magnify specific properties of the eBows, of which their ability to produce *ghost harmonies* - more-or-less arbitrary, but still somewhat predictable, 'twists of fate' - were to me undeniably the most magical, but often hard to observe due to the relative softness of the instrument in combination with other instruments.

Like *Prana, Waves 5 – 7* are similarly scored for an entirely amplified ensemble consisting of fixed, 'generative' parts (electric guitar and eBow piano) and free, 'responding' parts (percussion and an ensemble of winds). Where the eBow piano makes equal-tempered harmonic combinations, using five eBows, the electric guitar is instructed to make similar harmonies, but with free, microtonal intervals, using a loop-station. The use of both instruments in this case, however, is specifically designed to conjure up not only sympathetic vibration but, wherever possible, to allow the so-called ghost harmonies to appear. This

[6] With regard to the often very disruptive detuning of the guitars: in order to stay in tune the singers are required to intonate to the A 442 of the vibraphone. Both percussion as well as the singers are required to form a 'unified tonal front', regardless of the guitars' scordatura. A formidably difficult task, given the often-close interrelationships between some of the fundamentals.

[7] Started in January 2007, with the cycle *Waves 1 - 4*, for eBow piano, sines and pre-recorded material.

phenomenon occurs most noticeably in the central, microtonal, section of the piece, *Wave 6* – where at specific points, and sometimes only under close scrutiny, clear shadow-harmonies can be heard to appear.

Akin to *Structures*, the microtonal parts of *Wave 6* are 'placed-in-time' chromatically (meaning that each progression from pitch to pitch is accorded set time-intervals) and are notated in the form of a harmonic 'gamut' (i.e. collections of available pitches from which the instrumentalists can choose). Unlike *Structures,* however, this process is filled entirely with microtonal intervals, centering around a three-octave B natural, widening out to include either the C natural on one side or the A# on the other. Throughout the piece, the microtonal motion within each separate register occurs in the form of three simultaneous *parabolas* – revolving over or under a central pitch. These three parabolas are subsequently divided over eighth-tones (12.5 cents), sixth-tones (16.6666 cents) or quarter-tones (25 cents) – i.e. according to the interval-ratios 4:3:2. Linked to their 'chromatic' placement in time, this results in the eighth-tone parabolas making two complete revolutions before the section is up; the quarter-tone parabola, one complete revolution; and the sixth-tone parabola, one-and-half revolutions. The overall process in this way corresponds to the equivalent time-proportions of 2:3:4, thus placing 'time-ratio' entirely in sync with 'interval-ratio'. Combined with the aforementioned functions for eBow Piano and electric guitar, the clear beatings, which are inherent to these many close intervals, helped create the right conditions for 'harmony' to surface as well.

In its similar attempt to seduce the *God in the Machine*, *Wave 6* (as well as the entire set) is thus related to *Prana*, but with the major difference that none of the overtones are actually notated, making the overall sound more terse and the appearance of harmony much more illicit. With the arrival, in *Wave 6*, of 'authentic' microtonality based on chromatic gamuts, a new direction had however emerged, which brings me to the following, for the time being final phase of this particular development.

Waves 11-13 (no 39)

Leaving any trace of the series behind us from this point on, the following three works to be discussed are based entirely on chromatic relationships as basis for the harmony and on researching correlations between microtonal motion and microtonal pitch. Though retaining specific elements described before (most notably, chromatic time and the interaction between variable and fixed forms), these works can clearly be grouped together, since they not only feed off one another (a common trait in my working habits), but also immediately extend specific areas of research left untouched in a directly preceding work.

The first of these works, *Waves 11 – 13* – written in March 2008 for the *LOOS electronic acoustic media orchestra* and scored for 'Treble Instruments, Variable Ensemble and Sinetones' - 'simplifies' certain elements of *Wave 6* by reducing multiple-octave microtonal activity to microtonal activity within one single register, but also introduces two important new elements in the form of:

a) 'Moving' tones (supplied by an obbligato sine tone part);
b) regular, *Periodic*, entries.

Where many of the works discussed so far could be characterized by an ongoing 'entering and exiting' of instruments, resulting in a continuous flow, the introduction of these 'periodic entries' was made in order to not only enhance a greater perception of time-development (due to their regularity), but to include observable occurrences of silence as well. Also, in their guise as 'solo entries', the Periodic Entries were intended to obtain a higher degree of intimacy and detail than could be achieved with the thicker – and much more monumental - textures of some of the former works. Allotted to specific solo instruments, designed to stand out from the rest of the ensemble, these Periodic Entries subsequently became another of the so-called 'Fixed' score-elements (meaning that the notated information was obligatory and not subject to choice, as is the case in the 'Free' elements of these scores).

In essence, *Waves 11 – 13* is probably one of the clearest examples of 'Time-Interval' pieces I have written. Formatted into three uniformly long sections of six minutes each, the Periodic Entries (which are in this case equivalent to the overall 'form') subsequently revolve around one specific interval and one specific register per movement.

Thus,

- *Wave 11* consists of a minor second cluster in medium register, divided over two alternating lines of ten equal, 10-cent, divisions (twenty entries in total);
- *Wave 12* consists of a major second cluster in low register, divided over three alternating lines of ten equal, 20-cent, divisions (thirty entries in total) (see Fig.7) and
- *Wave 13* consists of a minor third cluster in high register, divided over four alternating lines of ten equal, 10- and 20-cent divisions (forty entries in total).

As can be seen from the above - and unlike the division of *Wave 6* into eighth, sixth and quarter tones - the microtonal increments in *Waves 11 – 13* are now standardized into an entirely abstract system of either ten or five equal divisions per minor second, using *cents* as the main method for identification. The decision to use decimal divisions of the semitone, signified by cents (instead of quarter-, sixth- or eighth-tone accidentals) was prompted partly by the desire to further subdivide the semitone and partly for practical reasons, since divisions into abstract cents are simply by far the most practical method for musicians to 'visualize' incremental proportions.

The Periodic Entries are then placed into clear 'Cross-forms' for each separate section, centering on pure unisons at the beginning, middle and end of each movement. Due to the combination of the expanding intervallic gamuts and the uniform durations of each movement, the entries subsequently both *speed up* with each section (from once every fifteen seconds in *Wave 11* to once every seven-and-half seconds in *Wave 13*) as well as achieve greater *density* per section, as more and more of the Periodic Entries overlap; thus bringing the domain of 'interval' and 'time' into a very close relationship.

Closely related to this 'Pitch-Time' unity, a second important element of the score lies with the introduction of 'moving' microtonality, in the form of sine tone sweeps. Aside from simple matters of beauty, these pure sine tones were mainly introduced in order to investigate the relationships between microtonal *motion* and time - resulting in a form of microtonal 'counterpoint' in the score - but also in order to give the Periodic Entries something clear to refer against – and thus enhance small fluctuations in sound. This resulted in the constructing of a sine-patch, which combines both of these functions: stationary, as well as moving tones, always alternating one-at-a-time.

Throughout *Waves 11-13* these 'sweeps' are divided over two alternating sine tones, which either approach each other and move away again (*Waves 11* and *13*), or move in ascending or descending forms of parallel motion (*Waves 11* and *12*). Striving for clear, observable parallels between the sines and the Periodic Entries, the sines then mirror these entries as closely as possible, in speed (accelerating per section, by gradually increasing the width of their individual sweeps while simultaneously decreasing the amount of time allotted to each sweep), as well as in register and density.

In this way,

- The sines in *Wave 11* - tuned a minor 2nd apart - move at speeds of 10 cents per 15 seconds, gradually approaching each other and meeting up at the halfway-mark between both sines, before eventually both descending and joining up on the lower of the two sines by the end of *Wave 11*;

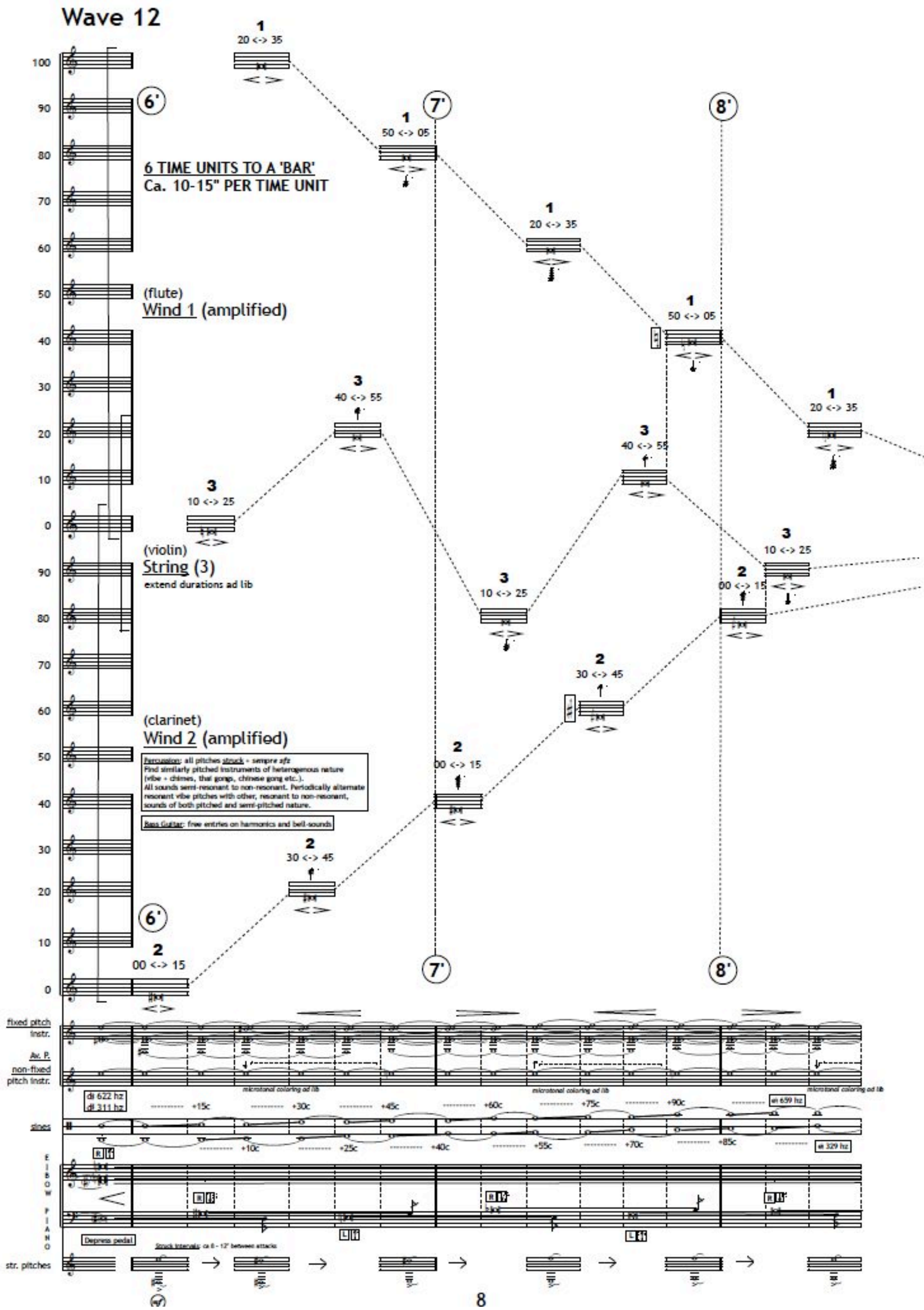

Figure 7: beginning of Adriaansz, *Wave 12.* ©AsZoh Press, 2008.

- The sines in *Wave 12* - tuned in octaves - move in alternating parallel sweeps of 15 cents per 10 seconds, ascending a full semitone by the halfway-mark, before descending again to their original positions (see Fig.7); and
- The sines in *Wave 13* - tuned a major 9th apart (and now doubled in both registers, i.e. four sines in total) – move at speeds of 25 cents per seven-and-half seconds, gradually approaching each other and meeting on a pure octave by the halfway-mark, before moving outward again towards the end.

As can be seen from the above, the sines thus complement the Periodic Entries in all respects: through acceleration (speed), expansion (register) and doubling (density), in this way contributing to a clear one-on-one relationship between both parties.

One final notable feature to be mentioned is the inclusion of extremely low, periodic, sub tones, contrasting with the overall range of the rest of the ensemble. Introduced, in fact, while working with the bass player of LOOS, this 'sound-chasm' became a recurring feature in subsequent works.

Enclosures (No 41)

The second of this trio of microtonal works, *Enclosures*, was written in the summer of 2008 for Trio Scordatura. This twenty-minute work, scored for voice, viola, MIDI-keyboard and sinetones, takes several features from *Waves 11-13* - most notably the 'interval expansion' per part, as well as the elements of Periodic Entries and Fixed vs. Free parts - but focuses to a far higher degree on investigating the speeds of extremely small microtonal increments. In this case: increments as small as 1/50th of a semi-tone. Superimposing various forms of clear logic in its construction, this leads to a work which is often highly complex in the area of microtonal reflection.

The decision to investigate this particularly minute area was actually prompted by a pragmatic problem I ran into when trying to deal with the instrumentation of Trio Scordatura: an instrumentation which included a MIDI-keyboard capable of any increment under the sun. A wonderful contraption, one might think, but in combination with the sine-tone patch I was intending to use, I found myself confronted with two very similar-sounding instruments, both capable of infinite sound and both capable of any increment imaginable. Part of this 'problem' was initially solved by giving both instruments entirely different functions: allotting the functions of *constant motion*, with static dynamics (only perceptually growing or decreasing due to matters of density) to the sine tones, while allotting the functions of *graded motion* and amplitude swells to the MIDI-keyboard. With the sine tones in constant motion however – and needing at least one instrument to stay as close as possible to the original chromatic gamut, for purposes of tonal focus – this meant that only very minute increments could be portioned out to the keyboard: a pragmatic solution, eventually resulting in no less than ninety-six separate tuning preparations for the keyboard.

'But are any of these infinitely small intervals actually *audible*?'… one might be tempted to ask. (In so far as this obvious question hadn't already surfaced several times in the reader's mind by now). To this I can only answer: as an isolated pitch-event, 'most probably not'. But in the form of long successions of regularly increasing or decreasing increments, gradually changing bit by bit, most definitely 'yes'. What one tends to hear first and foremost however is not a *pitch*-event, but simply the sensation of something speeding up or slowing down.

Which brings one of the not-so-hidden topics of this article up to date again:
'Pitch' and 'speed' are intimately connected and clearly discernable in the smallest of increments (so why even concern ourselves with matters of *rallentando* and *accelerando?* It's all there already…).

Divided over three uniform movements of 7 minutes each, the parts for voice and viola in *Enclosures* essentially conform to the formats used in *Waves 11-13*, i.e. 'Periodic Entries' consisting of two to four contracting or expanding lines - with forms of 'unison' at beginning,

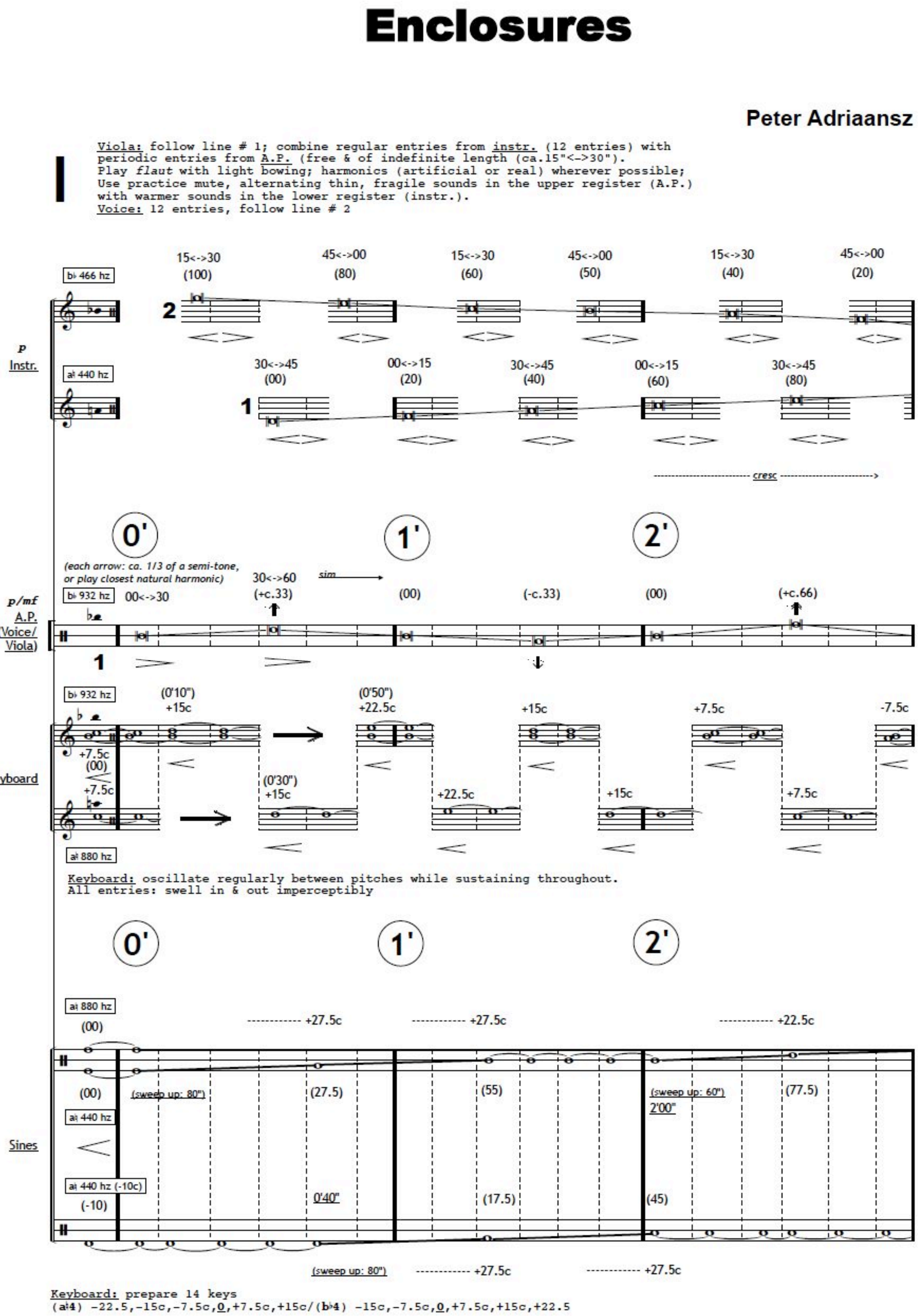

Figure 8: opening of Adriaansz, *Enclosures.* ©AsZoh Press, 2008.

middle and end – which are divided over gradually expanding chromatic gamuts in different registers. The microtonal subdivisions are similarly based on increments of 20 cents (*Enclosure 1*), 10 cents (*Enclosure 2*) and combinations of 30- and 10 cent-divisions (*Enclosure 3*), with the time intervals between entries again accelerating from once every fifteen seconds in the first section, via once every ten seconds in the second, to once every seven-and-a-half seconds in the third. Aside from the Periodic Entries, the two instrumentalists are also supplied with a gamut of 'available pitches', in the form of parabolic curves, which are placed in registers outside of the 'main' register and from which they can choose and combine at will.

The parts for keyboard and sines are however a good deal more complicated than in the former work and can actually only be explained by looking at each section as a whole.

Conceived in such a way that each member of the ensemble – i.e. (1) Periodic Entries (voice + viola), (2) keyboard and (3) sines - *encloses* the amplitude of one or more of the others,[8] each of the sections basically allots different increment values to each of its members. These values then remain consistent throughout the entire section. In this way, in the first section for example – divided over two semitones in two octaves and written in perfect mirror form - the Periodic Entries 'enclose' the sines in the lower register, while the keyboard 'encloses' the sines in the upper register. Though partially an abstract construction, this has the Periodic Entries moving at 20-cent intervals, the sines at 10-cent intervals and the keyboard at 7.5-cent intervals, though each of the members has different overall interval-widths in which to work (see Movement I, Figure 8).

Each member of the ensemble then proceeds through time in a different way, with the Periodic Entries moving in *linear steps* in the lower octave, the keyboard in *parabolic steps* in the higher octave ('over', for the first half of the movement and 'under' for the second) and the sines, starting as an 'out-of-tune' octave with the two lower pitches tuned 10 cents apart, gradually sweeping up over an entire semi-tone and approximately half of a semitone before retrograding this process for the second half. In this way, the sine tone part is a particularly complicated entity, since it concerns itself more with preserving specific amplitude-widths in relation to very precise speed divisions than with simple motion through time.

Throughout the remainder of the piece, the basic features described above – linear motion vs. parabolic motion, mirror forms vs. linear forms and, often wildly differing forms of 'amplitude enclosures' - remain intact, though subdivided and orchestrated differently for each section.

With keyboard increments eventually ranging from 2 cents and 5 cents in the final section, via increments of 7.5 cents in the first, to increments of 10 cents and 25 cents in the central section, each of the three sections ends up having an entirely different character, with the central, second section obviously standing out as the most 'microtonal' of the three due to the 'large' 25-cent increments.

Only in the last section, however, is the true topic of 'speed' fully revealed, when the keyboard passes through a gradual, linear, expansion of 2-cent intervals. Accumulating a string of twelve such consecutive 2-cent steps by the halfway-mark – against two static pitches - and then reversing the process, the section first speeds up dramatically, before winding down again, demonstrating clearly how microtonality and speed are interrelated.

Thus, even though partially using identical forms to those used in *Waves 11-13*, *Enclosures* eventually ends up sounding significantly different. This is due partly to the more limited setup - with fewer instruments allotted to the periodic entries than in *Waves 11-13* and a thus more horizontal, 'melodic' feel to the work - but is also due, and in a very significant way, to the special interaction between sines and MIDI-keyboard.

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[8] Meaning that each amplitude is 'surrounded' by a different, larger, amplitude – hence the title. A rule, which incidentally also applies to matters of register.

Music for Sines, Percussion, eBows & variable Ensemble (No 42)

The final piece to mention in the context of these three microtonal works is a work called *Music for Sines, Percussion, eBows & variable Ensemble,* written in the summer and fall of 2008, for ensemble MAE. As the title indicates, this work not only allots a role of importance to the sine tones, but also to the percussion, a role, which in essence deals with the relationship between microtonal motion and 'tempo'. Where *Waves 11-13* thus dealt primarily with 'time' and 'motion' and *Enclosures* with 'speed', *Music for Sines, Percussion, eBows & variable Ensemble* deals primarily with the areas of 'pulse' and 'tempo'. Though obviously related in many ways, each of these three works thus deals with fundamentally different aspects of microtonality.

Divided into five sections of uniform length (six minutes each, lasting 30 minutes in total) - and including all of the main ingredients discussed in the three preceding works - these five sections expand gradually, in a sort of jagged wedge-form (up one octave, down two, up three, down four etc.), while highlighting different registers and shape combinations with each new section. The more the piece moves away from the center, the larger the overall range and the more complex its figurations become. In the area of register, this work stands apart from the former two with the inclusion of both low and very low sections, thus giving the work a much 'darker' atmosphere than the two preceding works.

Since the activity of the Periodic Entries basically complies with most of the procedures described earlier – only now centering on wider interval constructions consisting of major-second gamuts – I will now mainly focus on the two most obviously deviating features of this work: the sines and percussion.

As for the Sines:
Constructed around varying combinations of major second aggregates, the sine-tones move at minute increments of 1/100th of a semi-tone in the first section (i.e. increments of 1 cent) to 1/20th of a semi-tone by the last (i.e. increments of 5 cents), while passing through the intermediary increments in the connecting movements (i.e. 2 cents, 3 cents and 4 cents respectively), hereby causing the overall sensation of tempo to either speed up or slow down depending on the register of each section. In this way, the sines automatically deal primarily with *pulse* - since 'motion' is as good as inaudible over extremely small increments. As a result, the motion of the sines is entirely *graded,* moving step-by-step through expanding and diminishing incremental loops and changing always at exact points in time.
In three of the movements, Movements I, III and V, these graded increment-changes are also accompanied by long, gradual sweeps.

In this way,

- The 'pulse tempo' for section 1 (1-cent increments in medium register) is basically 'slow' (lying between tempi of MM 10 and MM 30),
- The pulse tempo for section 2 (2-cent increments in high register) is basically 'fast' (lying between tempi of MM 42 and MM 328, with a central tempo of MM 126),
- The pulse tempo for section 3 (3-cent increments in low register) is basically 'slow' – yet slightly faster than section 1 (lying between tempi of MM 16 and MM 37),
- The pulse tempo for section 4 (4-cent increments in very high register) is basically 'very fast' (lying between MM 69 and MM 552, with a central tempo of MM 184) and
- The pulse tempo for section 5 (5-cent increments in very low register) is basically 'moderate' (lying between tempi of MM 12 and MM 72) – yet quite violent in its beatings.

As can be seen from the above, no 'absolute' relationships can thus be derived from tempo and register, since these are highly dependent on the width of the increments used.

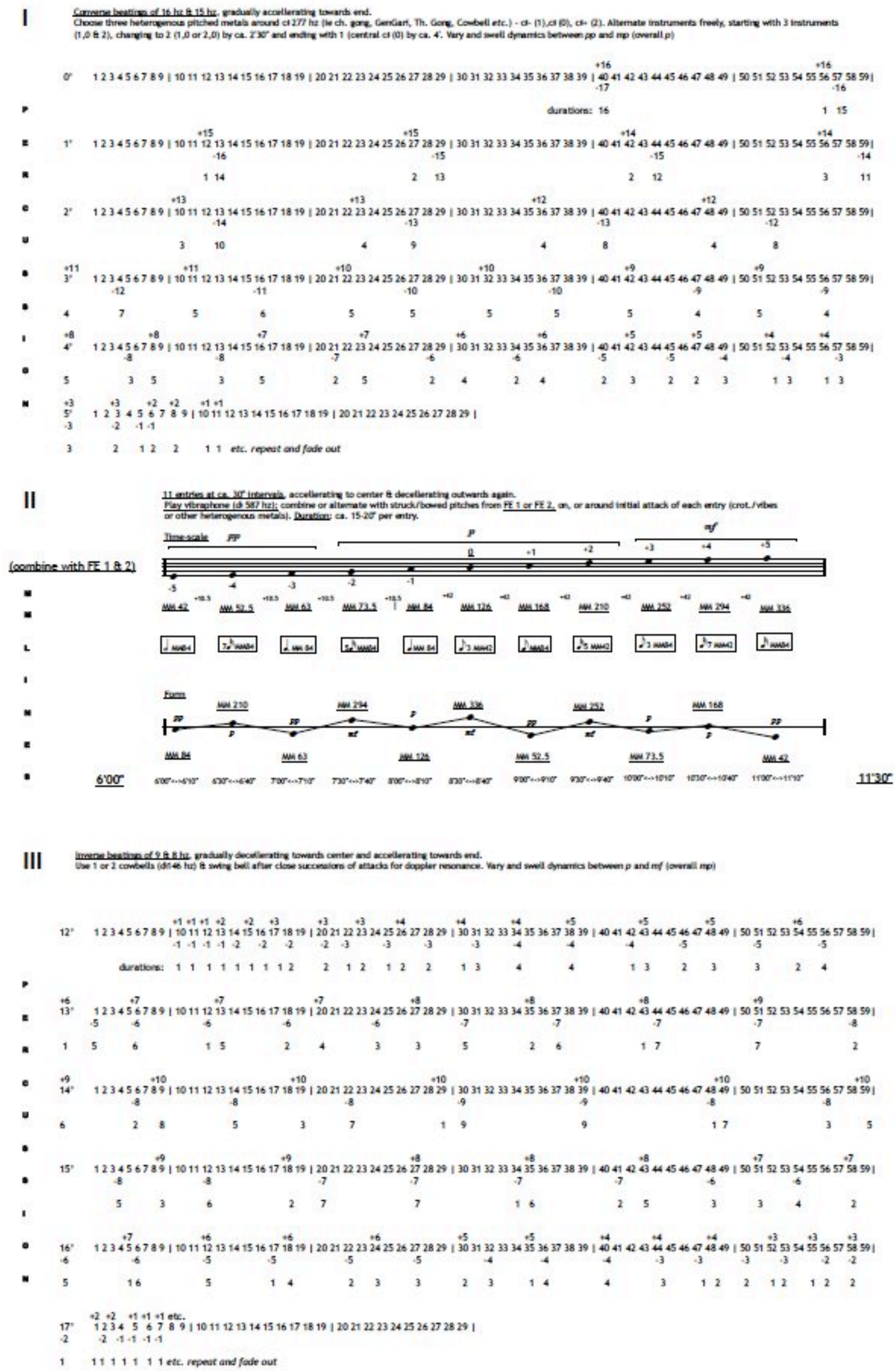


Figure 9: percussion material in Adriaansz, *Music for Sines, Percussion, eBows & variable Ensemble.* ©AsZoh Press, 2008.

The percussion part (see Figure 9 for Movements I to III) subsequently seeks to either highlight or complement some of these tempo properties. Constructed around specific lines from the Periodic Entries, the percussion essentially 'mirrors' the inherent beatings of these particular lines as they approach each other or move away from one another; but does this in two different ways:

a) As a simultaneous conversion of Hertz to Pulse, creating either converging or diverging, but always, *linear* attacks in relation to the lines it mirrors;
b) In the form of *Free Entries*, again based on a gamut of Hertz conversions, but creating *a-linear* attacks in relation to the lines it mirrors.[9]

In the first of these forms, the percussion moves through a series of gradually accelerating or decelerating attacks, which move either in *parallel* with the lines it mirrors (through copying the Hertz values of either line as they descend or ascend), or *a-parallel* with the lines it mirrors (through a retrograde of the same Hertz values). So where, for example, in the first section d 294 Hz and c 261 Hz gradually approach each other, the percussion, on c# 277 Hz, will play the corresponding attacks of 16:17 (in the form of one attack each 16 or 17 seconds) and gradually accelerate to 1:1 (in the form of one attack per second), thus *converging* as the two outer lines also meet up. And where, in the third section, Eb 156 Hz and C# 137 Hz gradually converge on D 146 Hz, the percussion will play the inverse attacks, through gradually decelerating from 1 attack per second to attacks of 10 against 9 - parallel to the Hertz difference between the adjacent pitches, but essentially *opposing* the outer lines' approach.

In the second form, the percussion entries are notated in the form of a 'Time Scale' of metronome markings - again derived from the Hertz motion of one specific set of intervals, but multiplying its tempo-proportions on both sides, with both higher as well as lower tempi. In this case however the percussion is free to enter at choice, thus creating a more random form of rhythmic counterpoint.

Through the interaction of *attack* (percussion) and *beat* (sine waves), *Music for Sines, Percussion, eBows & variable Ensemble* thus seeks to shed light on some of the more rhythmic aspects of microtonality.

Thus, summing up: as can be seen clearly – and this is something I hope to have demonstrated throughout the discussion of these final three works – everything, from time to motion and from speed to pulse, is derived from a simple, and sometimes not so simple, analysis of inherent microtonal properties.

Practice, Performance & Listening

Concerning the performance practicality of all these, often minute microtonal increments, I ought to point out, finally, that the musicians are never expected to intonate perfectly, for the simple reason that it is virtually impossible. They *are* however expected to approximate 'as well as possible'. Designing the scores in such a way that the role of the musician can in fact only exist by virtue of concentration (and, due to their variability, can actually only be accomplished in close collaboration), a far more important issue in this respect is the element

[9] Demanding an enormous amount of research, first calculating the placement of the increments and then having to convert each increment to its appropriate tempo (thus jumbling together seemingly logical, yet in practice highly *illogical* combinations of proportional numbers (the increments), sequential numbers (the metronome) and exponential numbers (hertz), *Music for Sines etc*. inadvertently ended up dealing with Stockhausen's attempt to *serialize* 'tempo' as described in his article *Wie die Zeit vergeht*. Having initially had the, somewhat logical, thought that each octave could, in theory, be twice as slow or twice as fast as its prime, I soon discovered that this could never be the case however, because tempo could never be derived from pitch, but only from pulse. Thus: no pulse, no tempo. Though sympathetic in its concept, Stockhausen's attempt to serialize tempo in the same way as pitch – by according specific tempi to specific registers, accelerating upwards - therefore turned out to be scientifically untenable: fast tempi can occur as easily in the lowest registers, as slow ones in the highest. A well-known fact of course, yet not to me.

of active *listening*. Listening, not only to one's own sound, but also to the sound of the others as well as that of the total environment – and then responding to this. This, in fact is the most important parameter of anything discussed up to this point.

It is also in this area, the area of 'listening', that I encounter some of the most common errors associated with the topic of microtonality, and especially the area of microtonal reflection; the main one of which can only be described as mistaking medium for matter. This 'error' (and it can really only be typified as such) occurs all too easily if one only listens to microtonality as a form of either 'pitch' or 'pitch development', or as a form of 'extended pitch technique', instead of focusing on the impact it tends to have on its environment: a form of listening which ultimately takes place on a secondary, transcendent*,* level. Unfortunately, this kind of listening, with ears trained to be on the constant lookout for meaning and often highly suspicious of what are sometimes derogatorily termed mere 'vibrations in the ether', is still quite paramount.

All it takes though, is a simple twist of the head…

The key to this music, in performance practice as well as in the concert hall, in my opinion, lies essentially in the ability to perceive its function as 'medium'. Akin, for example, to light refracting off mist: viewed from certain angles one sees nothing, but by turning the head slightly (an exact parallel to turning one's head when listening to small, interfering, increments through loudspeakers) a rainbow will often appear - seemingly out of nowhere.

In my own case, working with microtones does not occur out of a sense of purist tuning, or out of a desire to extend our tonal systems, but stems foremost from a fascination with their acoustic properties, both in thin as well as in thicker textures. Where the thinner textures tend to lead to the production of exquisite ripples in sound – like light briefly reflecting off a diamond – the thicker textures can lead to the summoning of harmony; and it is mostly from these pre-occupations that I use microtones.

Conclusion 2

Thus, the key issue to all of this, my so-called 'conversion', is that a particular essence of microtonality was only revealed to me through the medium of 'sound'.
Not through its horizontal properties, not through modes, scales or tunings, but mainly through its *vertical* properties. For me it ended up having everything to do with pulsation, resonance, vibration and speed, each of which was already imbedded in the DNA of any small interval. Coupled to my belief (see 'the tree') that everything is already embedded in everything – and that 'music' simply *is* - this was like discovering the atom: the kernel which caused all to grow and seemed to epitomize a way of listening, which eventually could lead to a real – and, in my opinion – necessary form of concentration.

Oberlin/The Hague, December 2008

SOME THOUGHTS ON LINEAR MICROTONALITY

Frank Denyer

The growing use of microtonal intervals in composition has influenced and been influenced by diverse forms of pitch analyses. This has, by and large, concentrated on aspects of the harmonic series, often advocating its authority as the most 'rational' or 'scientific' foundation for understanding musical scales. In such work musical intervals have been described as 'true' when they conformed to mathematical ratios that demonstrated their precise place and derivation in the model. This has opened up new areas of enquiry but has also led such work to be unusually susceptible to academic pedantry. The harmonic series, because it is 'harmonic', is made up of intervals that are most acutely appreciated when their component notes are heard as simultaneities.

In my own work I have approached microtonal issues from a different viewpoint, focusing primarily on the perception of *linear* microtonal relationships. For reasons that will become apparent, the two perspectives do not have many points of convergence. The fact is that our human perception of micro-intervals is considerably altered when we hear the constituent notes linearly (i.e. one after the other) rather than simultaneously, a fact that can be easily verified in the studio.

The linear investigation I advocate is not based on an extracted set of mathematical relationships but on the observations of our perceptual intelligence allied to the unaided capacities of the human ear and the interpretation of its data by the brain. So much of our hearing is interdependent with other mental functions that we must take the whole skein together, and there can be no excuse for excluding awkward aspects of listening – such as the inherent capacity to privilege certain aural information, or the propensity for misperception and aural illusion due to the natural limitations of the sensory organs and the associated processing. Neither should we devalue the ability of such a complex web to trigger responses in far flung neural networks of the brain, because that is exactly what gives sound its unrivalled suggestibility and essentially its capacity to become music.

Let us first consider one tiny piece of actual perceptual evidence. Laboratory data shows that even primary intervals from the harmonic series, such as the octave or fifth, when heard linearly, are usually judged by musicians as being 'completely in tune' only after their harmonic identity has been slightly modified, most often by making them a few cents narrower than that produced by the pure ratios. In a test I conducted at Wesleyan University in 1977, two tunable oscillators were set up in such a way that when either one was sounding the other was switched off. Thirty-five musicians attended individually and each was asked to tune one oscillator to a perfect fifth or an octave above the other, but they could never hear both notes simultaneously. However, they were free to go back and forth between the oscillators any number of times, and no time limit was imposed. Interestingly, the resulting (melodic) intervals were, on average, tuned flatter than their harmonic counterparts.

This appeared to demonstrate two different ways of being '*in tune'.* The question is: *being in tune with what?* Historically there have been, and may still be, many different but equally legitimate answers to this question. I also cannot fail to notice that my own temperament leads me to feel comfortable when I recognise an inner point of ultimate reference, with the power to at least modify the rigid application of externally imposed rules (much as the individual conscience is a significant factor to judgments of guilt or innocence in modern legal systems; when laws are absolute and their advocates cannot imagine circumstances where they might be modified, the result is tyranny).

Being *in tune.* Whatever it is we wish to be *in tune* with – whether an internal or external reality, the Indian atman or the Chinese huang chung (yellow bell), the voice of God, lay lines, the basic laws of the physical environment or merely our own inner nature –whatever it is, humankind has periodically become convinced that a superior form of music could be realisable, and one with unique revelatory potential, if only sufficiently rigorous efforts were made to re-establish pitch as music's deepest underlying fundamental. We seem to have carried this perennial desire to purify music so that it might better reflect a more perfect existence, perhaps even transmit knowledge of the divine itself or allow us to experience the sounds from a remote heavenly sphere, or just the essence of a bygone golden age, or at least intimations of a life more perfect than the one we now experience. Sadly, the holy grail remains elusive and as with many religious or political aspirations, the results never seem to succeed as potently as had been hoped. The quest, like that of the grail, partially fails. For some this inevitably triggers demands for the application of even more rigorous tuning theories. For others, such perfection remains to be found only in the dream of an unheard, silent or unstruck music, perfect because unrealised. Numerous world traditions are littered with tragic memorials that celebrate both sides of this divide.

In our own fragmented, individualistic and uncertain times perhaps we must be content with music that is just in tune with itself (oh, those wonderful unisons), but even then all is not health and fitness, for it still remains for us to find some practical accommodation between the *tuned* and the *out of tune.* In other societies the latter has frequently been treated with extreme caution and special roles devised even for its marginal inclusion. Not only roles but rules, their precise nature and scope being almost as diverse as humanity itself. In some form these have been formulated on every continent in almost every era. Incorporating notes that are *in tune* with others which are *out of tune* has implications that reach far beyond music, suggesting parallels with social definitions of 'belonging' and 'not belonging', the sacred and the secular, the insider and the foreigner, the civilized and the primitive, the professional and the amateur, the true and the false, or even the role of comfort and discomfort in a particular life-view.

In practice, this interface between the *tuned* and *untuned* may be extended from a sharp but crude division between good and evil to the addition of a more ambiguous but fertile no-man's land between them, or even to a complete gradation of values with the poles only as small rarified points on either end. In such circumstances the practical musician finds that being *in tune* or *out of tune* is not a mathematically fixed issue, but one that requires the negotiation of a subtle path between the physical capabilities of musical instruments and the limitations of the human ear while still remaining susceptible to wider aesthetic imperatives. This relates to many aspects of music making and not merely performance itself. Here is one very specific case: comparing a piano that has been tuned with an electronic tuner to one tuned by ear, it is clear that the exact type and degree of variation between these two methods remains an issue for musical discussion and personal judgment.

The first vague glimpse of this matrix of interconnections started to float into my mind in the early seventies. I had noticed that open-holed woodwind instruments, whether from Europe or Asia, could create remarkably fluid and organic melodic continuities, but that these features were diminished when the player performed the same phrases, with similar articulation, on the standard silver flute, even though paradoxically the latter had the capacity to produce notes that were said to be more *in tune*. Open-holed instruments allowed a rounding of certain intervals precisely because the intonation was more malleable and it was clear that an experienced player took full advantage of this. I concluded that late 19th/ early 20th century European woodwind instruments, with their greater uniformity of bore, accuracy in the location and size of finger-holes, precision key mechanisms, not to mention developments of mouth plates and reeds, might be less responsive to my particular aspirations as a composer, searching as I already was for a melodic line inherently softer, flexible and more fluid than any I had yet come across.

Therefore, when writing my piece *After the Rain* (1983) and trying to envisage a suitable ensemble that might support a solo shakuhachi and solo violin, I chose three ocarinas and percussion, partly because the ocarina had a particularly large number of variables that affected pitch, and this unpredictability tended to create a soft edged intonation. This was further reinforced by the instrument's soft attack and overall dynamic level. It could have been argued that this tactic would merely produce a certain randomness of intonation, but I considered that this uncertainty might already go some way towards modifying the hard-edged pitch-tyranny with which I was surrounded and from which I was trying to liberate myself.

Such experiences were indeed liberating and soon I was able to grasp some more focused specifics. For example, I found that in a linear context, flattening an harmonic interval by a few cents would soften its outline and when melodic intervals like octaves, fifths and fourths were treated in this way, there was also a greater propensity for the two notes to bind themselves together as a unit, an important factor when attempting to make coherent melodic wholes.

The opposite tendency occurred when a primary interval was slightly widened. The sharpening of an interval increased its outward movement and it appeared brighter and more energetic than it would otherwise. Here there was a tendency for the notes to separate and the linear bonds that link them to weaken. (In a real musical context there may be other factors that nullify both considerations. It is well to remember that harmonic content is particularly potent in this respect.)

If narrowing were to be compared to a visual artist rounding off the corners of a square, rectangle or triangle, then randomly mixing, narrowing and widening would be more like drawing geometrical shapes 'by hand'. Neither affects the fundamental identity of the shapes themselves, but compared with the hard, precisely delineated figures drawn with ruler and compass, they appear less rigid, more inherently flexible, and so more 'humane' perhaps.

Such adjustments of intonation all occur at the micro-level. But it is precisely at this level where another facet becomes inter-connected. In a linear context, the very tiniest changes of frequency (less than five or six cents) appear not as pitch alterations at all, but are heard as changes of timbre. In the other direction it follows that a particular timbre change might have an impact on our linear pitch perception. This suggests that instrumentation may actively affect intonation judgments.

At this point we might pause to consider the distinction between 'pitch' and 'note'. When the Berlin Philharmonic decides to raise its standard pitch very slightly (which they do periodically), clearly the musicians themselves continue to play the same notes as before. If the pitch of an unaccompanied singer gradually becomes sharper during the course of a piece, the actual notes remain the same although their individual frequencies may be increasing. While working in Kenya's Kerio Valley I noticed that lyre players could consider two strings to have an octave relationship and be acceptably *in tune* even when one of them was more than a hundred cents away from the 2:1 harmonic ratio. This is probably because they employ a gamut of just five notes, somewhat casually spread out between the octave, so the identity of adjacent notes is never compromised, and the essential pitch relationships remain the same, making them indeed *in tune*. In all three cases outlined above, the musical context has maintained the structural function of the notes and they are not considered as having been altered.

Thus arises an interesting question which has long fascinated me. What particular musical conditions might I create that would allow a very slight frequency change to be perceived as a distinctly *different* note rather than a variant of the same note; and how, on the other hand, could I make a significant frequency change of perhaps more than a hundred cents seem like the *same* note? The following example from *Tentative Thoughts, Silenced Voices* (2002-3) illustrates how I have dealt with this and other related issues in practice (Figure 1). (A key to the accidentals I use for microtones is given in Figure 2.)

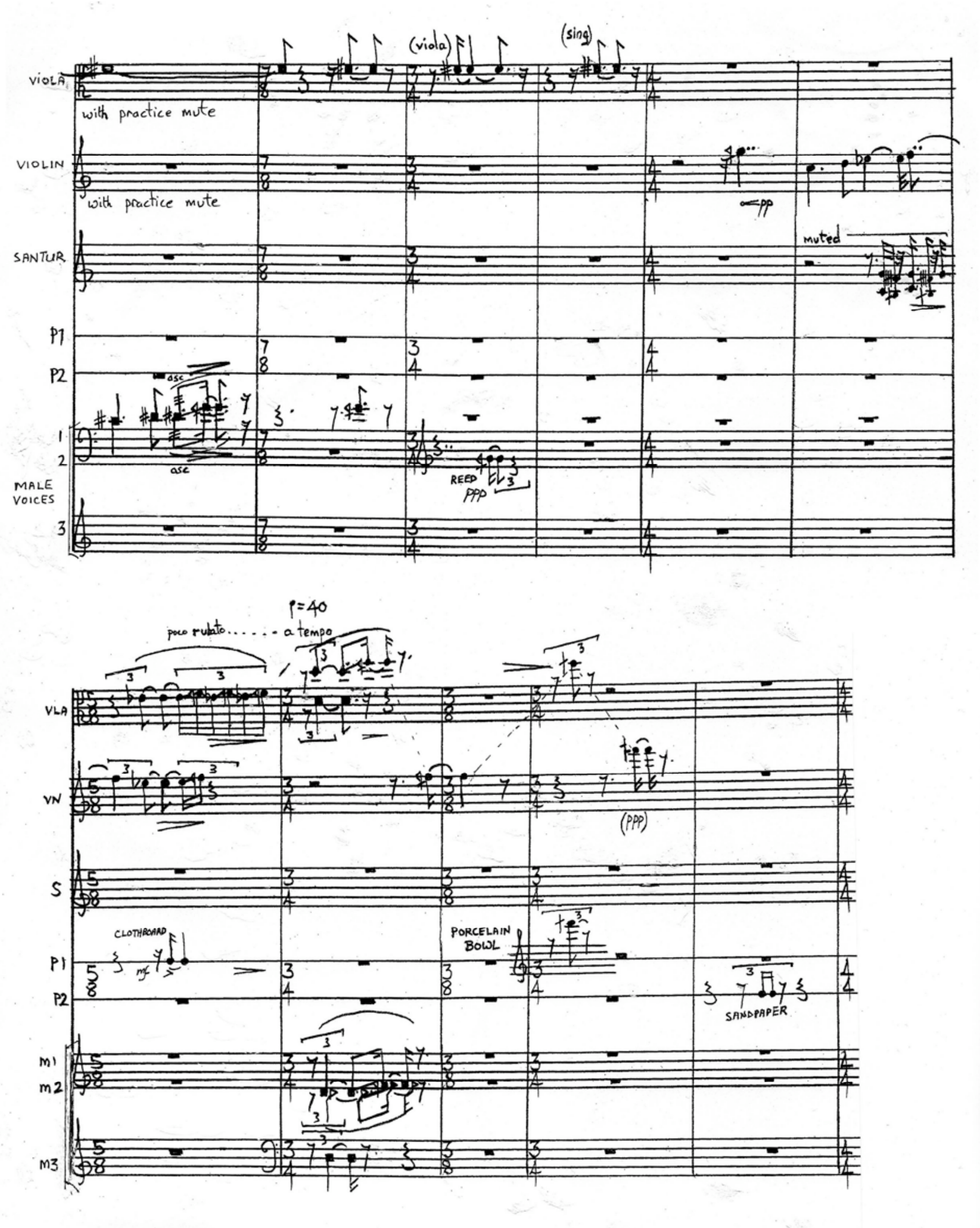



Figure 1: Denyer, *Tentative Thoughts, Silenced Voices* page 4, bars 1-9; © 2003, Frank Denyer

The play between the semitone sharp *f1* in the viola and the last note of the two male singers (a sixth-tone flat *g1*) is first heard as two versions of the same note, although it is certainly wide enough to be perceived as a pitch change and not a timbre change. The voice note is disguised by first appearing merely as the end of a small glissando. Subsequently (bar 2) these notes are repeated in alternation between the viola (sharp *f1*) and the first male voice (sixth-tone flat *g1*), and then in bar 3 between the viola and the concertina reed, and finally spread out over the whole of bars 4 and 5. During these four bars (bars 2-5) perception has been gradually changing from what appears to be two versions of the same note, to two quite separate notes in opposition. The upper one is then taken up by the violin an octave higher (sixth-tone flat *g2*) as the starting point for the next musical paragraph, which moves off with a more confident melodic intent through the interval of a falling perfect fifth, albeit narrowed by a sixth-tone. The violin adds the next five notes that are purely diatonic (bar 6) but accompanied by the santur with quarter-tone shifts. The latter do not appear as variants of each other as one might expect, or as triadic blurring, but as a definite *stepwise* movement, partly because the santur is muted to reduce its echo-like resonance. The main melody is transferred to the viola (bar 7), creating a subtle timbre change, and immediately thereafter a quarter-tone vibrato-like ornament is heard that is obviously a single note despite its pitch alterations. The addition of the rubbed clothboard to this particular viola note also helps smudge the variations in frequency.

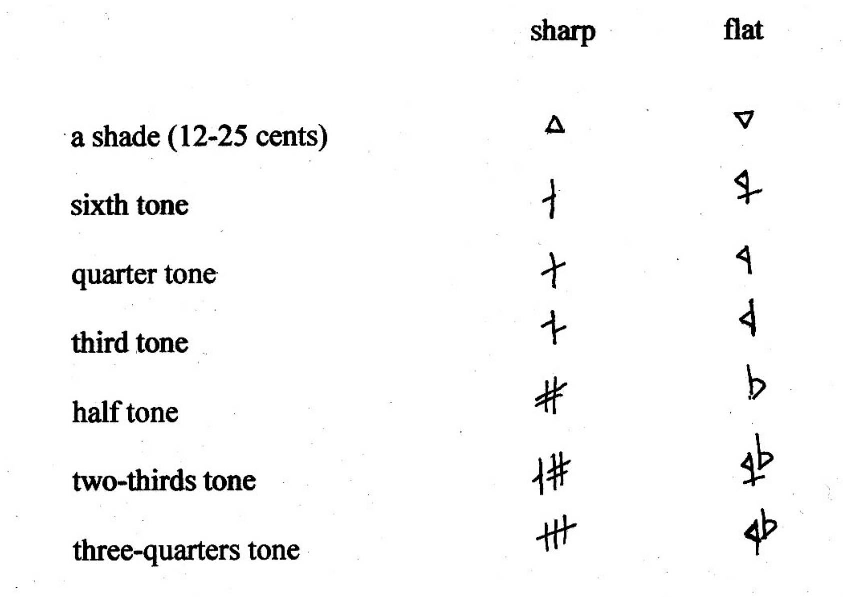


Figure 2: accidentals for microtones used in scores by Frank Denyer

Over the years I have accumulated a collection of simple pitched and non-pitched percussion instruments whose sounds are produced by friction. (Friction percussion is somewhat undeveloped in the western instrumentarium, so there are gaps that need filling and scope for experiment.) As in the musical example above, non-pitched friction percussion instruments can act as useful adjuncts to pitched instruments, as well as having their own inherent character. A flute, for instance, with its almost sine-wave purity may be easily modified by noise elements from the player’s voice or breath, but friction percussion instruments allow this process to be considerably intensified.

As a more subtle example of linear microtonal thinking I would like to turn to the opening of my piece *Ghosts Again* (2005) (Figure 3).

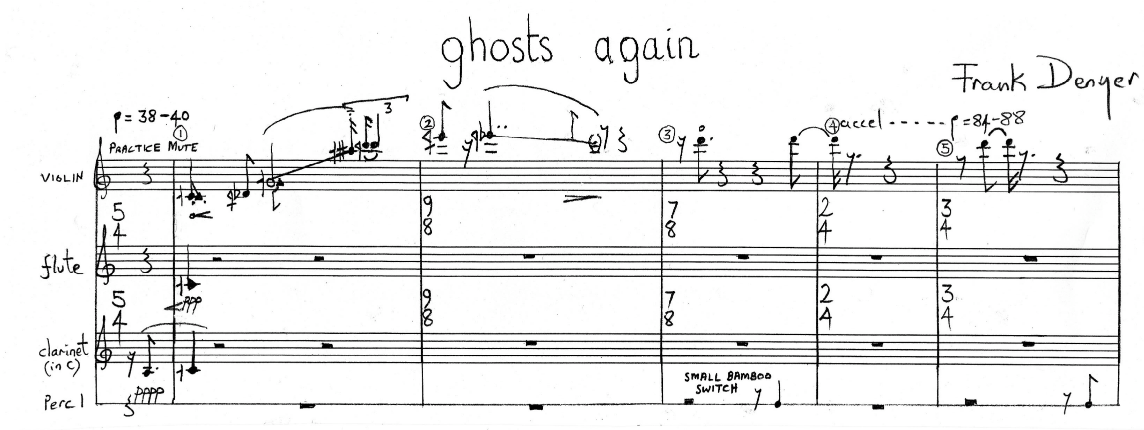


Figure 3: Denyer, *Ghosts Again* page 1, bars 1- 5; © 2005, Frank Denyer

The piece starts with a melodic arc that can be thought of as an elaborate anacrusis leading the ear forward to the note d3 (bar 2) which, as in the previous example, is first introduced only as the end of a glissando, but which is then more firmly established by being repeated. The main purpose of this anacrusis is to imbue d3, when it arrives, with a floating, un-rooted and somewhat strange character difficult to describe. I'll try to outline how this happens. The clarinet opens with an upward legato minor third that is flattened by one-sixth of a tone. This flattening softens and constrains the interval but at the same time gives it an inner tendency to expand outwards, which it does after it has been taken up by the violin (expanding from a sixth-tone sharp c1 to a two-thirds flat d1). From there it sweeps upwards in a long and unexpected curve that is tonally disorienting, especially as it comes to rest on a strange two-thirds sharp a2 that is immediately 'corrected' by a very slightly sharpened version of this same note (a quarter-flat b2). At this juncture the ear is naturally confused, but the perfect fourth leap up to the first beat of the following bar helps put firm tonal ground beneath our feet, despite the fact that the fourth is slightly widened by approximately 16 cents (from quarter-tone flat b2 to a sixth-tone flat e3). However, this sharpening pulls us back to a truer perfect fourth (quarter-tone flat e3), although any security gained is quite fleeting because the note continues to slide until it finally arrives on the all important d3. The latter now seems strange because, since the opening, the ear has been made to readjust its basic tonal orientation microtonally and this point of arrival is unrelated to any of the events immediately preceding it (but closely related to where we originally began with the first clarinet note). And so the pitch appears in all its oddness. This is crucial for what follows as the next few minutes are entirely taken up with its further adventures that evolve out of that uncertainty.

Although in this paper it is only possible to touch briefly on some simple aspects of this terrain, I would nevertheless like to add some thoughts about training and preparation. For me, unusual intervals are only viable after they have been completely internalised by the performer. This means more than merely being able to mimic them and implies that they have been absorbed into the substrata of the artist's subconscious. Is this asking too much? If not, how can it be achieved?

A culturally shared collection of musical pitch relationships is already an inner part of each individual's life from very early childhood. As such they act as a foundation for the later assimilation of musical experiences. This pitch repertoire slowly expands as the child matures but for those that are active as musicians, this development is faster and much more extensive. All intervals have the potential to accrue variants or modifications that can become deeply embedded by reference to familiar musical contexts and it is not uncommon for modified intervals to be used as a measure of stylistic authenticity. (The precise pitching of blue notes in jazz would be one obvious case but all genres are riddled with them; indeed at a more refined level it may be that the majority of notes fall into this category.) To give another example: performers of Hindusthani classical music will have certain absolute intervals (the primary harmonic ratios of the octave and fifth) both in their sub-conscious and represented externally by the ever present drone, but they will be able to utilise the other degrees of the scale, whose position is a little more subtle, having absorbed a feeling for their exact intonation through the aural tradition. There is a third category of notes whose precise pitch is contentious because even more variable and open to individual taste. The flattened 3rd in raga Jaijaivanti is one such note, its placing dependent on individual experience and always something to be argued over by cognoscenti. A dhrupad singer cannot sing Jaijaiwanti without employing this peculiarly flattened third which must be used very sparingly and with care, like a rare spice. It must also be approached and followed via the step below and never lingered over. An experienced musician can sometimes cleverly give the illusion of this note by subtle microtonal inflections of the second degree of the scale not directly touching the third at all. This aural slight-of-hand is heard in many performances by true masters of the form.

In music of all types musicians internalise different variants of particular intervals. Whatever comprises the musician's primary internal repertoire, it is of course perceived by them as 'the norm' and acts as their fundamental reference for any later expansion. However, in adult life the ability to add new and unfamiliar intervals usually slows down. This is the problem.

Nevertheless, I have found that for the preparation of my work, preliminary pitch training still pays considerable benefits. For example, performers can quite easily learn to reproduce a melodic relationship of 10-20 cents and not confuse this with an interval of 28-35 cents or one of 39-46. These distances soon become distinct and stable. It then becomes easier to progress to the introduction of larger new intervals such as +/- 240 cents, +/- 942 cents, or +/- 1041 cents. Each of these has a characteristic flavour that is also soon recognised. (I give these as simple examples but in reality the task is related to the particular demands of the composition being prepared.)

Practising equidistant heptatonic scales from various starting points can be a useful way to break out from the ever-ready western chromatic reference and the diatonic scales it supports. Then try alternating this scale with an equidistant octatonic scale on the same fundamental. In itself the octatonic scale is easier to navigate simply because alternate notes are a comfortable minor third apart (each interval is a three-quarter tone). When both feel comfortable, alter one degree of each scale by a sixth-tone. Then repeat the scale altering the same degree by a quarter-tone. Following this, alter two degrees of each scale by one of the microtonal intervals practised initially, i.e. 28-33 cents or 40-45 cents. Go on to alter one degree in one way and another by a different one. Such exercises can be extended as required. The technical limitations of unmodified equidistant scales derive from their rigid symmetry, a consequence of being comprised of identical intervals. Each transposition or tonic shift can therefore only produce a clone of the same scale.

In more recent years I have come to use more elaborate methods and to give an idea of them I would like to take an example from *Unnamed* of 1998 (Figure 4). This is a long solo composition for shakuhachi. It is helpful to keep in mind that here 'a note' is often a 'pitch-field' rather than a discrete frequency. These fields are not uniform in scope. In passages that use, or partly use, the equidistant heptatonic scale, I have attempted to give each note its own particular set of characteristics within its individually sized pitch-field. One degree might have variant alternatives that result in very slight shifts in its pitch position almost each time it occurs; another has satellite notes that tend to blur or colour it like ornamental moons and it will never be heard in isolation; then there are others that always appear in movement, traversing their field, while still others that have narrow fields and remain stable and unadorned. In addition to this now complex scale the piece as a whole contains several other note sources with quite different derivations but which simultaneously share the musical territory. First, there are the four strongest notes of the shakuhachi (foundation tone, fifth, octave, twelfth and fifteenth), then the pentatonic scale produced by the open holes of the instrument (not at all equal-tempered pitches), then some more complex notes produced through the shakuhachi's characteristic *meri* technique, and finally sections of the western chromatic scale (with the addition of some quarter-tone passing notes). All together, these make a very complex matrix of pitch material, an extremely fine but quite asymmetric grid or galaxy. For the player it would be impossible to internalise so many micro-pitches if they were all presented as equal dots in the firmament. However, by understanding the derivation of each note, the whole can be internalised by reference to a few simple subsets. I did this in the notation by indicating each of the principal subsets with a different colour. From a compositional point of view this unevenly distributed galaxy allowed a flexibility of line to emerge, as well as the possibility to rest in various tonalities along the way.

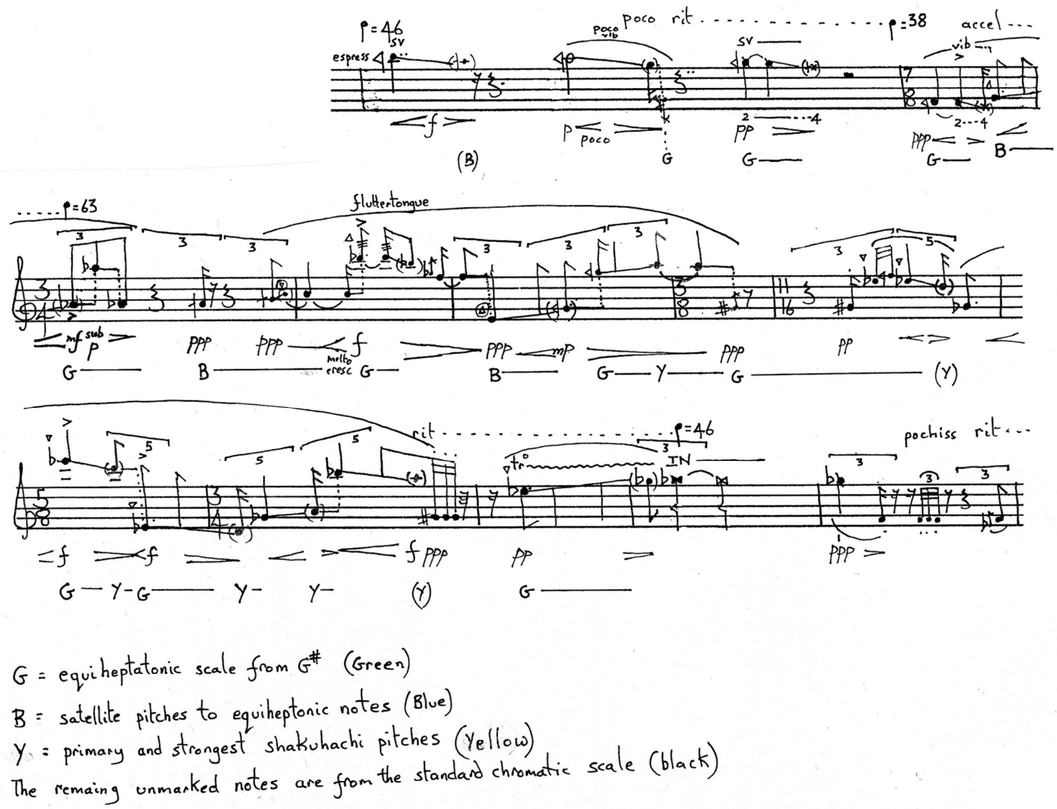


Figure 4: Denyer, *Unnamed* page 8, bars 6-14; © 1998, Frank Denyer

Such systems do not have any value in themselves and are of no concern to the listener; indeed the last thing I want is for the listener to be preoccupied with microtonality. They are used only as a compositional tool in order to make possible the kind of melodic structures I am interested in.

To some extent I can now find my way around such spaces instinctively. But even at its most prescribed, this terrain essentially remains an open one because it has to be forever susceptible to the subconscious aesthetic instincts of musicians. It is principally this factor that informs the linearity and allows for the exploration of those mysterious and ambiguous areas that form the borderline between conscious and sub-conscious perception.

December 2008

Note

Tentative Thoughts, Silenced Voices and *Ghosts Again* are recorded on *Frank Denyer: Silenced Voices*, Mode 198 (2008). *Unnamed,* performed by Yoshikazu Iwamoto, is recorded on *Frank Denyer: Music for Shakuhachi,* Another Timbre AT03 (2007). For more information: www.frankdenyer.eu.

KEY ECCENTRICITY IN BEN JOHNSTON'S SUITE FOR MICROTONAL PIANO

Kyle Gann

One of the most pervasive preconceptions about just intonation is that one can only play in the key to which a just intonation scale is tuned; that modulation is impossible. The obverse, more positive way of stating this is that, given a limited just intonation system, each pitch selected as tonic will reconfigure the scale into a different array of intervals. That doesn't mean you can't modulate: it means that each key will have its own personality, its own repertoire of affects, which was also true in 18th-century well-tempered keyboard music. Some of the most inventive composers of just intonation music have not only dared to write in keys unsupported by their central tuning, but have deliberately skewed the music away from the central tuning for more exotic effects. The result can be a kind of three-dimensionality whereby the scale shines through from several different perspectives.

Within the available repertoire, the principle is most obvious in keyboard works in which only twelve pitches in a repeating octave are available, and I will mention three. One is La Monte Young's six-hour improvisatory work *The Well-Tuned Piano*. The keyboard is tuned to seventh and third harmonics of E-flat and their derivatives. The work's primary theme, however, can be transposed within the scale from E-flat 1/1 to D 63/32, G 21/16, and C 7/4; and except for the last (which Young's improvisations have not yet led him to), it *is* so transposed, with attendant variations resulting from the peripheral intervals available in each key. I've written about this at length in 'La Monte Young's *The Well-Tuned Piano*' in *Perspectives of New Music*.[1] A similar though less extreme example is Terry Riley's *The Harp of New Albion*. The scale here is a relatively 'conventional' five-limit, 12-pitch scale centered around C-sharp. However, the eleven movements employ the tonal centers A#, F#, D, A, B#, and B.[2]

Easier to discuss in detail, because it is fully notated, is Ben Johnston's *Suite for Microtonal Piano* of 1977. The piece requires tuning the keyboard to 12 harmonics of the pitch C, namely harmonics nos. 16, 17, 18, 19, 20, 21, 22, 24, 26, 27, 28, and 30. Below are given the 12 keys of the piano scale, then the ratio of each note to C 1/1, and then the note's notation in Johnston's own just intonation notation:

C	C#	D	Eb	E	F	F#	G	Ab	A	Bb	B
$\frac{1}{1}$	$\frac{17}{16}$	$\frac{9}{8}$	$\frac{19}{16}$	$\frac{5}{4}$	$\frac{21}{16}$	$\frac{11}{8}$	$\frac{3}{2}$	$\frac{13}{8}$	$\frac{27}{16}$	$\frac{7}{4}$	$\frac{15}{8}$
C	C17#	D	E19b	E	F7+	F↑	G	A13b	A+	B7b	B

Figure 1: Tuning of the piano in Ben Johnston's *Suite for Microtonal Piano*

In Johnston's notation, C E G, F A C, and G B D are purely tuned 4:5:6 triads. The plus (+) raises a note by 81/80, the syntonic comma, or 21.5 cents. A sharp (#) raises by 25/24 (70.67 cents), and a flat (b) lowers by the same amount (24/25). A seven (7) lowers a pitch by 35/36 (48.77 cents) to alter a 9/5 minor seventh to a septimal minor seventh of 7/4. An

[1] *Perspectives of New Music*, Winter 1993 (Vol. 31, No. 1, pp. 134-162).
[2] Terry Riley, *The Harp of New Albion*, liner notes to Celestial Harmonies CD CEL 018/19.

upward arrow (↑) raises a perfect fourth by 33/32 (53.27 cents) to make it an 11/8, or eleventh harmonic. The 13, 17, and 19 all adjust the pitches affected to the implied harmonics (65/64, 51/50, and 95/96, respectively).

By the conventional wisdom, this keyboard can only be played in the key of C. However, of the five movements of Johnston's *Suite*, only the first and last are in the key of C. The second movement is in D, the fourth in E, and the middle movement is atonal, organized according to 12-tone method. Though the scale remains the same in all five movements, the movements in D and E have different interval resources available than the ones in C. For instance, and perhaps most importantly, only five of the 12 pitches have perfect 3/2 fifths built on them: B7b, C, D, E, and G. Johnston uses fifths to ground chords on roots, and only five such roots are available. The key of C, then, possesses a dominant chord (G-D), but no subdominant, since there is no F a 3/2 perfect fifth below C. The key of D, on the other hand, possesses a subdominant (G-D) and no dominant chord, since A-to-E is a beat-ridden 'wolf' fifth of 40/27.

Of course, Johnston could use whatever intervals he wants from the scale, dissonant or not. But by using an unequal scale, and limiting himself (in certain respects) to transposable intervals, he treats the scale analogously to a mode. For instance, the medieval Lydian mode contains no subdominant triad; the Phrygian contains no dominant; the Ionian has no perfect fifth on the subtonic while the Mixolydian does, and so on.

For much of the first movement, Johnston introduces his scale by emphasizing its derivation from the harmonic series. A low C is held silently at first as a melody made up of the simpler harmonics (3, 7, 9, 11) bring out sympathetic resonances. Higher harmonics are introduced largely in the upper register, and at one point a large harmonic series is arpeggiated. Toward the end, however, he introduces more complexity, closing on an unusual repeated chord with the harmonics out of order (from the bottom upward): 27, 11, 9, 13, 19. Stated in terms of the aggregate frequency ratios, this is 27:44:72:104:152 – a pungent, ambiguous sonority, and not one we hear every day.

Our primary concern here, however, will be the two movements *not* in the key of C. The second movement, 'Blues', is in the key of D. Transferring the tonic to D gives us the following array of intervals in relation to D:

D	E19b	E	F7+	F↑	G	A13b	A+	B7b	B	C	C17#
$\frac{1}{1}$	$\frac{19}{18}$	$\frac{10}{9}$	$\frac{7}{6}$	$\frac{11}{9}$	$\frac{4}{3}$	$\frac{13}{9}$	$\frac{3}{2}$	$\frac{14}{9}$	$\frac{5}{3}$	$\frac{16}{9}$	$\frac{17}{9}$

Figure 2: Interval relationships in Johnston's *Suite for Microtonal Piano,* with D regarded as the tonic

The statement of the blues melody takes place over a melody of perfect fifths in the left hand, using all five available perfect fifths on B7b, C, D, E, and G (actually the G is inverted as a fourth, D-G). We have gained a perfect fifth on the flat submediant, which wasn't available in the key of C, and which, along with the subdominant and flat subtonic, become the primary alternatives to the tonic harmony. What we do not have here is a dominant chord, because the fifth A+/E is not perfect, but a wolf fifth of 40/27. This in itself gives a nuance of folk or pop influence to the 'Blues' movement, since pop and folk music de-emphasize the dominant chord, relative to European classical music.

At times when Johnston is aiming for relative consonance, his choice of left-hand harmony determines distinctions among melodic pitches. For example, in mm. 14-16, he uses F7+ when the root of the underlying chord is G, and F↑ when it is C:

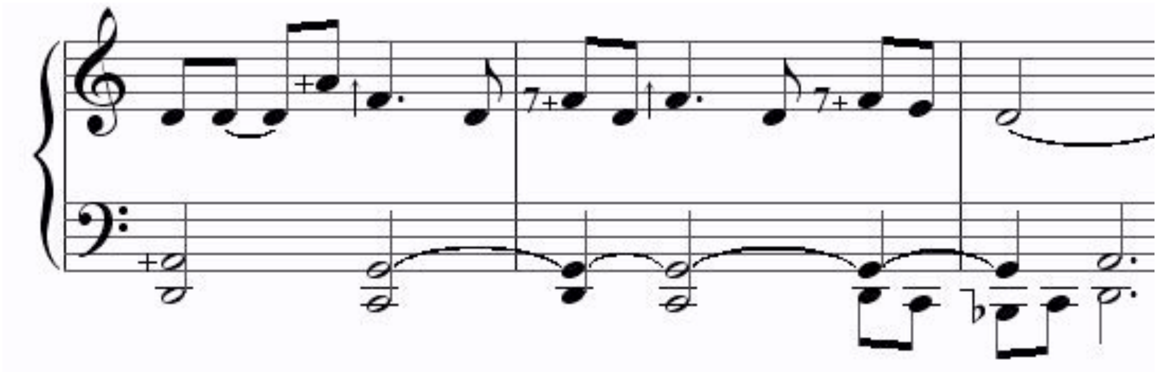



Figure 3: Johnston, *Suite for Microtonal Piano,* mov.2, mm.14-16

The D-G-F7+ chord gives a frequency ratio set of 3:4:14; the C-G-F↑ chord of 2:3:11. Were one to reverse the F7+ and F↑, the results would be D-G-F↑ (9:12:44) and C-G-F7+ (4:6:21), requiring higher numbers and therefore more dissonant. More simply put, F7+ is the 7^{th} harmonic of G, and more closely related than it is to C, and F↑ is the 11^{th} harmonic of C, whereas it is 11/6 above G. In each case Johnston uses the F in the harmonic series of the root, or lower in the harmonic series.

Later the 'Blues' does become considerably more dissonant, but there remains a tendency to contrast thicker chords on C or G with the comparative clarity of simpler chords on the tonic D. Here, a virtual harmonic series on C, containing the 3rd, 5th, 7th, 9th, and 17th harmonics, and then the 13th and 19th, resolving to a spare fifth on D (mm. 26-27):

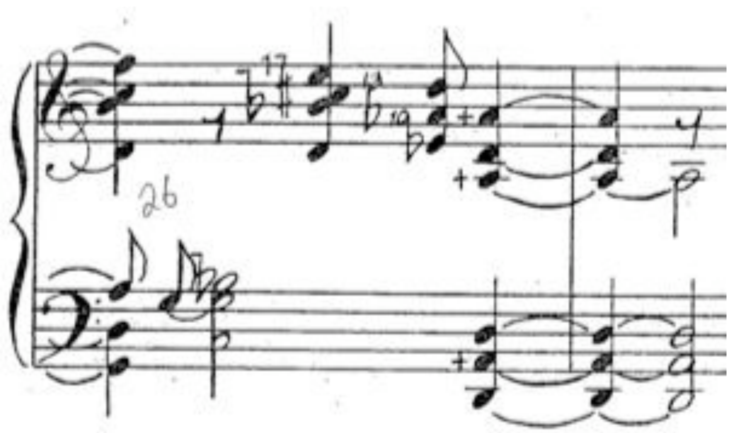



Figure 4: Johnston, *Suite for Microtonal Piano,* mov.2, mm.26-27

This is one of the effects Johnston enjoys most in just intonation music, and that he employs to greatest advantage. Just as JI consonances are even simpler and more consonant than equal-tempered consonances, so are JI dissonances more exotic and differentiated. Johnston enjoys moving from one extreme to another to accentuate that difference, and a more dramatic instance will occur later in the movement.

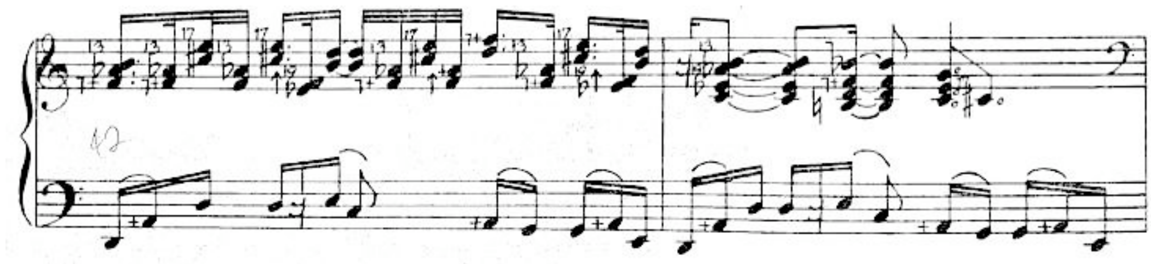
The middle section of the movement, constituting the climax, takes place over an ostinato in 13/16 meter, during which Johnston introduces more and more of the chromatic pitches, first as 'minor thirds' of a wide array of sizes (m. 42):

A13b/B	15/13	247.7
F7+/A13b	26/21	369.7
C17#/E	20/17	281.4
E19b/F↑	22/19	253.8
B/D	6/5	315.6
F↑/A+	27/22	354.5
D/F7+	7/6	266.9

Figure 5: Johnston, *Suite for Microtonal Piano,* mov.3, mm.42-43

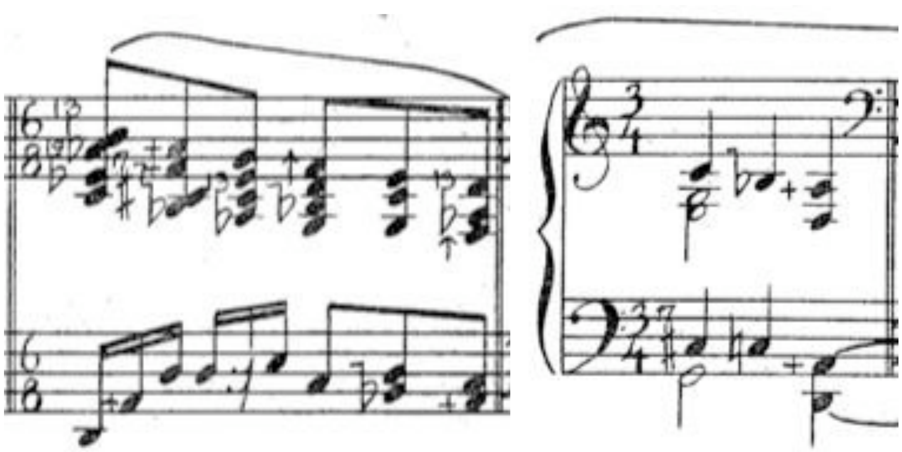
In the next few measures he applies this same strategy to parallel clusters and minor triads. In the aftermath of this buildup, the chords that descend from the climax (mm. 53-54) make a general but nonlinear descent in complexity of frequencies, as the size of the numbers show (reinterpreting the ratios of each note from the bass note as 1/1):

1/1	32/9	38/9	52/9	20/3	9:32:38:52:60
1/1	14/9	17/9	7/3	3/1	9:14:17:21:27
1/1	13/9	16/9	20/9	8/3	9:13:16:20:24
1/1	3/2	7/4	9/4	11/4	4:6:7:9:11
1/1	9/7	12/7	16/7	20/7	7:9:12:16:20
1/1	32/27	44/27	52/27	8/3	27:32:44:52:72
1/1	17/12	5/3	2/1	8/3	12:17:20:24:32
1/1	4/3	5/3	2/1	7/3	3:4:5:6:7
1/1	3/2	2/1	3/1		2:3:4:6

Figure 6: Johnston, *Suite for Microtonal Piano,* mov.2, mm.53-54

This is an immense, curved decrescendo of harmonic complexity, over a wider range than a conventionally tuned piano could afford.

In the movement's coda (mm. 55-59), Johnston eventually wanders through all of the notes of the chromatic scale (excluding the subdominant G, generally avoided in jazz scales) over a D/A+ drone, revealing in a sparer context the full array of unfamiliar X/9-based intervals that were avoided in the introduction. Thus within this brief movement Johnston goes through five stages of exploring his 9-based D scale or mode:

1. Aligning the most consonant intervals above the available chord roots
2. Contrasting harmonic series' on G and especially C with purer chords on D
3. Increasing complexity of dyads and triads over a D ostinato
4. Moving through 'parallel' chords of varying tuning
5. All available intervals (except the fourth) over a D drone

It's a satisfying, thorough, and efficient exploration of the D scale's potentials.

The fourth movement, 'song', is in the key of E, with a modal interlude on G. The opening and closing sections on E remain, until their final measures, within a Phrygian mode with the following tuning:

E	F7+	G	A+	B	C	D
$\frac{1}{1}$	$\frac{21}{20}$	$\frac{6}{5}$	$\frac{27}{20}$	$\frac{3}{2}$	$\frac{8}{5}$	$\frac{9}{5}$

Figure 7: Phrygian mode used in mov.4 of Johnston, *Suite for Microtonal Piano*

Like the one on D, this mode offers perfect fifths on the flatted seventh and sixth scale degrees, but adds a chromatic perfect fifth below the Neapolitan scale step, of which Johnston will make use. Here, there is neither a consonant dominant nor subdominant triad. In fact, one of the determinants of the counterpoint is that the A+ is a wolf dissonance with the tonic E, but consonant with D. Of the 13 A+'s used in the first 15 measures, 11 are sounded either with or immediately before or after a D, one is a quick passing tone and the other a neighbor note. The first two can be seen here:

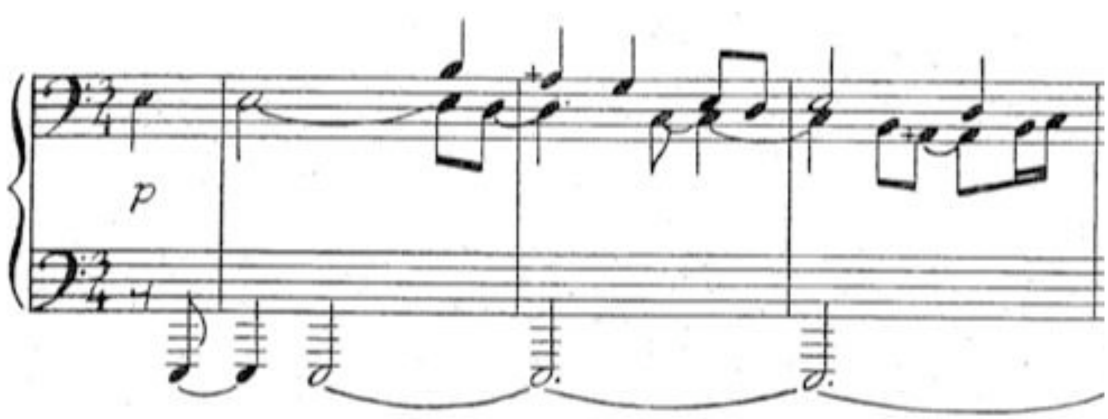



Figure 8: Johnston, *Suite for Microtonal Piano,* mov.4, opening

The E/A+ sonority is avoided throughout the movement except in the middle section in mm. 46-48, where either one note or the other is treated as an appoggiatura or passing tone over a bass D drone. (In m. 63 the A+ appears once over E as a passing tone.) Such meticulous dissonance treatment shows that Johnston is aware of where his wolf interval is, and is not allowing it to ring as such.

Beginning in m. 12 and increasing in importance, Johnston makes use of the flat subtonic triad D F7+ A+, a septimal minor triad with the tuning ratio 6:7:9 (actually more consonant than the Renaissance-era minor triad of 12:15:18). In the transition to the middle section, he suddenly raises the ambiguity level tremendously by running through an eerie series of chromatically descending 'augmented' triads beneath an E drone, harmonies deliciously unfamiliar without being terribly dissonant:

F↑ B7b D	11:14:18
F7+ A+ C17#	21:27:34
E A13b C	10:13:16
E19b G B	19:24:30
D F↑ B7b	9:11:14

Figure 9: 'Augmented' triads in mov.4 of Johnston, *Suite for Microtonal Piano*

The transition then settles into a drone on C, above which all pitches are harmonics. The middle section is a more relaxed episode in G mixolydian, over an arpeggiation of three of the five available perfect fifths (the largest chain of perfect fifths available in the scale, in fact), and with a delightfully flat seventh scale degree:

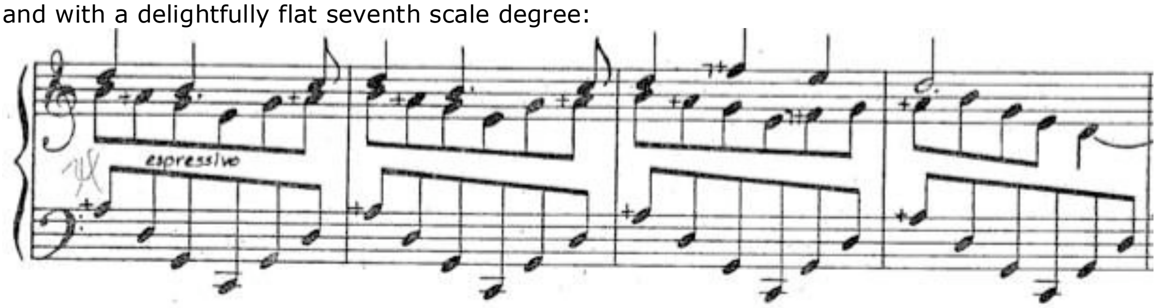


Figure 10: Johnston, *Suite for Microtonal Piano,* mov.4, mm.35-38

The final section returns to the motives and texture of the first, though with the upper melody switched into the bass, and harmonized in spare fourths and fifths. All scale degrees can be harmonized with a fifth either above or below within the Phrygian scale (E with B, D/A+, C/G, B/E, A+/D, G/C) except for the F7+, and Johnston adds unexpected spice to this line by harmonizing F7+ with B7b, the tritone of the tonality. Once again, as in the first section of 'Blues', he's fashioned a line from all five available fifths. In the last three measures, Johnston cadences on a picardy third by sounding an E drone note, then bringing in a 5/4 G# harmonic by having the pianist touch the string at the proper node for the fifth harmonic. Thus, on a keyboard tuned to 12 pitches, Johnston writes a piece employing 13.

As a composer writes, his imagination flows outward to take in all the resources he or she has available. Obstructed by limitations, the imagination turns in another direction, and can find new possibilities that might not have originated in pure thought. There is a give-and-take with the material, as a potter might have with clay or a sculptor with a block of granite. The kind of compositional thinking demonstrated above is shaped by possibilities of just intonation that no equal temperament can offer. Unless a composer is content to remain within a single key, a fixed, limited just intonation scale pushes him to think in terms of modes, and of harmonic variety among tonalities. By contrast, in any kind of equal temperament, any scale can be transposed to any pitch step; different modes can be constructed if one wants to define them, but the structure of the scale does not mandate or encourage them.

To make the kind of distinction between wolf fifths and perfect fifths that Johnston makes in movement 4, for instance, would require a very fine equal tempered grid indeed: the distinction is that between 680 cents and 702 cents, whereas, for instance, a 31-step equal scale would provide 658 cents, 697 cents, 735.5 cents, with interval distinctions twice as wide as needed. This is not to say that just intonation is superior to extended equal temperaments, merely that the two systems are conducive to different tendencies. Of course, non-modal, complete transposability is also available in an *unlimited* just intonation system, as Johnston has shown in some of his string quartets. But limitations are not a bad thing for a creative artist, and a limited just intonation system offers a resistance to the composer that can spur creativity.

Different tonalities applied to the same unequal scale can reveal the scale from different vantage points, and achieve varying levels of exoticism without the need for new pitch materials. The scale 'speaks' differently through different tonalities, as an actor might speak through different characters but still reveal a unifying sensibility. For those of us who work this way, it can be gratifying to enter into a dialogue with the scale and feel it 'push back' and force other potentials than the ones we first thought of. The varied results of that process are among the subtler pleasures we receive from hearing Johnston's, Young's, and Riley's piano music.

1. Chains of pure fifths

As is well known, a chain of consecutive pure fifths (combined with an appropriate number of octave jumps) never brings us back to the starting tone. Mathematically this is expressed by the following:

$$\left(\frac{3}{2}\right)^m \neq 2^n \tag{1}$$

that states that it is impossible to find two integers ($m; n$) such to satisfy the equality criterion (except the obvious trivial solution: $m = n = 0$).

However, pairs of integer numbers ($m; n$) can be found such that the following C_m approaches 1:

$$C_m = \frac{(3/2)^m}{2^n} \approx 1 \tag{2}$$

The first sensible solution of Eq.(2) is found to be

$$m = 12 \; ; \; n = 7 \;\; \Rightarrow \;\; C_{12} = 1.013643265 \;\; \square \;\; C_P \tag{3}$$

the well known *Pythagorean comma*. For example, this means that if we start from a note (say F) and go 12 fifths up and 7 octaves down, we find a note (E#) sharper than the starting one by a factor C_P. Still a perceptible difference.

The next more precise solutions of Eq.(2) are

$$\begin{aligned} m = 41 \; ; \; n = 24 \;\; &\Rightarrow \;\; C_{41} = 0.988602548 = (1.011528852)^{-1} \\ m = 53 \; ; \; n = 31 \;\; &\Rightarrow \;\; C_{53} = 1.002090314 \end{aligned} \tag{4}$$

C_{53} is also known as Mercator's comma, the last interval listed in the comprehensive compilation given in [1] (a difference that would yield only slow beats with the starting tone). We give the subsequent solution only as a mathematical curiosity:

$$m = 306 \; ; \; n = 179 \;\; \Rightarrow \;\; C_{306} = 0.998978282 = (1.001022762)^{-1} \tag{5}$$

Measuring the intervals in *cents*[10] one has[11]:

$$\begin{aligned} I(C_P) &= 23.5c \\ I(C_{41}) &= -19.8c \\ I(C_{53}) &= 3.6c \end{aligned} \tag{6}$$

[10] The measure in *cents* of an interval between two tones, whose frequency ratio is R, is defined as $I(R)=1200\cdot\log R/\log 2$. In this paper it will be sufficient to specify such measures up to one decimal place.
[11] Note that, since C_{41} is less than 1, a negative number corresponds to its interval measure $I(C_{41})$.

Thus, dividing the octave in 12, 41, or 53 equal parts amounts to achieving the first approximations to Pythagorean intervals and scales. In fact, the tuning in such a *12-tone* equal temperament[12] corresponds to the nowadays widespread equal temperament and is performed by narrowing each fifth by about 2*c* , in order to reach the exact starting tone over a cycle of 12 perfect fifths.

2. The 53-division

Let us proceed further to the division in 53 equal parts. In this case fifths are to be narrowed by an extremely tiny amount ($I(C_{53})/53 = 0.06c$) to close the cycle after 53 steps and one gets perfect Pythagorean scales in the sense that the intervals between notes cannot be distinguished from those obtained by chains of pure fifths. This division is known as *Mercator's division* and is represented in Figure 1. Of course, as we all know, Pythagorean major thirds are very wide, larger than pure thirds (ratio=5/4) by a syntonic (or Didymus or Zarlino) comma ($I(C_Z) = 21.5c$). As a consequence pure minor thirds (ratio=6/5) are also too narrow by the same amount. Since major thirds are obtained after a sequence of four fifths, they will be even wider in the 41-division (the comma C_{41} <1 implies a widening of the fifth); surely they sound a little better to our ears in the 12-division (though still not quite satisfying), because in that case major thirds are reduced by 7.8*c* with respect to the Pythagorean ones and the deviation from pure thirds reduces to 13.7*c*.

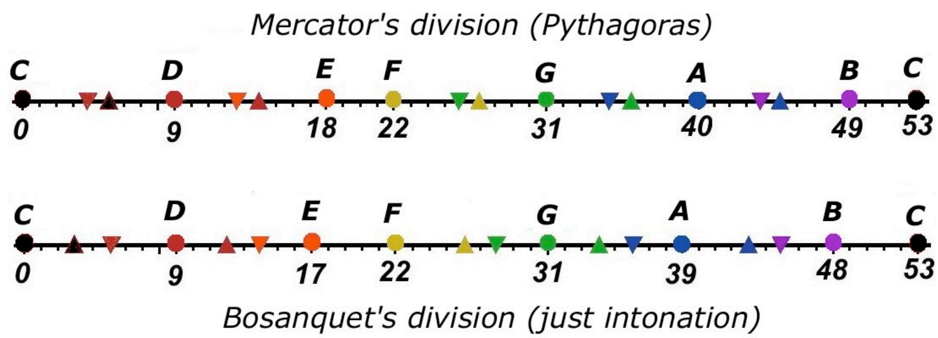


Figure 1: Comparison between Mercator and Bosanquet 53 degrees division. The first alterations are also drawn: sharps are represented with triangles pointing up; flats with triangles pointing down.

53 happens to be also a good number to get an acceptable frame for just intonation, as envisaged by R.H.M.Bosanquet [2]. Each degree in this division measures $d^{(53)} = 22.6c$ (half-way between the Pythagorean and Zarlino commas). In Fig.1 we show the comparison between the two cycles. Note, in particular, the striking difference in the location of enharmonic notes (triangles pointing up and pointing down) between the two schemes. In Mercator's division the chromatic semitone is 5 degrees, larger than the diatonic one (4 degrees). On the other hand, in the Bosanquet case, they are separated by 2 degrees (~ 45*c*), with the sharp note being lower than its flat neighbour.

Actually, the difference between enharmonic notes in the just intonation framework stems from the difference between an octave and three consecutive pure major thirds. This is known as the *diesis* (or *great diesis* or *minor diesis*) or even as the *wolf-comma*:

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[12] Throughout this paper we shall be concerned with *generalized equal temperaments* that consist of the division of the octave in *m* equal parts (or *degrees*). To refer to an *m*-division, abbreviations are often used such as *m*EDO or *m*-TET. In the following we shall simply refer to it as *m*-division.

$$C_W = \frac{2}{(5/4)^3} = \frac{128}{125} = 1.024 \Rightarrow I(C_W) = 41.1c \quad (7)$$

The three commas are related, since three syntonic commas minus a Pythagorean comma exactly yield the wolf-comma. We give a circular representation of this relation in Fig.2. On a circle it is natural to measure musical intervals by means of angular degrees: so, pure thirds are 115.89°, Pythagorean thirds are 122.34°. Their difference (6.45°) is the syntonic comma in these units. Starting from C, after three steps, we get B# (dashed path) or $B\#_{pyt}$ (dotted path), the angle between them amounting to three syntonic commas. On the other hand, the angle between C and $B\#_{pyt}$ (7.04°) is the Pythagorean comma. The difference is just the wolf-comma (12.32°). In fact, in Bosanquet's 53-approximation the enharmonic gap is twice a mean (Pythagoras-Zarlino) comma.

Furthermore in Mercator's temperament on Pythagorean scales, each degree gets its own precise musical name. Splitting alterations between sharps and flats symmetrically, one could go as far as up to 4 sharp and down to 4 flat. Synonymy occurs only at the far border of enharmonic modulations where sharps and flats coalesce. For instance degree=20 corresponds to *C####* as well as to *Abbbb*.

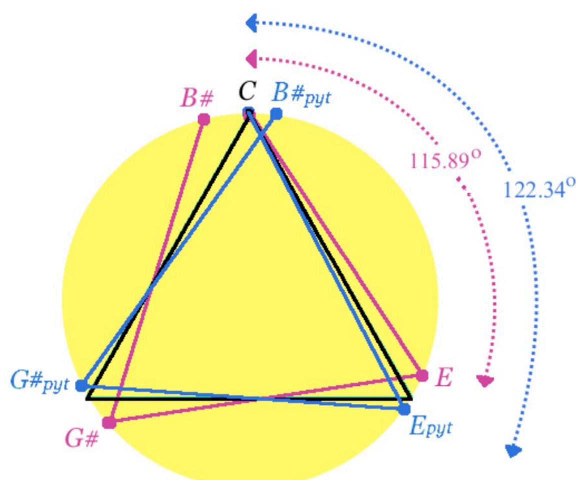

Figure 2: Circular representation of a chain of three thirds illustrating the relation among the three commas. The dashed path follows pure thirds. The dotted path follows Pythagorean thirds. The equilateral triangle represents the same path with thirds in 12-division (120° each).

On the other hand, in Bosanquet's just intonation system, it is even cumbersome to supply the 53 notes with names. As an example, a different notation (such as *E*1 or *E*, see [2]) should be used for the degree = 17 in Fig.1 instead of *E*, to be distinguished by the next *E* at the degree= 18, (roughly) a syntonic comma higher. Further complications arise from the fact that both the intervals for diatonic and chromatic semitones do not have fixed values (see Fig.1).

3. The mean-tone and the 31-cycle

Since the sixteenth century it has been sometimes thought that, in the just intonation framework, the existence of two distinct tones (the major tone (9/8) and the minor tone

(10/9), whose ratio is just the syntonic comma=81/80) prevents the establishment of a system suitable for transpositions and modulations.

The best solution may be traced back to Pietro Aron [3]: the syntonic comma is split in two equal parts so to get a *mean-tone* of frequency ratio:

$$T_M = \frac{10}{9}\left(\frac{81}{80}\right)^{1/2} = \frac{9}{8}\left(\frac{80}{81}\right)^{1/2} = \left(\frac{5}{4}\right)^{1/2} \qquad (8)$$

and the major thirds kept pure. This task is achieved by tempering the fifths by 1/4 syntonic comma:

$$F_M = \frac{3}{2}\left(\frac{81}{81}\right)^{1/4} = 1.49535 \Rightarrow I(F_M) = 696.6c \qquad (9)$$

i.e. narrowing each pure fifth ($I(3/2) = 702.0c$) by $5.4c$. This is still a tolerable amount and leaves triads quite harmonious.

Eq.(9) defines the *(quarter-comma) meantone temperament.*[13] A tour of 12 such fifths leads to a couple of enharmonic notes, a wolf-comma apart. For instance, starting from C, 8 fifths up and 4 fifths down (and due octave displacements) yields the enharmonic interval G#–Ab. With 12 notes available in an octave one has to give up one of the two, remaining with a bad interval (usually G#–Eb) known as the *wolf-fifth*. So the meantone temperament (with 12 notes) works quite well in central keys but the *wolf-fifth* heavily limits the freedom of modulation. Of course one can continue adding fifths, providing pairs of enharmonic notes, and populate the octave with more and more notes, but the process, as for pure fifths, never ends.

Now the question: how many (equal) degrees are needed in an octave to establish a sufficiently good approximation to meantone temperament? In what follows we shall answer the question in three different ways.

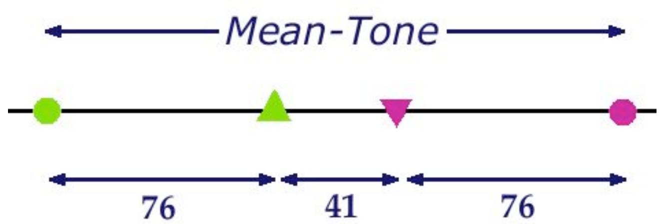

Figure 3: The splitting of a mean-tone into chromatic and diatonic semitones in meantone temperament. The mean-tone is $193c$ wide. The chromatic and diatonic semitones are $76c$ and $117c$ respectively. Their interval-ratio is $I(DS_M)=I(CS_M) = 1.54$.

Firstly, let us analyze how a mean-tone, in meantone temperament[14], is split by the diatonic and chromatic semitones (see Fig.3). The mean-tone is 193 cents wide while the chromatic and the diatonic semitones are respectively 76 and 117 cents wide[15]. The ratio between these

[13] We shall use the symbols: F_M, T_M, DS_M, CS_M for the frequency ratios of the fifth, mean-tone, diatonic semitone, chromatic semitone respectively in the meantone temperament.

[14] The specification is not superfluous, since the term *meantone* is used in general whenever an interval of major third, even not pure, is divided in two equal parts.

[15] Recall that, in meantone temperament, both the diatonic and chromatic semitones are larger than those in the just intonation (16/15 and 25/24 respectively) by 1/4 syntonic comma.

two intervals is $I(DS_M)/I(CS_M) = 1.54$. So, to answer the question, we should find two (possibly small) integers n_D and n_C such that:

$$\frac{n_D}{n_C} \approx \frac{I(DS_M)}{I(CS_M)} = 1.54 \tag{10}$$

Since there are 5 mean-tones and 2 diatonic semitones in an octave, the total number of degrees will be:

$$m = 5\,(n_D + n_C) + 2\,n_D \tag{11}$$

Indeed the m= 12 equal temperament corresponds to the choice $n_D = n_C = 1$, which is not a good approximation to Eq.(10). A bad approximation is also obtained taking $n_D = 2$, $n_C = 1$, i.e. dividing the mean-tone in 3 equal parts ($m = 19$). Instead one gets a fine approximation for $n_D = 3$ and $n_C = 2$ that corresponds to the division of the mean-tone in 5 equal parts, three of them giving the diatonic semitone, two the chromatic semitone and one fairly reproducing the interval between enharmonic notes[16]. So, the division of the octave in 31 equal parts (see Eq.(11)) appears as the best possibility from this point of view[17].

Secondly, we may proceed as for chains of pure fifths (see Eq.(2)) substituting them with the *meantone-tempered fifths* (see Eq.(9))[18], and look for numbers Z_m approaching 1:

$$Z_m = \left[\frac{3}{2}\left(\frac{80}{81}\right)^m\right] \Big/ 2^n \approx 1 \tag{12}$$

The first solution to Eq.(12) is (once more) $m = 12$; $n = 7$, which now gives:

$$Z_{12} = 0.9765625 = (1.024)^{-1}$$

i.e. just the (inverse of the) wolf-comma. Distributing it uniformly among the 12 (meantone-tempered) fifths leads back to the 12-degrees equal temperament, which, from this point of view, may be considered as something intermediate between the pure Pythagorean system and the meantone-tempered one. However, as an approximation to the meantone temperament, this compromise cannot be accepted, since, as already remarked in section 1, major thirds, though better than Pythagorean ones, are still too wide to be harmonious.

So we must go on and try the next solution: $m = 31$; $n = 18$:

$$Z_{31} \approx 0.996501 = (1.003511)^{-1} \;\rightarrow\; I(Z_{31}) = -6.1c \tag{13}$$

This is a small interval. Distributing it among 31 (meantone-tempered) fifths amounts to enlarging each of them by only $0.2c$, so we obtain:

$$F^{(31)} = 1.49552 \;\rightarrow\; I(F(31)) = 696.8c \tag{14}$$

These fifths are narrowed by $5.2c$ with respect to pure fifths (instead of $5.4c$; compare Eq.(9)). Since major thirds are built up in four steps, they will be only $0.8c$ wider than pure thirds, an imperceptible amount as emphasized by Huygens[19] in his *Letter concerning the harmonic cycle* [4].

Thus, a chain of fifths tempered as in Eq.(14) will close itself in a cycle after 31 steps and yield a 31-degree equal temperament that provides an excellent approximation to the meantone temperament.

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16 In fact the wolf-comma ($I(C_W) = 41.1c$) is approximated even better within this division ($38.7c$) than in the 53-Bosanquet division ($45.2c$, see Sec.2).

17 The next possibility would be the couple of prime numbers (n_D =17, n_C =11) which provides an extremely accurate solution to Eq.(9) but yields too many degrees (m = 174).

18 This is the method produced in the essay [5].

19 Huygens specifies this amount as about 1/28 of a (syntonic) comma.

The third way will be the subject of the next section.

4. Chains of pure thirds

Up to now we have being setting a certain number of degrees in the octave using sequences of fifths. We have looked for tempered fifths whose chains close themselves in a cycle. Since meantone temperament privileges the major third as a harmonic interval, it seems natural to face the stated question starting from chains of thirds, instead of fifths, in a totally analogous way.

First of all it is clear that, as for pure fifths, a chain of consecutive pure thirds never brings us back to the starting tone. In fact we may write an equation similar to Eq.(1):

$$\left(\frac{5}{4}\right)^m \neq 2^n \tag{15}$$

and try to find integer numbers ($m; n$) such that:

$$H_m = \frac{(5/4)^m}{2^n} \approx 1 \tag{16}$$

By the way, as chains of meantone-tempered fifths yield pure thirds, one may wonder whether using chains of pure thirds, as a method for generating tones, may lead to the same notes (possibly after a sufficiently large number of steps) as those of the meantone temperament. The answer is negative, since, for example, for any integer numbers ($m; n$):

$$\left(\frac{5}{4}\right)^m \Big/ 2^n \neq F_M \equiv \frac{3}{2}\left(\frac{80}{81}\right)^{1/4} \tag{17}$$

Eq.(17) states that the meantone-tempered fifth F_M can never be recovered by chains of pure thirds. In order to get something in the neighbourhood of F_M one has to climb at least 8 steps (i.e. m = 8 and n = 2):

$$H_8 = \left(\frac{5}{4}\right)^8 \Big/ 2^2 \approx 1.490116 \Rightarrow I(H_8) = 690.5c \tag{18}$$

that is 6.1c below F_M and 11.5c below the pure fifth.

Coming back to Eq.(16), the first obvious solution is

$$H_3 = \left(\frac{5}{4}\right)^3 \Big/ 2 \equiv Z_{12} = C_W^{\ -1} \tag{19}$$

i.e. again the (inverse of the) wolf-comma. To close the chain, each third should be made wider by I(C_W)/3 = 13.7c and one gets again the usual equal-tempered thirds that divide the octave in three equal parts (the equilateral triangle of Fig.2).

Next more precise solutions are:

$$H_{28} = \left(\frac{5}{4}\right)^{28} \Big/ 2^9 = 1.009742 \rightarrow I(H_{28}) = 16.8c \tag{20}$$

$$H_{31} = \left(\frac{5}{4}\right)^{31} \Big/ 2^{10} = 0.986076 = (1.01412)^{-1} \rightarrow I(H_{31}) = -24.3c \qquad (21)$$

These suggest a division of the octave in 28 or 31 equal parts respectively.

Let us examine these two possibilities. At first sight a 28-division looks like a favourable chance for an excellent solution, because of the smallness of $I(H_{28})$. In fact, to close the chain, each third should be tempered only slightly (-0.6*c*). In this case each degree is $d^{(28)}$ = 42.9*c* wide and the interval for a fifth amounts to 16 degrees, i.e. –16.2*c* flatter than a pure fifth, badly out of tune. There is a further drawback: the interval for major thirds is 9 degrees, an odd number that does not allow the splitting into two equal mean-tones.

So we are left with the second possibility. Now the degree is $d^{(31)}$ = 38.7*c*, the major thirds correspond to 10 degrees and the fifths to 18 degrees. Note that the "comma" H_{31} defined in Eq.(21) corresponds to an interval quite similar in magnitude to the Pythagorean comma but of negative sign. This means that we should slightly widen the pure thirds in order to close the chain. Indeed, distributing uniformly H_{31} among the 31 thirds amounts to widening each of them of $||I(H_{31})|$ /31 = 0.8*c* (compare the discussion at the end of Section 3). With regard to the fifths, we recall that in Eq.(14) we saw they are 5.2*c* narrow (a little bit better than the meantone-tempered fifths – see Section 3). Note that in Section 3 we got $F^{(31)}$ by means of a further temperament of the already tempered meantone-fifths F_M. In the present scheme, on the other hand, we recover the same fifth after 8 steps in the chain of thirds. In fact H_8 (see Eq.(18)) is quite a narrow fifth when built up with pure thirds, but it gains 6.3*c* from the slight temperament of the thirds, so to coincide with $F^{(31)}$.

Conclusions

The Huygens-cycle has many valuable features. It displays a sufficient number of notes to allow a distinction between double sharps and double flats[20] so that it provides the conceptual melodic and harmonic framework of baroque, classic and romantic western music. Moreover the 26th degree happens to coincide nearly exactly with the 7th harmonic (since $25 \cdot d_{31}$ = 967.7*c* and $I(7/4)$ = 968.8*c*)[21], so opening new perspectives in musical languages [5]. In fact the exploitation of the 7th harmonic was advocated in the 18th century by scientists [6] and musicians [7] and more recently by the physicist and musician Adriaan Fokker [8, 9] and others.

Though various divisions of the octave in many parts have been explored and tested since the 16th century, the division in 31 parts was refused by people like Salinas and Mersenne. Huygens attributed this misunderstanding to the inability of exactly tuning 31 equal degrees without the help of logarithms, not yet known at those times. The interest of Huygens in tuning and temperament goes back to 1661. About the same time Lemme Rossi [10] published a treatise where the 31-division is explicitly described. It appears that Huygens did not know about this work. However his main point was to find a division of the octave providing the best approximation to meantone temperament, i.e. precisely the point of view adopted in the present paper.

We do not know which method Huygens exploited to get the solution (in fact Fokker [8] suggests the first one of those outlined here); in any case we would think it reasonable to refer to H_{31}, the analogue of the Pythagorean Comma for chains of pure thirds, as the "*Huygens comma*".

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20 With the exclusion of *Cbb; Fbb*, which coincide with *A##;D##* (28thand 10th degree respectively) and *E##;B##* with *Gbb;Dbb* (15th and 2nd degree respectively).

21 For comparison, the *A#* (≡ *Bb*) in 12-degree equal temperament amounts to 1000*c*.

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TECHNISCHE ASPECTEN VAN HET 31-TOONS-ORGEL, 1950-2009

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Toen de Tweede Wereldoorlog een spaak in het wiel van zijn wetenschappelijke werk stak, richtte Adriaan Fokker zijn aandacht op muziektheorie en in het bijzonder op het 31-toonssysteem dat Christiaan Huygens in de late zeventiende beschreef. Om de stemmingstheorie om te zetten in klank, liet Fokker in 1943 een klein orgeltje bouwen waarmee tien zogeheten Euler-Fokker-genera tot leven werden gebracht. Na 1945 zette hij zich in de voor de bouw van een groot orgel ingericht volgens het evenredig zwevende 31-toonsstelsel. Fokker organiseerde lezingen en bespelingen rond zijn geliefde thema in het Teylersmuseum in Haarlem. Het wekt geen verbazing dat daar het nieuw te bouwen orgel geplaatst werd.

Op enig moment kwam Fokker in contact met orgelmaker Bernard Pels uit Alkmaar die hem introduceerde bij de destijds bekende orgeldeskundige pater franciscaan Caecilianus Huigens [sic] (1878 – 1966). Fokker nam Huigens in de arm als adviseur en er ontstond een levendige briefwisseling tussen de bevlogen initiatiefnemer en de pater. Het archief van Huigens is grotendeels bewaard gebleven en berust hedentendage in de bibliotheek van het Utrechts Conservatorium. Het dossier 'Haarlem, Teygelersmuseum' [sic] bevat bijna vijftig documenten uit de periode september 1947, toen de plannen nog volop in ontwikkeling waren, tot en met begin november 1950, toen het orgel inmiddels in het Teylersmuseum opgebouwd was. In een schrijven aan Fokker van 19 augustus 1948 gaat Pels in op het bijgevoegde contract, beschrijving en tekening van het nieuw te bouwen orgel. Het bestek is later op enkele details na gevolgd en biedt daarom een actuele technische specificatie van het Fokker-orgel.

De hieronder geboden omschrijving van de opbouw van het orgel is niet uitputtend en poogt een basaal inzicht in de technische aspecten van het instrument te geven. De tot nu toe verschenen literatuur over het orgel gaat meestal uitgebreid in op het uiterlijk van de speeltafel. Niet onterecht overigens, de claviatuur is met zijn enorme aantal toetsen nu eenmaal spectaculair om te zien. Dat neemt niet weg dat het overige deel van het instrument in technisch opzicht eveneens boeiend is. Nu het Fokker-orgel na demontage in 1999 en de daarop volgende opslag in het komend voorjaar opnieuw zal klinken in de BAM Zaal van Muziekgebouw aan 't IJ in Amsterdam, is het een goed moment om de opbouw van het instrument voor het voetlicht te halen.

Het instrument heeft zes registers (klankkleuren) verdeeld over twee handklavieren en een pedaal. Het eerste manuaal heeft de registers Bourdon 8' en Prestant 4'. De apostrof staat voor 'voet' een oude lengtemaat die de toonhoogte van een register weergeeft. In het geval van een achtvoetsregister klinkt op iedere toets dezelfde toonhoogte als op de gelijknamige toets van een piano. Bij een viervoets registers klinkt de toon een octaaf hoger, bij een zestienvoets register een octaaf lager dan de normale pianotoonhoogte. Het tweede manuaal heeft een Salicionaal 8' en een Roerfluit 4'. Het Pedaal tenslotte beschikt over een Subbas 16' en een Gedekt 8'. Verder kunnen de handklavieren ieder afzonderlijk aan het pedaalklavier en de handklavieren onderling gekoppeld worden. Er zijn dus drie koppelingen.

De speeltafel van het orgel waarin de klavieren zijn ondergebracht, is afgewerkt met eiken fineer. Het houtwerk dat de handklavieren omlijst, is van gepolitoerde mahonie. Dit materiaal en deze afwerking zijn typerend voor de bouwtijd van het orgel. De orgelbank en het pedaalklavier zijn van eiken. De speeltafel kan worden afgesloten met een houten rolluik voorzien van een slot. Vlak boven het pedaalklavier is in het zogenaamde knieschot een basculetrede aangebracht ten behoeve van een geplande crescendokast. Deze inrichting waarmee de speler door middel van jalouzieën het orgelgeluid traploos van sterkte verandert, is er echter niet gekomen; de basculetrede in de speeltafel heeft dus nooit een functie gehad. Verder bevat de speeltafel zes knoppen voor de registers en drie voor de koppelingen tussen de klavieren.

De windvoorziening van het orgel bestaat uit een elektrische windmotor en vier balgen. De motor voedt de hoofdbalg waaruit windkanalen lopen naar drie kleinere balgen, zogenaamde regulateurs. Deze verzorgen de wind voor afzonderlijke secties van het orgel. Alle windkanalen zijn van vurenhout gemaakt, sommige kleinere windleidingen van flexibele slang.

De pijpen staan opgesteld op zogenaamde windladen. In een windlade wordt aan de hand van de registerkeuze van de organist (klankkleur) en de aangeslagen toetsen (toonhoogte) de windtoevoer naar de afzonderlijke pijpen geregeld. Het Fokker-orgel heeft drie windladen voor de registers van de handklavieren en eveneens drie windladen voor de pedaalregisters. Alle onderdelen van de windladen zijn van hout, merendeels eiken en mahonie.

De verbinding tussen toets en pijp, de tractuur, komt in het geval van het Fokker-orgel tot stand met behulp van elektriciteit en luchtdruk. Dit systeem wordt elektro-pneumatische tractuur genoemd. In de speeltafel is iedere toets van een contact voorzien. Met het contact wordt een magneet aan de onderzijde van de windlade in het orgel in werking gesteld die op zijn beurt lucht toelaat in een serie lederen membranen. Deze opgeblazen membranen openen ventielen in het binnenste van de windlade zodat er orgelwind in de betreffende pijp kan stromen. Of die orgelwind voor een register (klankkleur) inderdaad aanwezig is, wordt bepaald door de stand van de registerknop in de speeltafel. Een pijp spreekt dus wanneer én de toets én het register van de betreffende pijp ingeschakeld zijn. De verbinding tussen de registerknoppen in de speeltafel en de windladen in het orgel is overigens ook elektro-pneumatisch. Het type windlade dat men voor het Fokker-orgel gebruikt, heet kegellade, naar de ventielen onder de pijpen, de zogeheten kegels.

De 31 grootste pijpen van de Bourdon 8' zijn van hout (oregon pine, blank gelakt), de overige pijpen van orgelmetaal (legering van 25% tin en 75% lood). Het register Prestant 4' heeft 15 zinken pijpen en 128 metalen (60% tin, 40% lood). De Salicionaal 8' is van C—c (31 tonen) van zink, het vervolg is van half lood, half tin. De Roerfluit 4' is geheel van metaal: eenderde tin, tweederde lood. De 76 pijpen van de Bourdon 16' en de Gedekt 8' van het Pedaal zijn van hout. Deze twee registers gebruiken, voorzover ze elkaar in toonhoogte overlappen, dezelfde pijpen. De zinken pijpen zijn gelakt ter bescherming. De onderdelen van de zinken pijpen die van invloed zijn op de toonvorming: de voetspits waar de orgelwind binnenkomt en het zogenaamde spraakstuk tussen de conische pijpvoet en het klanklichaam (het corpus), zijn van orgelmetaal. Dit materiaal is veel zachter dan zink en makkelijker te bewerken bij de afwerking van de klank, het zogenaamde intoneren.

Samenvattend wat getallen op een rij. In totaal telt het orgel 648 pijpen. Iedere pijp heeft een eigen kegel en membraan. Iedere toon van ieder klavier heeft een magneet. Er zijn dus twee maal 143 (handklavieren) plus vijfenveertig (pedaalklavier), in totaal 331 magneten in het orgel verwerkt. Bovenop dit alles komen nog ruim tien magneten en membranen van de registerbediening.

Het meest opzienbarend zijn de klavieren. Ieder handklavier heeft 319 toetsen, het pedaalklavier heeft er vijfenveertig. Dat levert behalve een indrukwekkend aanzien aan de buitenzijde ook een indrukwekkend aantal contacten in het inwendige van de speeltafel op: 683. Elk van de contacten heeft een eigen bedrading die in de compact gebouwde claviatuur aangebracht werd, voorwaar geen sinecure. De ontwikkeling van de speeltafel heeft veel denkwerk gevergd, op het unieke ontwerp is in 1948 octrooi verleend.

In de oude situatie in het Teylersmuseum in Haarlem stond het orgel tot 1999 opgebouwd in een een soort kastruimte, onderdeel van het museumgebouw. Deze ruimte was relatief diep en had een onregelmatig grondplan. Het orgel paste in deze ruimte alleen in een ongebruikelijke rangschikking van de windladen. De diepte van de orgelkamer was van ongunstige invloed op de klankuitstraling van het instrument.

In het Muziekgebouw aan 't IJ kan het orgel klanktechnisch veel voordeliger worden opgebouwd. Het ontbreken van een eigen orgelmeubel is in het ontwerp in gunstige zin omgebogen. De modulaire indeling van het instrument in zes windladen biedt de mogelijkheid voor verschillende opstellingen waaronder die waarin alle windladen naast elkaar staan. Op die wijze past het orgel in zijn geheel op de rand boven de glazen wand van de BAM Zaal en is als het ware onderdeel van de zaalarchitectuur.

Voor wat betreft de rangschikking van de windladen is gekozen voor een oplossing die zoveel mogelijk recht doet aan een logische eenheid binnen het instrument en tegelijk een levendig aanzicht oplevert. De verschillende lengtes, vormen en materialen van de pijpen dragen bij aan een speelse aanblik. Tegelijkertijd wordt in deze 'open opstelling' iets zichtbaar van de gebruikelijke complexiteit van een orgel, en niet in de minste plaats van dit 31-toonsinstrument. Het ontbreken van een eigen orgelkas zal naar verwachting akoestisch worden gecompenseerd door de ruimte, de zaal is als het ware de orgelkas. Aan de linkerzijde komen de pijpen van de handklavieren te staan, gerangschikt van groot naar klein. Dan volgt een module met de grootste pijpen van de handklavieren, van klein naar groot. De meest rechtse drie compartimenten bevatten het houten pijpwerk van de pedaalregisters, grofweg van klein naar groot met intern nog weer contrasterende dalende en stijgende lijnen. De onderzijde van het orgel wordt omkleed met een houten betimmering die het stellingwerk en de onderdelen van de windvoorziening aan het oog onttrekt en tegelijk als overgang fungeert tussen het orgel en de glazen wand van de zaal. Helemaal rechts zal de windmotor en de hoofdbalg worden geïnstalleerd, achter een zaalgordijn.

Alle onderdelen van het orgel ondergaan op dit moment technisch herstel. Alle onderdelen worden grondig gereinigd. In de tractuur worden alle membranen vervangen en de magneten nagezien en waarnodig vernieuwd. Er zal een nieuwe windmotor worden geplaatst; de balgen worden gecontroleerd op windlekkage en met leer weer winddicht gemaakt. De windkanalisatie moet worden aangepast aan de nieuwe opstelling. Alle pijpen worden gecontroleerd op vervorming, schade aan de steminrichtingen en de spraakstukken.

Speciale aandacht bij de huidige restauratie heeft de speeltafel. Het exterieur daarvan wordt gerestaureerd. De eiken afwerking en de orgelbank worden ontdaan van de oude lak en krijgt een nieuwe laag. Het mahonie binnenwerk ondergaat eveneens restauratie. Het pedaalklavier zal geheel worden uiteengenomen en schoongemaakt. Het originele rolluik blijft gehandhaafd maar de speeltafel zal voorzien worden van een plexiglazen kap waardoor in afgesloten toestand de handklavieren zichtbaar blijven als visueel visitekaartje van het orgel. De basculetrede die zoals eerder vermeld geen functie heeft, wordt verwijderd.

In het inwendige van de speeltafel worden de toetscontacten ontdaan van aanslag. De andere zijde van de contacten wordt geheel vernieuwd om dezelfde reden. Dat geldt ook voor de integrale sterk verouderde bedrading in de speeltafel. Belangrijkste verandering is de plaatsing van een computer die de aansturing tussen speeltafel en instrument regelt. Dit zogenaamde midi-systeem wordt voorzien van mogelijkheden om met een externe computer het orgel of, anders, met de speeltafel van het Fokker-orgel een externe computer aan te sturen. Deze opzet biedt grandioze mogelijkheden om de het instrument volledig te integreren in de uitvoering van moderne muziek waarin elektronica een cruciale rol speelt. Zo zal het bijvoorbeeld mogelijk zijn om het kleurenpalet van het orgel zelf te combineren met elektronisch gegenereerde geluiden of een partituur via een laptop te laten spelen door het orgel.

De speeltafel wordt geplaatst op een verrijdbaar podium op de zaalvloer. De organist kan zo dichtbij andere musici meespelen. De verbinding tussen speeltafel en orgel bestaat uit een eenvoudig datakabeltje in te pluggen in een daarvoor bestemd contact.

De mogelijkheid tot aansturing van buiten af is een van de redenen om de oude tweede twaalftoonsspeeltafel van het orgel te laten vervallen. Deze speeltafel 'vertaalde' het 31-toonssysteem naar een 'gewone' klavierindeling met twaalf tonen per octaaf. Door middel van presets kon de speler kiezen uit acht Euler-genera en er was een vrij instelbare toonreeks beschikbaar. Met behulp van een midi-klavier en software zijn deze functies van de tweede speeltafel eenvoudig te imiteren en bovendien schier oneindig uit te breiden. De twaalftoonsspeeltafel blijft overigens bewaard.

In 1943 bouwde Van Leeuwen uit Leiderdorp het kleine instrumentje waarmee Fokker een deel van het 31-toonssysteem kon demonstreren. Het grote Fokker-orgel werd zeven jaar later gemaakt door Pels uit Alkmaar. De werkzaamheden van 2008/2009 uitgevoerd door de firma Pels & Van Leeuwen uit 's-Hertogenbosch. Zoals de naam al doet vermoeden, is de Bossche orgelmakerij voortgekomen uit een fusie van twee voornoemde bedrijven. Het tweede leven van het Fokker-orgel is stevig geworteld in het verleden.

REVIEW OF PATRIZIO BARBIERI: ENHARMONIC INSTRUMENTS AND MUSIC 1470-1900

Rudolf Rasch

Patrizio Barbieri, *Enharmonic Instruments and Music 1470-1900.* Revised and Translated Studies; CD Included. Latina (Italy): Il Levante, 2008. Tastata - Studi e Documenti TAS 2

One of the most expert and prolific authors on the subject of tuning and temperament of the last quarter century is, without any doubt, the Italian musicologist Patrizio Barbieri. Trained as an engineer, he teaches musical acoustics at the University of Lecce (in the very south of Italy, at the end of the heel of the peninsula) and organology in the stricter sense (meaning the science and history of the organ) at the Pontifical Gregorian University of Rome. Since 1980 he has produced an unbroken stream of articles, books and other contributions on tuning systems from the fifteenth to the twentieth century, often in relation to instruments designed to produce other sounds than just those of equal temperament, the standard temperament of Western music ever since the eighteenth century. Unfortunately, at least for the non-Italian reader, most of his writings have been written and published in Italian periodicals, editions, collective volumes, etc. They found little reception in the rest of Europe or North America. Only a minority of his output has been published in English and in media outside Italy, mostly in the last decade of the bibliography of his writings, that is, from 1997 onwards.

Therefore, one cannot but praise his initiative to forge a book out of the many articles and this not by merely reprinting them in a single volume, but by updating and rewriting them where necessary and in such a way that the result can be read as a single text. The result is impressive. Barbieri explains in his preface which articles were used to produce which chapters, but reading the respective chapters one does not notice at all the boundaries of the articles that are the basis of these chapters. If one would read the book without knowing its origin in a collection of articles, one would not suspect such an origin. Looking backward at Barbieri's twenty-five year production, it is almost as if he wrote all these articles with the intention to merge them at one time into a single text, the book that lies now in front of me on my desk.

The book delivers exactly what its title promises: an account of the various attempts to build enharmonic musical instruments and to write enharmonic music, from the middle of the fifteenth century onwards until about 1900. Enharmonic instruments should be understood as musical instruments presenting a number of pitches per octave that significantly surpasses the twelve notes of the standard western tuning systems (equal temperament, meantone tuning or whatever). This begins with harpsichords or organs with a few split upper keys, goes to keyboards with 17, 19, 31 or 43 notes per octave and ends with theoretical systems and ideas for instruments (less often the instruments themselves) up to far over 100 pitches per octave. Enharmonic music is music that requires such extra pitches and that is mostly to be found in the surroundings of enharmonic instruments. Without those instruments nearby, it makes little sense to produce such music.

Although mention is lacking in most standard texts on the history of music, western music history has produced quite a number of enharmonic instruments or (in other cases) ideas for such instruments, be it that for every enharmonic instruments perhaps a million or more non enharmonic (diatonic and chromatic) instruments were built. They have indeed remained singular attempts and experiments from the beginning of their history onwards, primarily known to a small circle of cognoscenti or aficionados. Best known outside this in-crowd world is probably the archicembalo devised by Nicola Vicentino in the middle of the sixteenth century. This is certainly due to its description in a respectable book on the theory of music, Vicentino's L'antica musica ridotta alla moderna prattica (Rome, 1555). It probably was the first enharmonic instrument to arouse public curiosity and gave Italy an important place in the history of enharmonic instruments. But, at some point after 1550, many other European countries, such Spain, France, England, the Netherlands and the German-speaking countries, also made significant contributions to the history of this very special branch of music theory and musical practice.

As is to be expected when articles are combined to make up a book, they are not put together just in chronological order, but ordered according to a certain plan, to create a logical succession for the reader. The 550 pages of proper text of this book (the remaining sixty bring a bibliography, a subject index and a name index) are divided into two parts: Part I, dealing with instruments and music that follow 'open-chain systems' of tuning, and Part II, dealing with 'closed-chain systems' of tuning. The open-chain systems are based on the summation of pure intervals and, as is well known, sums of pure intervals never result in circles of intervals, that is a return to the original pitch. In western music, the justness of the octave (frequency ratio 1:2) has been an axiom; the justness of any other interval, the fifth (theoretical ratio 2:3) and the major third (4:5) to begin with, but also the 'harmonic seventh' (4:7), the 'harmonic eleventh' (8:11) and possibly higher harmonics based on prime numbers, is left free to be filled in, and every choice for a certain interval implies problems or compromises for other intervals. That means that the aspect of taste comes into the picture and instead of a simple best solution there is an infinite number of solutions, each with its own advantages and disadvantages.

The two parts of the book are each divided into five chapters, not numbered by consecutive figures (1, 2, 3, ...), but by letters (A, B, C, ..., until K). It is impossible to give a full description of the contents of the entire book. The writing is rather dense and business-like, with very few unnecessary words or phrases. This means that the information density is very high, in fact increased only further by the fact that most subjects are discussed briefly, even where one would expect or wish for a more comprehensive explanation of what is going on. Many of the systems are described, after a brief exposition of the basics, in just a few paragraphs, in fact often too briefly to be understood well in all its details, especially by the non-initiated reader.

Chapter A starts with the application of just intonation on keyboards. Twelve-tone just intonation is possible but inevitably includes a number of very out-of-tune ('wolf') consonant intervals. Therefore, if playing all consonant intervals in tune is the goal, one should add extra keys, making the instrument chromatic or enharmonic. Such keyboards were designed by theorists such as Gioseffo Zarlino in Italy, Francisco Salinas in Spain, Marin Mersenne in France, Joan Albert Ban in the Netherlands and others in the sixteenth and seventeenth centuries. Many of these designs were put into practice by instrument builders. The keyboards are based on the ordinary twelve-note keyboards but with split upper keys, extra keys between E-F and B-C, etc. After the middle of the seventeenth century they disappear from the 'enharmonic scene'. Another way to build enharmonic keyboards as extended open-chain systems are the extended meantone keyboards, of which Vicentino's archicembalo is the prototype.

Chapter B continues the discussion of enharmonic keyboards based on Pythagorean tuning or just intonation. Now, attention is focused on England, the country that has produced the largest number of these instruments in the eighteenth and nineteenth centuries, invented by Robert Smith, Henry Liston, Thomas Perronet Thompson, Henry Ward Poole, Colin Brown, and Robert Holford Macdowall Bosanquet and others.

In Chapter C Barbieri leaves the keyboards aside and discusses enharmonic intonation in melodic instruments, especially the various stringed instruments and woodwinds. As is well known, many authors writing on these instruments, among whom the best-known are Johann Joachim Quantz (flute) and Leopold Mozart (violin), prescribe different intonations for enharmonically equivalent sharps and flats, and this gives rise to many extended discussions as to which tuning system is followed by players of these instruments. An endless discussion, because harmonic intonation derived from either just intonation or meantone tuning requires low sharps and high flats, whereas melodic intonation, which one cannot say to be derived from Pythagorean tuning but which nevertheless follows its basic properties, requires high sharps and low flats. Enharmonic changes is a particularly difficult field to treat theoretically. I am afraid that most musicians merely employ practical solutions here, that defy all theory.

Traditional tuning theory is based on intervals with frequency ratios consisting of products of the prime factors 2, 3 and 5, in modern times called the 5-limit. Attempts to incorporate into the theory intervals with higher factors, first of all 7 and 11, date, however, already from the seventeenth century. Barbieri discusses, in his Chapter D, various treatments of the 'harmonic seventh' by Giovanni Battista Doni, Christiaan Huygens, Johann Philipp Kirnberger and Giordano Riccati, from the seventeenth and eighteenth centuries. It is, of course, acknowledged that certain intervals of meantone tuning - and, therefore, of 31-note temperament - are very close approximations of septimal intervals, such as the augmented second (nearly 6:7), the augmented fourth (nearly 5:7) and the augmented sixth (nearly 4:7).

The next chapter (Chapter E) deals with the various instruments built in connection with the theories of Giovanni Battista Doni (1595-1647), mostly to revive the Greek modes. Either they are harpsichords with various keyboards (for the various modes) or viols, with several fingerboards and fretting systems (for the same reason). We can name the cembalo triarmonico, the cembalo tetrarmonico, the violino diarmonico, the violino panarmonica, the lyra barberina amphicordus and the chitarra triarmonica. These instruments have inspired a number of composers to create music for them, among them Pietro della Valle with his Dialogo della Purificazione (1640).

The second part of the book deals, as said before, with equal tempered systems, ETS in Barbieri's abbreviation. The first chapter of this part, Chapter F, deals with the development of the mathematical theory of equal tempered intervals from Vicentino (1555) to Ivo Salzinger (1721). Especially interesting is the rise of the use of logarithms to calculate the ratios of equal tempered intervals in the seventeenth century (including the first logarithmic units for interval size) and the growing awareness of the relation between equal tempered systems and 'open-chain systems', such as that between 19-note ETS and 1/3-comma temperament, between 31-note ETS and meantone temperament, between 43-note ETS and 1/5-comma temperament, and between 53-note ETS and Pythagorean tuning. From this time onwards many instruments were designed or even actually built to put these correspondences into practice, among them Christiaan Huygens's description of 31-note ETS (1661-1691) as a generalization of meantone temperament and Joseph Sauveur's theories (1701-1711). Chapter G reviews the theories of ETSs in the eighteenth century.

The next chapter, Chapter H, is devoted to two remarkable enharmonic keyboards designed and built in Naples in the first half of the seventeenth century, the sambuca lincea by Fabio Colonna and the tricembalo by Scipione Stella, both described in Colonna's booklet entitled La sambuca lincea (1618). Both have 31 pitches per octave, but larger numbers of keys, Colonna's 42 keys, Stella's 53 keys. Chapter I is entirely devoted to the another seventeenth-century archicembalo, the cembalo omnicordo by Francesco Nigetti, an instrument that went through various versions and was elaborately described by its eighteenth-century owner Benedetto Bresciani.

Chapter J is the last chapter on 'closed-chain equal tempered systems' and is devoted in its entirety to the flauto traverso enarmonico designed by Giovanni Battista Orazi toward the end of the eighteenth century and described in Orazi's booklet *Saggio per costruire e suonare un flauto traverso enarmonico* (Rome, 1797). The enharmonic flute is a flute with an extension to low G (so that violin parts can be played upon it) and with extra keys to make possible the chromatic and enharmonic genera. The enharmonic genus is in fact realized by the addition of quartertones to the 12 ETS. Orazi also provided some compositions, for three flutes, for the new instruments, which are transcribed in Barbieri's book, and, indeed, the third flute goes down to low G frequently and all parts employ quarter-tones, mostly as passing notes or written-out glissandos, sometimes in a more essential way.

From the summary presented above it will be clear that Barbieri very definitively stops his discussions at 1900 and does not pay attention to any twentieth-century development in the area. On the one hand this seems wise, since the musical environment changed radically around or briefly after 1900 with many new ways to approach musical composition, many of them leaving behind conventional harmony, melody, rhythm and metre. But on the other hand many twentieth-century enharmonic instruments seem to follow the leads of the past. The various quartertone instruments, the 31-note keyboards and the just intonation percussion could be perfectly described in the terms developed for the instruments of the previous four centuries.

Barbieri's book is not one to read from beginning to end. Rather, one should read single chapters, digest the information contained in them, and then pass on to another chapter. Or one can use it as a reference work, not to be read in the strict sense of the word, but to be consulted when one wants to know something about a certain theorist, a certain instrument or a certain enharmonic composition. Barbieri's knowledge of sources is amazing. In many cases he not only uses the primary published and often-discussed texts of a certain author, but in addition he is able to cite contemporary letters, references, unpublished manuscripts relevant for the case discussed but rarely if ever cited by previous authors on the subject.

It is true, Barbieri's work is a to certain extent italo-centred: among the most frequently quoted theorists in the index we find many Italian 'enharmonic' authors: Benedetto Bresciani, Pietro Della Valle, Giovanni Battista Doni, Athanasius Kircher, Giordano Ricati, Nicola Vicentino, Gioseffo Zarlino. Except for Ricati, these are all familiar names. Two seventeenth-century Spanish authors, not yet universally known, are quoted often by Barbieri, namely Juan Caramuel Lobkowitz and Joseph Zaragoza. The most often quoted foreign (that is, not Italian) authorities bring no surprises. They include, in alphabetical order, Robert Holford Macdowall Bosanquet, Leonhard Euler, Marin Mersenne, Jean-Philippe Rameau, Joseph Sauveur and Thomas Perronet Thompson, all well-known names in the history of tuning and temperament. Among the modern authors James Murray Barbour and Mark Lindley are most often quoted, and this is no surprise.

The book is, as to be expected, full of formulas, tables, diagrams, illustrations (often from the sources described), photographs of instruments (original or reconstructed copies) and paintings, and so on. Barbieri's style of writing is derived from the sciences: brief and succinct and quickly going from the premises to the conclusions. Each chapter starts with a short overview of the topics to be discussed, as does the book as a whole. Most chapters start with a little theory, if only to introduce the concepts, symbols and quantities used to analyze the various systems to be discussed later on. Chapters are always concluded by a section entitled 'Conclusions', in which the results of the analyses are summed up. Some chapters, such as Chapter F on Equal Tempered Systems, are centred around theoretical discussions, but most often it is the source to be discussed that steers the theoretical discussion and not the other way around. Barbieri rarely creates a framework of his own. The source has the absolute priority, and accordingly the book contains many quotations, sometimes too many to my taste. The book is indeed centred around (and 'controlled by') the enharmonic instruments, rather than the theory of tuning and temperament or the enharmonic musical repertoire.

Despite the theoretical introductions to most chapters this is no book for 'beginners'. It presupposes at least some general knowledge of the subject - otherwise, one is too overwhelmed by the avalanche of information to be able to grasp the tenor of the various chapters - and some experience in dealing with interval ratios, with temperings, with logarithmic measures, and so on is no superfluous luxury. Knowledge of the Italian language is not required. All quotations after Italian authors are given both in the original wording and in English translation. The same is true for the quotations after texts originally written in Latin, Spanish or French. German sources are used every now and then.

As Barbieri has done in some of his earlier publications, this one also include a few source texts in full transcription, such as the documents around Nigetti's cembalo omnicordo on pp. 479-505 and those around Giovanni Battista Orazi's flauto traverso enarmonico on pp. 530-545.

The title of the book also promises a discussion of enharmonic music, not just the instruments. And indeed, wherever music can be connected to the instruments and systems to be discussed, Barbieri provides information on it or even provides a transcription. Not always can such music can be found: many instruments were designed with the goal to play 'normal' music but in better intonation. Sometimes fragments are quoted that illustrate particular advantages of certain systems. It is a pity that not all the musical material (including many 'ordinary' music examples) has been set in a uniform and easily readable way. Now we find computer-set music examples and pieces, music photographed from other publications, facsimiles, handwritten transcriptions and so on, in many cases, to my taste at least, in too small a type. (For the rest the typography is very good, apart from the often rather overcrowded pages due to the many tables, illustrations, quotations, and so on.) I would have like some more analysis and explanation of the pieces of enharmonic music, especially to understand in which way the composition made use of the additional possibilities that the enharmonic instruments made possible. A little CD is added to the book on which most of the more extended music examples can be heard in a synthesized performance, without any aesthetic claim, merely to make audible how they sound.

Barbieri's Enharmonic instruments and music is certainly a book to be possessed, to be consulted and to be read by all those interested in the history of enharmonic instruments. One cannot say or write something about enharmonic instruments or enharmonic music any more without first referring to the information contained in Barbieri's book.

REVIEW OF BOZZINI QUARTET: ARBOR VITAE (JAMES TENNEY: QUATUORS + QUINTETTES)

Bob Gilmore

James Tenney, *Arbor Vitae, Saxony, Stochastic String Quartet*, *String Quartet in One Movement*, *Koan for string quartet*, *Cognate Canons*, *Diaphonic Study*, *Quintext*. Quatuor Bozzini (Clemens Merkel, Nadia Francavilla, Stéphanie Bozzini, Isabelle Bozzini) with Rick Sacks, percussion, Eve Egoyan, piano, Miriam Shalinsky, double bass. CQB 0806, 2008. www.actuellecd.com.

Let's get the "review" out of the way first, so we can talk about the music. This two-CD set of quartets and quintets by the American composer James Tenney (1934-2006) is one of the finest recordings to have come my way recently, essential listening not only for anyone interested in Tenney's music or in microtonality in general, but for anyone wanting to understand some of the ways in which new music has developed in the past three or four decades. That's a weighty claim but I stand by it. Relatively little played for much of his lifetime, Tenney's music became better known only in the last dozen years of his life and now the ears of the new music world are wide open to it. With this new recording we have a Tenney release that offers superb performances of a collection of some of his finest, most individual works (here represented by *Quintext, Saxony,* and *Koan*) together with some tougher nuts that nonetheless prove tastier as time goes by (works like *Cognate Canons, Diaphonic Study,* and his last work, the string quartet *Arbor Vitae*). Previous fine Tenney discs have appeared (Marc Sabat and Stephen Clarke's recording of the violin and piano music on Hat Hut, the Barton Workshop's of the *Postal Pieces* on New World Records, among others), but for all the excellence of the playing these earlier discs have often tended to offer works from what feels to me like the periphery of Tenney's achievement rather than the centre. If you don't like the music on this Bozzini Quartet release, you can conclude that Tenney is just not for you. The Montreal-based Bozzinis have established themselves beyond question as one of the finest new music quartets on the scene, skilful and dedicated young players with a consistently adventurous approach to repertoire. Their performances here are never less than outstanding.

Tenney's explorations of microtonal tunings began in 1972, more than a decade after his brief and argument-filled "apprenticeship" with Harry Partch at the University of Illinois in 1959. Tenney's theoretical writings offer an expansion of many of Partch's tuning concepts, placing Partch's interest in extended just intonation ("extended" through the use of harmonies derived from the seventh and eleventh partials) in a broader conceptual framework that acknowledges the complexities of our perception of pitch and the sophisticated mechanisms our brain uses to process aural data. Not all of Tenney's post-1972 works employ just tuning, although most of them use harmonic relationships made possible by the expanded pitch world of microtonality – more specifically, through a particular navigation of that world by means of a pitch matrix that Tenney termed "harmonic space", which offers quantitative measures of "harmonic distance" between two or more pitches. These theoretical ideas, brought to sonorous life in his compositions, are described in his article "John Cage and the theory of harmony" – *Soundings 13: The Music of James Tenney*, ed. Peter Garland, pp. 55–83 (Santa Fe, NM: Soundings Press, 1984).

At the conceptually simpler end of Tenney's spectrum is a work like *Saxony* (1978), originally for saxophone with tape delay but heard here in one of its various possible incarnations, for string quartet with delay. This piece, like several others laced through his output, takes its pitch material from a single harmonic series. The series is revealed gradually, in an ever-more-dense texture, with the delay system catching the long tones and phrases of the players and re-injecting them into the texture. Characteristically for Tenney, this music avoids drama or incident (more so than does much of the contemporaneous "spectral music" from France, with which it otherwise has several things in common) and offers instead a rich listening context in which the listener's perceptual experience seems to count for more than the decoding of any "message" from the composer. *Koan*, a 1984 reworking for string quartet of a much earlier solo violin piece, is a twenty-minute exercise in slowly moving string glissandi set against steady drone pitches. Conceptually elegant and perceptually engaging – if one is in the mood for it – the work can be a real challenge for many audiences not sympathetic to its particular sort of austerity. The Bozzinis play it superbly (with special praise due to violinist Clemens Merkel, who has to negotiate slow glissandi evenly and musically over long spans of time in a steady eighth-note rhythm continually crossing two strings).

For me the real gem of this set, and practically a textbook of Tenney techniques, is the 35-minute *Quintext,* never before recorded (and rarely, if ever, played complete). Subtitled "five textures for string quartet and bass", this dates from the all-important year 1972. The individual movements are: "Some Recent THOUGHTS for Morton Feldman", "CLOUDS for Iannis Xenakis", "A Choir of ANGELS for Carl Ruggles", "PARABOLAS and HYPERBOLAS for Edgard Varèse" and "SPECTRA for Harry Partch". As the subtitle indicates, each movement creates and sustains a texture without dramatic change of any kind, and each has a connection to the work of the composer invoked in its title – although Tenney's homage could never actually be mistaken for the music of the composer concerned. The first movement is a study in soft, sustained, non-developmental, dissonant vertical harmonies, an obsession in much of Feldman's early work (especially, perhaps, the *Vertical Thoughts* series, from which Tenney derived his title). However, in "Some recent THOUGHTS for Morton Feldman", the harmonies specified are microtonal, and tuned just intonation (using a scale of intervals analogous to the first 13 odd-number harmonics), one of Tenney's own obsessions, but a concept totally at odds with Feldman's devotion to equal temperament. The second movement is a tapestry of sound and silence, with the 'sound' sections being a homage to the string cluster textures of Xenakis's *Metastasis* and other works, albeit randomly derived. The third movement is a sort of textural parody of Ruggles's *Angels*, this time involving actual quotations of chords from Ruggles's score, though once again in just intonation; it is played *sul ponticello* throughout, invoking the muted brass of the original. The fourth movement, with its continual but irregular glissandi finally converging around middle C, evokes the parabolas and hyperbolas that Varèse wanted to create in sound by use of instruments like the siren; again, however, the movement is technically speaking almost antithetical to Varèse's own compositional methods, with its use of graphic notation and consequent degree of randomness. Finally, "SPECTRA for Harry Partch" proposes yet another sort of homage. In terms of its sonority and its compositional approach the piece is quite far from the sound of Partch's music, yet the complex scordatura that Tenney specifies for the strings yields music that uses the most complex fabric of just intervals he had so far employed (surpassing in complexity, thanks to its use of intervals derived from prime number partials as high as the thirteenth, the harmonic resources of Partch's own musical language).

The two other quintets on this disc are much later works. *Cognate Canons* (1993)*,* which adds a percussionist to the quartet, is dedicated to Nancarrow, some of whose rhythmic techniques it employs. (Among his many other achievements Tenney was among the first to study the music of the long-neglected Nancarrow, contributing detailed liner notes to the recording of Nancarrow's *Studies for Player Piano* released by Wergo in the late 1980s.) Tenney gave me a cassette of *Cognate Canons* shortly after its premiere (by the Arditti Quartet and Robyn Schulkowsky), but it has taken me all these years to warm to it – here the persuasive playing of the Bozzinis and the sympathetic sound of the recording (by Hessischer Rundfunk in Frankfurt) do much to help a work whose material at first can seem rather anonymous and even stilted, its rhythms well calculated but not especially vibrant. The piano quintet *Diaphonic Study* is a thorny (and perhaps overly prolonged) exercise in dissonant counterpoint of the sort explored by Ruth Crawford and her husband Charles Seeger earlier in the 20th century, here recast in a microtonal tuning system. This work seems, at least initially, to resist straightforward aural comprehension in the way that *Saxony* or *Koan* positively revel in it, although for those listeners prepared to invest the necessary time *Diaphonic Study* offers its own particular rewards.

The set also offers two early, short quartets – the *String Quartet in One Movement* of 1955 (a student piece; interesting, but to my ears not really more), and the *Stochastic String Quartet* of 1963, one of Tenney's (and the world's) first computer-generated compositions. While perhaps not especially engaging as a listening experience, the *Stochastic String Quartet* is representative of a way of working by means of which Tenney creates a field of musical experience mid-way between the architectural calculations of Xenakis and the intention-free indeterminacy of Cage. His last work, the string quartet *Arbor Vitae*, like the *Stochastic String Quartet* of more than forty years earlier, is also algorithmically derived, its expanding/contracting pitch range and increasing/decreasing temporal density having been worked out with the programming skills of the young composer Michael Winter during Tenney's last illness in the summer of 2006. It's a piece I found hard to make much sense of at first but, here again, repeated listenings reveal a world of sonic fascination and ever-more-audible structure. The Bozzinis commissioned *Arbor Vitae*, and their stunning recording of it and the seven other works on these discs is a monumental achievement, a fitting testimony to a composer whose real stature is becoming clearer with every year that passes.

If you are interested in reviewing CDs, books, websites or other material relevant to the aims of this journal, please contact the Editor at thirty-one@huygens-fokker.org.

PETER ADRIAANSZ is a Dutch composer based in The Hague. Recent works have been premiered by Sonsoles Alonso and Jorrit Tamminga, Compagnie Bischoff, Crash Ensemble (Dublin), Electric Guitar Quartet Catch, Ensemble Klang, the Ives Ensemble, LOOS Electric Acoustic Media Orchestra, Ensemble MAE, Percussion Group Den Haag, Trio Scordatura, and others. Adriaansz' work can be characterized by a systematic, research-oriented approach towards music, in which sound, structure and audible mathematics constitute the main ingredients. In recent years an increasing interest in flexibility, variable forms and - especially - microtonal reflection can also be observed in his work.

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