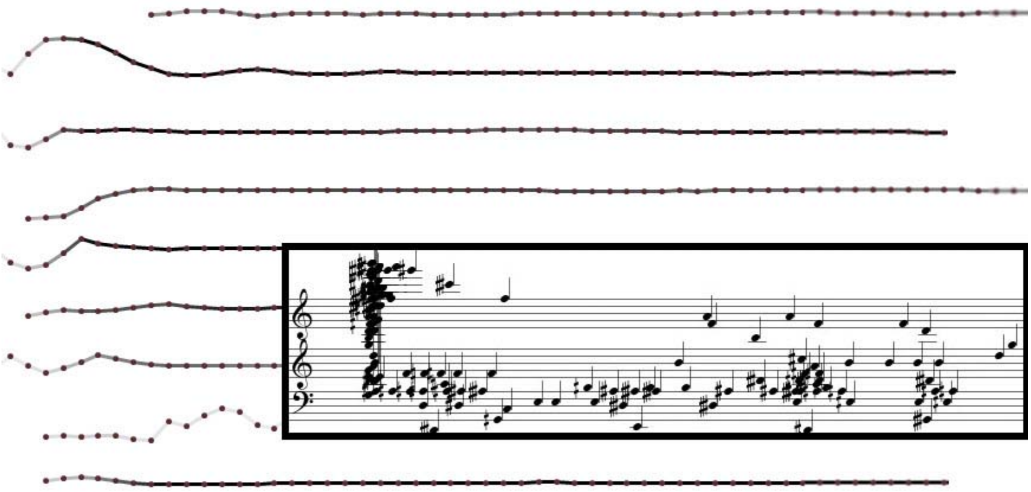
Portfolio and exegesis: Composing through a spectral scope

PhD Thesis

Charalambos Sophocleous

Supervised: Dr. Michael Young



Goldsmiths
UNIVERSITY OF LONDON

Acknowledgments

I would like to express my gratitude to my supervisor, Dr. Michael Young, for his valuable guidance and support.

I would also like to thank my family, especially my fiancé Myria and my son Michael for their love and unlimited support throughout the course of my studies.

Special thanks go to Panagiota and Yianna Schiza, my mom Ariadni and George Petrou.

Abstract

The current research focuses on the spectral nature of sound, its timbre manipulation and contribution to the overall syntax of a composition. It describes the compositional thinking that emerged in the early 20th Century, and further recognized by the spectralists, which acknowledges timbre as an autonomous phenomenon and an agent of music creation. It also describes the spectral composers' technological advancements and influences from the early electronic studios and the adaptation of electronic techniques in the acoustical domain. Furthermore, it includes my methodology and preoccupations concerning the creation of compositional models and the reliance on dynamic analysis techniques for the fabrication of material that serve as a guide for formal structures.

Table of Contents

Acknowledgments……………………………………………………………………………………………………i

Abstract……ii

Table of Contents…………………………………………………………………………………………..iii

Introduction…………………………………………………………………………………………………..1

Chapter one
Methodology

1.1 Introduction………………………………………………………………………………………6
1.2 The role of the body and instrument…………………………………………………………..6
1.3 The role of the composer…………………………………………………………………………7
1.4 The role of the 'live'………………………………………………………………………………8
1.5 The role of technology (hardware/software)…………………………………………………..9
1.6 The role of analysis………………………………………………………………………………11
1.7 The role of silence………………………………………………………………………………..12
1.8 The role of microtones……………………………………………………………………………12
1.9 The role of notation……………………………………………………………………………..13
1.10 The perceptual role of pitch and timbre…………………………………………………….14
1.11 Conclusions………………………………………………………………………………………16

Chapter two
Analyses

2.1 Drops and Pipes……………………………………………………………………………………18
2.2 Bushology……………………………………………………………………………………………23
2.3 Hz Discrimination…………………………………………………………………………………28
2.4 Metabolos……………………………………………………………………………………………32
2.5 Transient…………………………………………………………………………………………….49
2.6 The God Particle…………………………………………………………………………………..56
2.7 Cicada……………………………………………………………………………………………….63

Conclusions…………………………………………………………………………………………………70

List of included material………………………………………………………………………………71
1. Audio CD
2. Data CD
3. Scores

Bibliography…………………………………………………………………………………………………73

Introduction

At the beginning of the twentieth century, the Enlightenment thinking of absolute expression and Romantic ideals were demolished. This was the start of the formation of modernism. Thinkers began to question the authority of the unquestioned universal knowledge in all fields - Charles Darwin (biology), Ludwig Boltzmann (physics/thermodynamics), Baudelaire (literature), Mallarmé (poetry) - to name a few. This questioning combined with the massive material and cultural devastation of World War I and World War II gave fertile ground to various movements in arts. Impressionism, Futurism, Symbolism, Cubism, Dadaism, Surrealism, Expressionism, were some examples of this artistic upheaval. In music, tonality came to an end with the last movement of Schoenberg's 2nd String Quartet (1908), and culminated in his first completely twelve-tone work, the Suite for Piano, Op. 25, sixteen years later. For Schoenberg, the twelve-tone system was able to provide and replace the structural differentiations formerly furnished by tonality which he believed would permit the continuation of traditional musical values (as seen by the use of standardized Baroque dance forms in his Piano Suite) (Morgan, 1991, p.188). In contrast, the Darmstadt school of composition saw Schoenberg as an 'old relic' treating the twelve-tone series in a thematic manner under traditional forms and pronounced an affiliation with Webern's transparent compositional thinking. Boulez's *Structures I* was a monumental composition and an influence to his contemporaries, treading all parameters of sound on an equal base. This marked a tendency towards systematization and parameterization that is best appreciated from the perspective of *information* and interpreted in terms of *programming*, characteristics of our technological era (Deliège, 2010). In a way, serial thinking promoted uniqueness, focusing on avoiding repetition, aiming for completeness, and tending towards permanent innovation (Bandur, 2001). The integral serialism of the 50s also encouraged heated debates among Boulez's contemporaries (for example Boulez vs. Cage on indeterminacy) but most crucially sparked a new creative wave that veered away from the orthodoxy of integral serialism of the 50s into a pluralistic 'post-serial' 1960s. Examples were Cage's *Music of Changes* (1951) based on *I-Ching*, Boulez's *Le Marteau sans maître* (1954) (incorporating serialism with approachable textural and timbral transformations based on a continuum of sonorities), Xenakis's stochastically derived *Achoripsis* (1958), Stockhausen's intimate and personal work *Aus den sieben Tagen* (1968), the 'quotation' works of Berio and the 'theatrics' of Kagel's works (third movement of *Sinfonia* and *Staatstheater* respectively), the minimalist works of La Monte Young, Steve Reich and Philip Glass, and lastly the politically engaged music of Nono and Cardew. Adding to this, the rise of the electronic studios in the 1950s and 60s had accumulated an interest on timbre's multidimensional properties, with researchers examining and decomposing sound into its constituent attributes. Noise became as important as sinusoids, the spectral envelope and formants were realized as indisputable elements of vocal attributes, the time envelope and sounds' onset and decay characteristics became as important as its steady state.

A shift towards a postmodern terrain is evident; a collapse of the hierarchical distinction between high and popular art, an eclectic mixing of aesthetic codes, a nostalgia of the past, a playful and ironic attitude, a blur between science and nonscience, and a reconfiguring of knowledge (Seidman, 1994). There is an a-historical approach to the past, a pluralism characterized by stylistic diversity, a breakdown of overarching stylistic or linguistic norms that lead to the celebration of difference and diversity (Paddison, 2010). In Lyotard's words, the chief theme of postmodern culture is the decline of the legitimating power of 'metanarratives' (theories of knowledge, morality, or aesthetics) (Seidman, 1994). How is a 21st Century composer able to cope with this postmodern terrain? Can the composer keep his individuality? Can he construct his own aesthetic codes?

The composer needs to formulate a hybrid aesthetic theory that embraces his innermost feelings, his academic and cultural background among with his constantly shifting influences and scientific thoughts; in other words to be *eclectic*. Personally, my research originates from the observation and spectral analyses of natural resonances and the realization of these timbral entities into streams of quantified/transcribed components that are consequently grouped into perceptual unities, thus creating horizontal streams evaluated based on their spectral continuity, frequency/time proximity and timbral similarities, which are further manipulated by incorporating dilated and contrasted time units (whether locally or globally), utilizing modulation techniques like frequency or ring modulation extended into new models (figure 1).

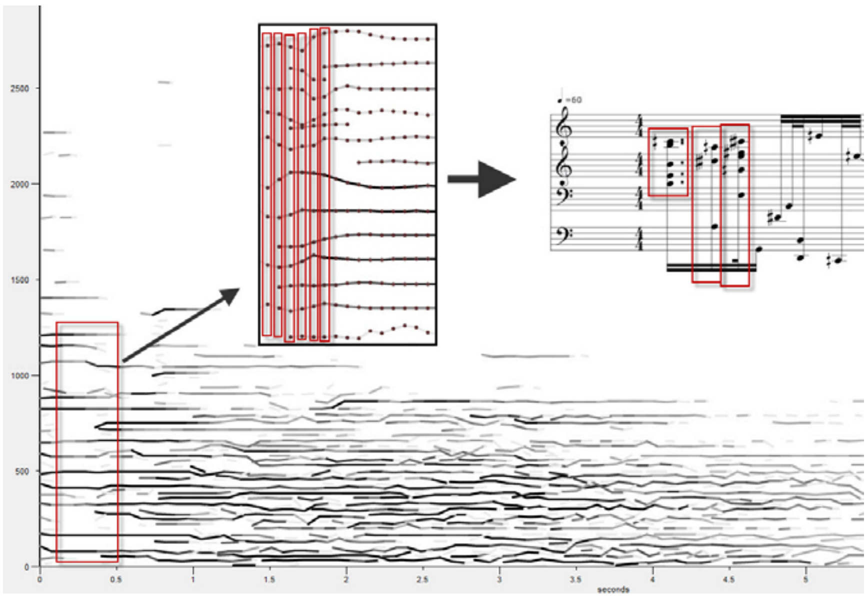


Figure 1: Fourier analysis, partial tracking and quantification.

These analyses include pitch tracking, spectral, formant or partial tracking of audio samples of acoustical instruments, natural phenomena, and even speeches of political figures. Thus, my compositional syntax stems out of a non-dogmatic, all-inclusive attitude having sound as paradigm for the creation of formal structures. The observation of sound's resonances and its dynamic FFT analysis serve as a model to rediscover the inner life of sound and its perceptual impact. This is on a par with the definition of spectral music as being *any music that foregrounds timbre as an important element of structure* (Reigle, 2008). Ligeti also considers that ‘there must be some kind of order [in a piece of music], but not too much of it and should not be dogmatic, but there must not be disorder either’ (Ligeti, 1983, p. 52). *This thought on equilibrium of dissimilar powers is crucial to my work*. Humor has the same driving force as seriousness (see *Bushology* for example); tradition and modernity; form and openness; pulse and free flow; microtones and equal-tempered tuning; harmonicity vs. inharmonicity; time vs. uncertainty of time. Extra-musical issues are also stressed such as politics (Bushology), issues related to social psychology due to the ‘irrational tuning of our equal-tempered system’ (Hz Discrimination) (Ben Johnston in Duckworth, 1999, p.151-52), even stochastic formulas for the creation of macroforms in *Cicada*.

Furthermore, there is a convergence but also a divergence between the orthodox spectral aesthetic goals and my aesthetic theory. Convergences include the attitude of ‘a more ‘ecological’ approach to timbres, noises and interval’ with an ‘integration of all sounds’ (from white noise to sinusoidal sounds) into a composition (Grisey, G. & Fineberg, J. 2000, p. 2-3). A break out of the tempered system is also evident with a ‘re-establishment of the ideas of consonance and dissonance as well as modulations’ (e.g. FM/RM modulations) (*ibid.,* p.2). Sections also have an ‘attentive attitude towards the phenomenology of perception’ with an exploration of ‘stretched’ and ‘contracted’ time, but also explore ‘the thresholds between different parameters’ and the use of ‘invention of processes, as opposed to traditional development’ (*ibid.,* p.2). At the same time, divergences can be noted from the orthodox spectral argument. I would like to quote Dumitrescu on the contradiction between phenomenological characteristics in his music and rationalization, which also applies to my work:

> . . .yes, you are right, there is a contradiction in my work. . .this contradiction is in me, and is fundamental. I'm split between two tendencies, one towards the past, the other towards the present and the future emerging in the present. So there is a discontinuity, a kind of dialectic without conclusion, unresolved. There is a nostalgia for something that I never knew, but feel that I once lived - which isn't true, or only in an anthropological sense - and there is also something that is absolutely necessary to say now. The conclusion? I am a person who is exposed in an X-ray photograph revealing divergent tendencies, and out of this divergence comes something which is a part of my necessity. I am incapable of being other than I am (Hodgkinson, 1997).

Indeed, every composer has an unresolved inner dialectic that is on constant alert. Dumitrescu with his ‘hyperspectral’ works has transformed timbre into a teleological entity that refuses explanation; an ‘ineffable’ shadow in comparison to the ‘structural’ music of Grisey and Murail. From the point of view of Dumitrescu, the orthodox spectral concerns can be argued as being attached to a *structuralism* school, especially when the musical material is being highly subjected to formalised manipulations. In my portfolio, both worlds are being equally explored. In *Metabolos*, the structural dimension of the harmonic series is being investigated as well as its entropic image at the end of the composition, reminiscence of the ‘spiritism séance’ and ‘sound plasma’ of Radulescu (Radulescu, 1984; program notes). Other instances (e.g. *The God Particle*) the partial tracking analysis of the sound is being dilated and transposed to the usable range of the instrument. This creates a distance from the original source and produces linear note-based textures; however it retains the inner rhythmic skeleton of the sound that is equally important for the overall realization of macroforms. The immediate problem with this argument, perhaps shared with some musicologists that want to label everything with 'isms', is that it veers away from the original concept of spectralism. My argument to this is that I use spectral techniques simply as a *reference point of departure*; a neutral field that can grow (or not grow; for example the spectral stasis in Grisey's *Jour,Contre-Jour* or Haas's *In Vain*) in unexpected ways but also solid enough to have a strong presence. There is a thin line between harmonicity vs. inharmonicity, between timbre and harmony, between natural and treated material (in electronic or mixed works), or between effable and ineffable concepts. This flexibility is what makes spectral music transcend meaning. In my opinion, it is perhaps the antidote to the postmodern era of 'anything goes'.

Of course there is another criticism on the opposite side of Dumitrescu's argument that regards spectral music as too 'naturalistic'. Why is the natural harmonic series any better in creating musical meaning than any other material? Obviously, this comes from critics attached to the post-war avant-garde. From the point of historical significance, spectralism seems to be the last link in the chain of music theories, from Pythagoras, to Rameau, to Hindemith, to spectralism. On the other hand, serialism can be considered as unique; as a visionary movement that doesn't imitate nature, a movement built from the ground up. But of course throughout the course of the second half of the twentieth century its original orthodoxy has slowly been eroded. In the case of Boulez, his pure non-contaminated musical language of the 50s has fallen 'from modernist grace into a postmodern netherworld of libidinal self-gratification' (Thomas, 1995, p.225). Thomas reveals the example of *Le visage nuptial*, a 'work in progress' that started in 1952 with a revision in 1989. Boulez simplifies rhythmic values, rewrites quarter tones to equal tempered pitches and assigns conventional sung pitches to text rather than keeping the original sprechstimme words, invoking a 'musical vocabulary closer to Debussy than Darmstadt' (*ibid.*, p.225). Nevertheless, this freedom from constrains has slowly transformed avant-garde thinking. This can be traced back to Boulez's 'pretty monotonous and monotonously pretty' (quoting from Stravinsky) (Stravinsky, 1971) *Pli selon pli*. The onset gesture of the work as well as its static texture can be mistaken for a 'naturalistic' spectral composition. Similarly, the same can be argued in some sections of the spatially derived *Répons* as being too close to expressionistic Stravinsky-anisms. It seems that serialism found its 'naturalness' by inclusiveness, divergence and pluralism. This is once again a conflict of 'isms'. Consequently, I argue that in a postmodern society, natural vs. arbitrary binaries are eroded so much that a composer can finally have a symbiosis of both. A clear example would be that of Grisey. By the end of his life he was no longer a spectral composer. His 'liminal' music accumulated a haunted mystical dimension that resists codification. It transcended meaning without being linked to any 'isms'. Perhaps this is where Truth lies and that is why I don't subsume myself in any dogmatic fetishisms. My music is open for interpretation.

In Chapter one, a list of seven of my works will be cited among with the ideas, concerns and methodology regarding the formation of the works. In Chapter two, the compositions will be presented and analysed in detail.

1. Methodology:

1.1 Introduction

In this chapter, my compositional thought and methods will be discussed. Composing is a multifaceted experience; therefore this Chapter is divided into subsections on ideas that I have been preoccupied with throughout the course of my studies. Special mention is given to the first composition that marked a turn to my compositional style. Added to this, being mainly an acoustic composer who wants to adapt electronic techniques in the acoustical domain, I find the role of the human body and the composer intrinsic to the creation of a composition. Real-time vs. studio synthesis composition is another critical issue as well as the choice of software and the role of technology linked with questions of sustainability of a composition. Furthermore, spectral techniques and the instrumental simulation of complex timbres either from field recordings of natural phenomena or from analyses of instrumental sounds are discussed, as well as the psychoacoustic principles of pitch and timbre.

The compositions referred in this Chapter and further analysed in Chapter three are the following:

1) *Drops and Pipes* (2006) for Flute and Live Electronics.
2) *Bushology* (2007) for Tape and Alto Saxophone.
3) *Hz Discrimination* (2009) Acousmatic composition.
4) *Metabolos* (2011) for String Quartet.
5) *Transient* (2012) for Piano and Electronics.
6) *The God Particle* (2012) for Flute, Clarinet, Percussion, Piano, Violin and Cello.
7) *Cicada* (2012) for Flute, Clarinet, Bassoon, Percussion, Piano, Violin, Cello and D. Bass.

1.2 The role of the body and instrument

Three of the above compositions utilize a performer who interacts with electronics and another three are purely acoustic compositions. In *Drops and Pipes* there is a real-time environment in which event decisions are reciprocally intertwined between the computer and the performer. In *Transient*, electronics are triggered live and in *Bushology* there is a simple 'interaction' with pre-composed tape material. Garnett supports the notion that interaction has two aspects, one that the performer's actions affect the computer's output and secondly the computer's actions affect the performer's output (Garnett, 2001). He highlights that the interaction 'becomes a more significant aspect of the work the more the performer can actually effect changes not only in spatialization but in tempo, dynamics, timbre, rhythm and pitch' (*ibid.,* p.23). This instant reciprocity was a significant factor in the creation of *Drops and Pipes* as the player is free to improvise on a set of rules affecting the overall macrostructure as fluctuations of the parameters mentioned above instigate an immediate response from the computer, and vice versa. The acoustical instrument can also bring gestural nuances to the performance (rubato, subtleties of phrasing, articulations and dynamics) as well as the inherited physical constraints of the instrument that can become a feature in a composition (e.g. extended techniques), even interpretative possibilities that can open up potential in the 'growth of the work over time or across cultural boundaries' (*ibid.*, p.27). These gestural nuances can easily be apprehended by the audience as acoustical instruments are culturally accepted because of the 'instrument inclusiveness' of our Western tradition, while a computer is disreputable as a vehicle of expression for a broad audience (disregarding here the sophisticated institutionalized audience). For me, this *modus vivendi* between the acoustical and the electronic is of high importance and is reflected in my compositions as a discourse between a live performer and electronics (e.g. *Drops and Pipes*, *Bushology* and *Transient*) or by using electronic techniques (for example FM or RM) in a purely acoustical environment (e.g. *Metabolos*, *The God Particle* and *Cicada*). Even an acousmatic composition can indirectly assume a physical presence as in *Hz Discrimination*, involving techniques which directly correlate with the psychoacoustic principles of the auditory system.

1.3 The role of the composer

Adorno considers the revolutionary art movements of the early twentieth century to have unleashed the 'vortex of the newly taboo' (Adorno, 1997, p.1). As Garnett describes, this 'newly taboo' mirrors the attitude that 'once something has been accomplished, it becomes taboo to do it again, thereby leading to another round of system-building, again requiring validation' (Garnett, 2001, p.28). Electronic music of the 50s and 60s had also spiralled into this mentality mainly due to the over objectified and formalist influence from the serial school of composition; always creating something new for the sake of the experiment, and we still see vestiges of this attitude in the twenty first century disguised as experiments, a 'banal play with abstraction, algorithm and parameterization without sufficient attention to the resultant sound and its possible significance' (*ibid.*, p.30). Garnett proposes to bridge the gap by injecting the artist, the composer, 'back to the current cultural scene rather than reinforcing the current institutionalized isolation' (*ibid.*, p.30). In *Drops and Pipes*, the reliance on parameterization drives the work forward, but there is a conscious effort not to let any parameter be controlled automatically without any judgment (hence mapping parameters on a physical keyboard to be triggered live based on a *score*, always having the sound as reference). This first composition had a significant influence on my future compositional work, giving more attention to the resultant sound and its intricate details rather than focusing on the algorithm behind the composition or the blur of distinctions between the composer and the performer. This is evident nowadays in manifestos of laptop performers (BileEnsemble, 2012), creating an amalgam of sound events with sometimes obfuscating discourses, devaluing our relationship with the psychoacoustic principles of hearing. As Garnett contends, there is an assumption 'that if a formula generated it, and the formula is coherent then the resultant music is not just coherent but somehow, and usually thereby, aesthetically valuable' (*ibid.*, p.30). For me, and as it solidified at a later stage in my studies, the inner structure of the sound and its psychoacoustic repercussions are more important than open platforms. This interplay between control and interaction is critical as I don't what to alleviate the role of the composer in a creation of a work.

1.4 The role of the 'live'

Drops and Pipes was also my first and only real-time interactive composition. This is partly due to the need for meticulous control of the temporal succession of partials/sine tones as accurately as possible. A slight deviation in frequency or temporal shift of a harmonic cluster negates the effect of hearing the event as a unified timbral entity with the same fundamental, consequently becoming quite the opposite sonority with an inharmonic character. As Emmerson asserts, 'in a studio the unexpected can be tamed and contained' (Emmerson, 2007, p.113), and paradoxically in some of my compositions (e.g. *Transient*), that is exactly what I was aiming for; to tame the unexpected as precision or vagueness in spectral music correlates with the success or failure of realizing a sonority as harmonic or inharmonic which is intrinsically significant to its theory. Furthermore, Cort Lippe highlights that 'real-time transformations using the instrument's sound as input to the transformational process, cannot easily avoid a kind of 'call and response' relationship' (Lippe, 1996, p.2) (figure 2).

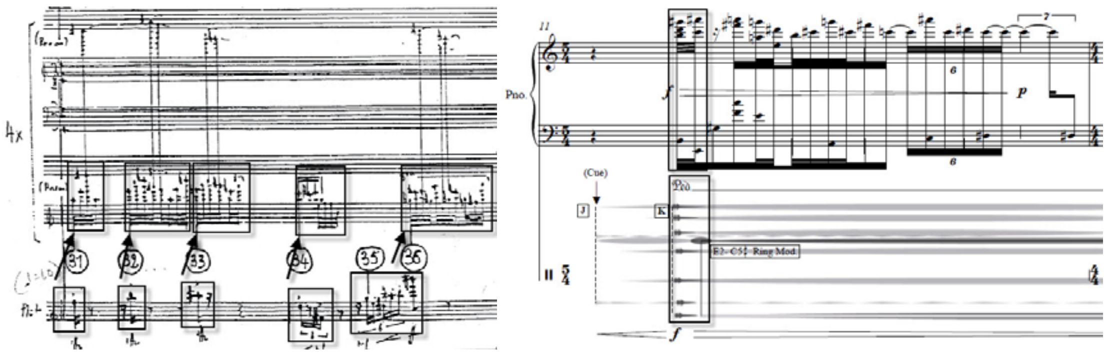


Figure 2: 'Call and response' in Philippe Manoury's *Jupiter* (Manoury, 1992)(left).
Simultaneous onset in *Transient* (right).

In *Transient*, this 'call and response' relationship was undesirable, as the piano attacks must be persistently synchronised with the attacks of the harmonic/inharmonic clusters of the electronics as well as following a strict sequence of patterns, hence the need for sample triggering rather than real- time transformations. With today's technological standards and negligible latency, *Jupiter's* 'call and respond' problem (in both live and non-live situations) can be argued that is finally alleviated. This is not quite true though. Temporal issues, by locating the loudspeakers further away from the listener, can result in excessive delay (approx. 3.4ms per metre of difference from the listener as well as adding the inherited hardware delay) (Barrett, 2009). We cannot avoid the laws of nature. This also has philosophical repercussions of what constitutes a 'live' electronic performance, a subject which is outside the scope of this thesis. Barrett also recognises that sometimes the electroacoustic material, although taken directly from the live performance at one point in time, involves a large temporal dislocation such that traces of 'real-time' are remote (what she calls 'conceptual live transformation') (*ibid.* 2009). Indeed, there are instances where random algorithms aesthetics can destroy the instrument-computer relationship. Furthermore, in his article "Composing in Real-time", Jean-Claude Risset plays the 'devil's advocate' and raises some critical issues regarding real-time compositions which I found valid during the writing of my only real-time composition *Drops and Pipes* (Risset, 1999, p.31). He asserts that 'complexity is often achieved in real-time systems through layering, thus forsaking real-time' and that real-time synthesis is hidden behind a few menus through certain gestures, thus being 'restricted to certain features which have been selected - ahead of time – to be controllable in real-time' (*ibid.,* p.33). Furthermore, he maintains that 'random manipulations is hard to resist' and that 'patterns which are easy to produce through live manipulation tend to become clichés' (*ibid*., p.34) and that real-time operations dictate haste, instancy, habits and reflexes (*ibid.,* p.37). Moreover, Risset, although having a negative attitude towards real-time techniques, clearly advocates that real-time composition has a lot to offer for example instant adaptation, renewal and even the challenge of risk in the performance (Risset, 1999, p.36). Some of the above arguments were noticed while composing *Drops and Pipes* rethinking the aesthetic values of the 'live', its drawbacks and advantages throughout the course of my studies. I've finally concluded that studio work (and all that is symbolizes; time to think, experimentation, modification, compositional directions unanticipated at the outset, and most of all *precision* in performance) was more favorable to my needs than live electronic manipulations (Barrett, 2009). Sometimes, the nature of the composition itself foretells the technological requirements and not the other way around. In *Bushology*, because of the motoric rhythms in fast tempos, no score following software is able to interact with the saxophone in real-time and most importantly in an exact timing, as its homophonic texture and precise 'hocketing' of voices is a situation to which the software is inadequate to respond; hence my decision to use a fixed medium for the electronics (even sensitivity issues and microphone placement is all that it needs to make onset detection fail in a patch). The subject of 'live' is inexhaustible. For now, we don't have enough historical detachment in order to truly be objective about its advantages or disadvantages. Only time will reveal its multifaceted journeys.

1.5 The role of technology (hardware/software)

Drops and Pipes was based on a live interactive environment between a flute and electronics. After the first performance of this composition in 2006, questions had emerged regarding technology in general. Can technology be restrictive in any way? After a successful concert, the night ended with the loss of everyone's recordings due to a power failure. This also raised questions about the vulnerability and ephemerality of technology and seeing technology as a helping tool rather than as an equal partner in the creation of a musical composition. Grisey argues that 'the technology of new instruments, of synthesizers or whatever, is not done for us. It's done for the business' and gives an example of the erroneous thought that technology will one day be stabilized (Grisey, 1996). How does technology and the choice of hardware or software affect a composition? In their informative article "Time to re-wire? Problems and strategies for the maintenance of live electronics", Polfreman et al. argue that the choice of devices and their availability play a significant role on the number of performances over time. Giving examples of two Jonathan Harvey's compositions, *Advaya* and *Madonna of Winter and Spring*, the rare and expensive hardware in the latter work (DX1 and TX816 synth, E-mu Emulator II sampler) restrict its potential performances (figure 3) (Polfreman et al., 2006). This is still valid nowadays as the choice of an obscure list of requirements could potentially ruin future performances (I also add to the list *any* objects that could produce sound and especially custom made hardware or software).

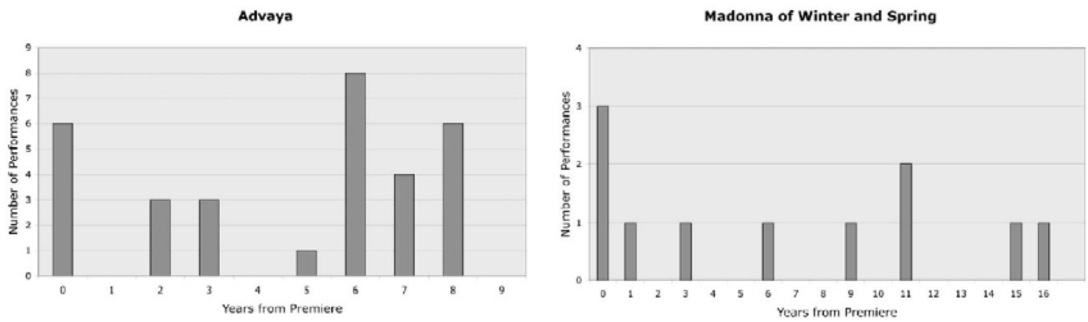


Figure 3: Number of performances of *Advaya* and *Madonna of Winter and Spring* since their premiere (Polfreman et al. 2006).

Consequently, what is the relation of technology with the audience? While laptop performers proclaim their democratic manifestos in relation to the openness of their collaborative attitude (BileEnsemble, 2012), they also spread an oligarchic attitude mainly due to the over-complexity of the technological requirements (not maximizing the potential of sharing their compositions with as many people as possible and not only with a specialized audience). This is also evident in institutionalized sponsored and festival performances and the relation with local systems that is hard to be transferred to a broader audience (for example, the BEAST sound diffusion system). The more obscure the hardware/software requirements, the fewer performances will occur; this is demonstrated by figure 3 above. Furthermore, the issue of sustainability of a composition was realized when an upgrade of Audiomulch, which was the main software used in *Drops and Pipes,* and an upgrade of my laptop's operating system made the patch non-functional. This single incident, although negative in nature, has opened the horizon to the embrace of a vast array of software and to avoiding fervently and dogmatically following a single software package for the creation of a composition (e.g. Soundplant for audio triggering, Roland's V-vocal for formant analysis and melody extraction, Sonar X1 for sequencing, Audiomulch for live improvisation, SPEAR for partial editing and synthesis, Pluggo and Hipno as well as various other audio plugins, HighC for score and audio realization and OpenMusic for partial tracking quantification and so on). If software selection was a political issue, I would say that my argument is leaning towards a democratic ideal; *all software is created equal*. Having more options in the software domain is always an advantage as inspiration may derive from the intrinsic functions of a software package that other software may lack (HighC is a friendly graphical user interface and is able to realize a sound event and extract a detailed graphic score at the same time). Added to this, frugality and efficiency of hardware/software in a live performance was and still is of major importance (e.g. *Transient* uses only a simple software sampler triggered from a regular QWERTY keyboard rather than using an external midi keyboard, audio card and complicated software).

To conclude, Murail observes the usefulness of technology and claims that 'the ease with which the computer generates material can give composers much more freedom to imagine, to let their intuitive ideas fully ripen into the imagined musical realization' (Murail, 2005d, p.237). He recognizes, even paradoxically, that algorithms can liberate our intuitions and allow us to concentrate on higher-level work rather than focusing on 'accounting issues' (ibid., p.237). That is exactly why I utilize technology, to be liberated from the burden of calculations, to consummate greater structures from single ideas and to use associations that otherwise would not be possible to imagine (e.g. the use of linear or exponential stretching/dilation of material and quantification of partial tracking analysis of natural phenomena or interpolations from one state to the other).

1.6 The role of analysis

Fourier analysis is utilized either for extractions of melodies from sound events (e.g. the extracted ostinato bass pattern from field recordings in *Drops and Pipes* or the melodic contours in *Bushology* from speech patterns), or for partial tracking (e.g. in *Hz Discrimination*), or to convey partial tracking data calculated in OPENMUSIC as the core pitch and rhythmic materials for either the acoustical instruments or the electronics involved in a composition (used in *Transient*, *The God Particle* and *Cicada*). Partial tracking is a technique of taking successive dynamic Fast Fourier Transforms and predicting the partial amplitudes and frequencies to determinate the best continuations for sinusoidal tracks (Klingbeil, 2009). The construction of an instrument and its resonance or simply a natural phenomenon (e.g. cicadas singing) serves as a model which integrates into the musical discourse of the composition, not just as a reification of the phenomenon or even for its anecdotal nature, but as 'indispensable events within the totality of the musical discourse' (Murail, 2005d, p.203). For example, in *Cicada*, the partial tracking transcription of the field recordings is not simply a programmatic element (a technique used in Messiaen's bird song transcriptions), but is an indispensable event which creates the rhythmic aggregates as well as the microform and the macroform of the composition based on the probabilistic nature of their singing patterns.

Furthermore, ring and frequency modulation using exact amplitudes of resultant partials (seen in *Metabolos*), as well as stretched and compressed spectra and virtual fundamental calculations (seen in *The God Particle*), are extensively applied in the majority of my works. Murail suggests that the paradigm of ring modulation allows for the creation of new types of harmonic relationships that can serve as a technological model for the creation of new spectra (Murail, 2005d). These modulated models are easily manipulated and their resultant sound is digested and recognized by the listener (a simple ratio between the carrier and modulator produces a more harmonious end result as opposed to a complex ratio).

Furthermore, the use of the harmonic series is easily perceived as an arrival point, a 'steady state', vs. an inharmonic sound (e.g. RM sound) which is exactly the opposite; a shift from the norm.

1.7 The role of silence

Contrary to the continuous texture transformations of *Metabolos,* inspired by early spectral compositions, silence is utilized in the rest of my works (except in *Cicada*) as a consequence of the observed analysis of a sound. The envelope of the sound (onset, sustain and decay) is directly involved in the creation of the form of the piece (much like Saariaho's conceptual idea of creating macro forms out of brushstrokes in *Verblendungen*). In *Transient*, the onsets are as important as the silence at the end of each passage, clearly pointing out to the listener that each section of the piece is a mirror of the analysis model that becomes more obscured as sections are stretched beyond recognition, directing focus onto the innate details of the sound. The same principle is applied in *The God Particle*. Also, contrary to the mentioned compositions, the macroform of *Cicada* is created by using a stochastic formula to determine the probability and consequently the density of the spectrally derived material. In this example, silence is a direct consequence of the probability formula.

1.8 The role of microtones

Microtones come as a necessity since a Fourier analysis of a sound reveals a spectrum with partials that are not part of our tempered system. As Murail describes, it is just pragmatic to use microtonal inflections instead of developing a new system (e.g. Harry Partch's theory of intonation based on a *theoretical* harmonic resonance) but to observe *natural* phenomena and deduce consequences rather than reproductions of the original sound (Hirs, 2009b). Furthermore, the more precise the microtonal approximation of a harmonic aggregate, the less beating occurs; the ear perceives the sound as fused into a single object rather than as a chord with different elements (figure 4) (Murail, 2005d). Murail explains this phenomenon using the term 'harmony-timbre' (*ibid.,* p.195). A harmonic event can change its character into a timbral event by simply increasing the precision of approximation of its constituent elements. Consequently, micro-intervals do not produce an 'out-of-tune-ness' as many believe but quite the opposite effect (*ibid.* p.195).

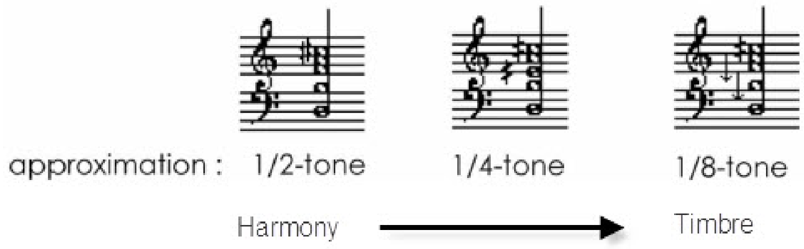


Figure 4: Different approximations of the same aggregate (harmonics 3,5,7,9 and 11 of G1 fundamental) (Murail, 2005d, p.194).

Microtones play a crucial role in my works. In *Bushology*, some microtones are used based on the pitch analysis of Bush's speeches but are not overstated. In *Hz Discrimination*, microtones are highlighted, micromanaging formant areas creating inharmonic spectra. In *Metabolos*, microtones are tied with the 'harmony-timbre' definition that specifically enhances the perception of frequency and ring modulation aggregates, as well as harmonic and inharmonic spectra, by meticulous notation, sometimes in exact cent deviations rather than in quarter-tone approximations. In *Transient*, the piano's equal-tempered tuning combines with the non-equal-tempered material of the electronics and in the last two compositions (*The God Particle* and *Cicada*) microtones are exclusively used on all instruments (except the piano) as these compositions are based on the Fourier analysis of traditional instruments and natural phenomena (spectra of acoustical instruments and cicadas singing respectively); therefore, attention to microtonal details is needed as analysed material can produce various inharmonic spectra which must be translated in a non-tempered notation (and most of the time, with the exception of *Metabolos*, a quarter-tone resolution is chosen).

1.9 The role of notation

All my compositions, with the exception of *Hz Discrimination*, are based on written scores for their realisation. I valorise the act of writing music on paper the same way a sculptor uses his material to create a sculpture. There is an 'art' behind it, a struggle that imprints itself on paper. Much can be said about score proliferation in the past sixty years, ranging from open scores (Boulez's *Third Piano Sonata*), to pure chance scores (Cage's *Fontana Mix*), to Feldman's graphic scores (*Projections*), to Christian Wolff's 'word-scores'. In some of my most experimental scores, for instance in *Metabolos*, my approach to score setting is neither one of a detailed network of open-ended sections, nor that of 'letting the sounds be themselves'. It is rather a 'play of details' on the micro scale of the composition; a play with micro fluctuations of timbre, time, dynamics and pitch. It is a permutational exploration of the micro form that also has repercussions to the overall textural and spectral continuity. This micro 'ebb and flow' of timbre, time, dynamics and pitch is achieved by an elaborate discourse above each critical detail of the score. This way, the player is clear of the rules of what is acceptable and what is not, involving his intelligence, his initiative, his opinion, his experience and his sensibility to contribute to the musical collaboration which the composer initiates (Nyman, 1999). This detailed planning is needed to explain the 'unexplainable'. For example, in the last section of the composition, the variables of bow speed, pressure, tremolo speed and bow position play a crucial role to the 'spectral aura' of this section; a concept that can only be explained by a rigorous discourse. Sometimes, the notation fails to explain the 'extra-musical', which is also a characteristic of Radulescu's and Dumitrescu's music.

1.10 The perceptual role of pitch and timbre

Pre-spectral and spectral composers are using techniques that are directly related to auditory perception (e.g. the interplay of critical bands in Scelsi's music, inharmonic vs. harmonic spectra and the notion of 'harmony-timbre' in Murail's works, compressed and dilated time in Grisey's music, tone/noise axis in Saariaho's works as well as the interplay between instruments and electronics in Hurel's compositions based on the research of auditory stream theory), but none of these would ever be realized without the extraordinary ability of our auditory system to distil meaning out of the complex codes it receives. As Pressnitzer et al. recognizes, 'the relation between the pressure wave and what we hear of it can only be understood by studying the physiological mechanisms of perception' (Pressnitzer et al., 2000, p. 42). It is a well-known fact that the ear acts as a sophisticated Fourier analyser with higher frequencies vibrating the basilar membrane close to the ossicles, where low frequencies stimulate the other end of the membrane (figure 5).

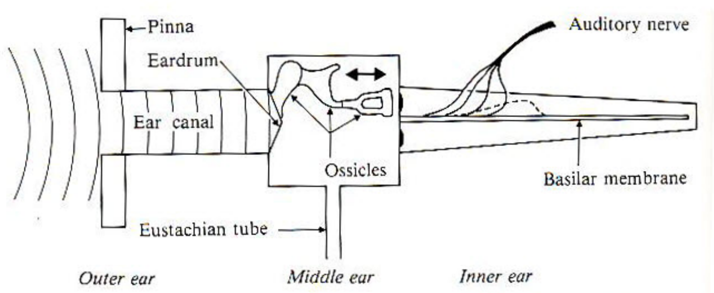


Figure 5: A schematic representation of the ear (Rossing, 1990).

Figure 5 illustrates how, after the sound propagates through the air, it reaches the ear drum through the ear canal and is converted into mechanical vibrations by the ossicles, amplifying the incoming signal and immediately transforming it into hydraulic pressure variations through the liquid in the cochlea. This creates a travelling wave on the basilar membrane which in turn causes the hair cells in the organ of Corti to bend slightly, producing a chemical imbalance that transmits electrical impulses to the brain via the auditory nerve. Until the signal reaches its final destination at the auditory cortex, it passes through various relayprocessing stations which are responsible for various tasks; for example, the localization of the signal, frequency and intensity resolution and pattern recognition (Roederer, 2008). It is crucial to notice that the auditory nerve is not fast enough to encode the entire waveform shape (every nerve fibre has to recover from each firing) so there is a neural pulse time distribution like an on-off-on 'Morse code' that carries information about the vibration pattern (Roederer, 2008). Consequently, there are two theories regarding pitch perception, the *frequency or place theory* explained by Helmholtz (1877) regarding the ear as a frequency analyzer and supported in his experiments by Békésy (1960), and the *periodicity or time theory* which contends that 'the time distribution of the electrical impulses carried by the auditory nerve has encoded into it information about the time distribution of the sound wave', which is decoded in a process called *autocorrelation* by the central nervous system which scans for repetitive features (Rossing, 1990, p.118). The *periodicity theory* explains phenomena such as the *missing fundamental* and *pitch discrimination* (however, it is assumed that hearing is dominated by the frequency principle at low frequencies and the place principle at high frequencies) (Mannell, 2008) and has been explained in modern theories of pitch perception by various authors (Schouten, 1940; Plomp, 1967; Goldstein, 1973; Terhardt, 1974; Scharf and Houtsma, 1986), but most importantly illustrates the importance of a *central pitch processor* in the nervous system (Rossing, 1990).

We instantly notice that the human auditory system, no matter how extravagant it is, has its limits, but its main function is to create associations, a matching process to 'make sense' of the input stimuli. Composers try not to work around these problems, but on the contrary, incorporate them as part of a composition as an interplay between thresholds (for example the use of critical bands in Scelsi's music).

In *The God Particle*, virtual fundamentals are calculated from chordal aggregates of the partial tracking analysis of acoustical instruments and used as a bass pattern in section two of the composition. Adding to this, just an aggregate of two or three adjacent harmonics are enough to perceive a virtual fundamental (e.g. the harmonic aggregates in Radulescu's *Das Andere* and the last section of *Metabolos*). Furthermore, pitch discrimination is the main compositional idea behind *Hz Discrimination* utilized clearly at the beginning and end of the work. In a similar vein, 'pure tones, complex sound, narrow and broad bands of noise all show differences in their ability to mask other sounds' (Rossing, 1990, p.101). Masking is extensively used in the second section of *The God Particle* as the attention of the listener alternates between the two dissimilar textures with the high frequencies of the first texture periodically masking the second texture. The aleatoric nature of *Drops and Pipes* as well as the sharing of the audio effects between the flute and the electronics fuses the two textures together. Masking of high frequency textures from low frequency high intensity textures is also noticed in *Hz Discrimination* as well as broad band noise masking in the electronics of *Transient*.

Regarding timbre perception, the temporal envelope of a sound, including attack and decay, influences the perceived timbre (Berger, 1963). Berger performed an experiment in which the first and last half seconds of the recordings of various instruments were removed. Subjects erroneously identified the instruments (an example of the alto saxophone being identified as a French horn). From this example, we conclude that the transients of a sound are important for source identification, hence my involvement with onset manipulation in *Transient* as well as in the middle section of Hz Discrimination in which the violin sound mass is set free from its onsets, transformed into a vestige of its original self. Furthermore, regarding timbre manipulation in *Hz Discrimination*, mistuned partials out of a harmonic sound are utilized and perceived as separate entities (Roederer, 2008). Even phase differences can induce timbral change, so these perceptual artifacts are being manipulated in the work as well as spatial illusions, as these mistuned partials are distributed to the left and right audio channels creating an aural 'spinning' sensation best experienced through headphones. In a similar vein, Wishart draws some observations from the work of McAdams (1982) on *aural imaging* for the creation of coherence and integration of sound-objects. He states that 'components having the same (or very similar) overall amplitude envelope, and, in particular, components whose onset characteristics coincide will tend to be grouped together' and that sounds that have the same formant characteristics, the same parallel frequency modulation (vibrato) and the same apparent spatial location, will also be grouped together (Wishart, 1996, p.65). What can be drawn from the above is that the polymeric nature of sound influences its reception and composers are aware of this property to create their compositional syntax.

1.11 Conclusions

Music creation *is the art of sound manipulation in time*. It is a multifaceted experience that is intertwined with not only certain values that stem out of the environmental and social interactions, but is also hidden in the imagination of every composer as well as in the perceptual properties of sound that invites inner exploration and manipulation through the use of technological advances, hence methodological investigations are important to reveal this multilateral compositional syntax. Furthermore, the role of the composer as an instigator of creation is important. His desires, concerns, passions, researches, obsessions are all part of this network of ideas that bears the 'spirit of our times', thus, extra-musical politico-social subjects are as important as musically related subjects. They are all part of the creative web.

The organizational principles behind my compositions are dependent on the process of homogeneity vs. heterogeneity of the three basic musical parameters: timbral (harmonic/inharmonic), temporal (compressed/dilated time) and rhythmic (pulse/no pulse) with focus on the use of timbre as the foundation of my compositional methods and specifically the use of pitch, formant, spectral and partial tracking analysis for the creation of the pre-composed material and its adaptation to acoustic instruments. Furthermore, there are new types of harmonic relationships being developed. The paradigm of ring and frequency modulation allows for the creation of new types of harmonic relations that can serve as 'technological models' for the creation of new spectra (Murail, 2005d). This in turn creates a paradigm that alters the orthodoxy of spectral music and swerve into past territories of structure and 'parameterisation'. Added to this, macroforms are being explored deriving from dilated 'moment forms' of analysed sounds, or in one example, from the stochastics of probability theory. This eclectic attitude is what drives my music forward; an attitude which encompasses everything, whether it is between tradition vs. modernity, harmonicity vs. inharmonicity, time vs. uncertainty of time, etc. I believe this is where the originality of my music rests. In the following chapter, seven compositions are introduced as cited in the beginning of this chapter and are presented and analysed in detail.

Chapter 2: Analyses of Compositions

2.1 Drops and Pipes

Drops and Pipes (for flute and live electronics) experiments with all aspects of compositional material, method and form. Michael Nyman observes that experimental pieces are not 'defined time-objects whose materials, structuring and relationships are calculated and arranged in advance' (Nyman, 1999, p.4).

In *Drops and Pipes*, the micro-texture and micro-time of its material are always fluctuating but within a linear, defined macro-structure. The flute and laptop performer are presented with material that requires active participation, a choreographed interconnection to choose articulations, tempi, dynamics and pitch material. Decisions are reciprocal due to the interlinked back and forward cueing. To eradicate a 'call and response' relationship between the flute player and it audio manipulations, sometimes the flute audio is routed so that there is no live signal coming out of the speakers, just the processed sound mixed with the laptop electronics diminishing the instruments role to a 'triggering machine'.

The main inspiration behind *Drops and Pipes* came from the conversations of Stockhausen about *Mikrophonie I* in *Stockhausen on Music,* specifically a question asked of the composer 'must it be a tam-tam?'. Stockhausen replied 'No, I can imagine the score being used to examine a Volkswagen' (Maconie, 1989, p.87). So, why not using the sounds of a water tank and brass water pipes (specifically my apartment's water tank and pipes) for the raw material of the composition? Bringing together unrelated visual objects to the concert hall creates an interplay of the familiar with the unexpected: this is what Michael McNabb finds to have the most expressive potential, as do I (McNabb, 1986, p.146).

A spectral analysis of the recording of the water droplets dripping inside the tank was created, revealing a constant 'motif' due to the physical constrains of the water tank. From pitch extraction, the exposed pitches were F4, E4, A4, Bb3, E5, A5, G#4, E4/F4 and C#5 in repeat (figure 6)(data cd: Drops spectra). These pitches were converted into a bass ostinato, but it was also used as the joining link between the flute part and the laptop. There is also a real-time manipulation of this ostinato with two RM modulating frequencies of 322Hz and 188Hz producing various levels of extreme inharmonic spectrums (these two carriers have been chosen in order to produce maximum beatings and inharmonic spectra).

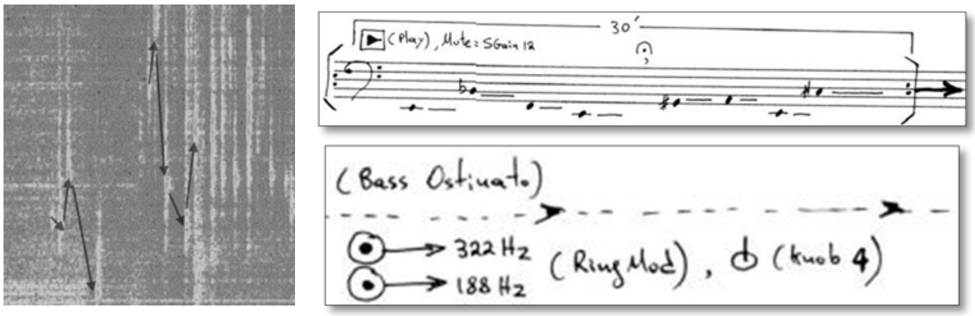


Figure 6: Pitch extraction from the field recording (left). Bass ostinato realization (right).

The samples of each water drop (and a variety of inharmonic water brass pipe sonorities) were then mapped on the keys of the midi controller with some randomisation of octave, tempo, pre-delay and seek rate of the sample (figure 7 - upper chart). These samples were further manipulated by the use of a low-frequency oscillator. The Audiomulch sample granulator named 'blower' was used (figure 7- bottom chart), triggering and manipulating pre-recorded flute samples using various parameters like amplitude change, panning, grain panning, density, duration, etc., further enhancing the aleatoric character of the composition.

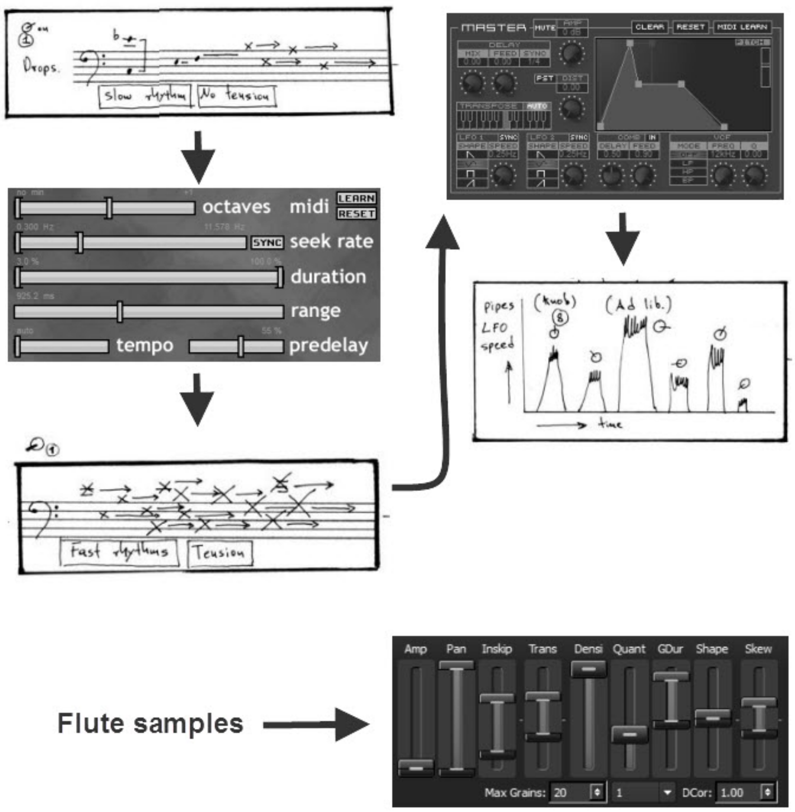


Figure 7: Drops samples, randomizer, LFO and the sample granulator named ‘blower’ (lower part).

The sound of the flute has almost the same manipulations as the drops and pipes sounds; a ring modulator frequency of 340Hz (creating even further inharmonic spectra colliding with the 322Hz modulator of the ostinato), a randomizer, a vocoder based on the ostinato pitches, and a step-sequencer called ‘anarchy rhythms’ which provides rhythmic modulation based on amplitude modulation, band pass filtering and compression. The flute part, when processed, impinges the drops and pipes sounds creating an aleatoric amalgam of sonorities that are timbrally fused together, but also shift the visual discourse of the composition as the flute gestures do not correspond to the sound emitted to the audience.

There is also a special significance of how the score is formed. Firstly, there are no time constraints. *The performance can be five minutes or thirty* (the premiere of this work lasted around 15 minutes). This is the result of the back and forward cues between the flute and the laptop performer. The performer chooses whenever he/she feels that the section is adequately developed and moves to the next one. The flute and laptop performer are presented with some linear blocks of notational ‘rules’ that give some freedom to the performers to choose their own tempo, pitches, articulation and dynamic range.

Another important aspect of the score is that it is constructed by acknowledging the gestalt principles of organization (Ellis, 1938). Cognitive psychology describes the set of rules that people tend to use to organize objects into units as the principles of *Proximity, Similarity, Continuation* and *Closure.* Elements close together tend to organize into units (Proximity), objects that look alike tend to be grouped together (Similarity), lines that run straighter or smoother are grouped over lines with sharp angles (Continuation) and shapes that are completely enclosed tend to be seen as separate units (Closure) (Northwestern University, 1999). Taking figure 8 as an example, humans tend to group objects together especially if they are in close proximity and in an enclosure, so motives *e, f, g, h,* and *i* will be favoured to be performed together as a group even though the instructions specifically instigate to alternate between motives *a* to *i*. Cornelius Cardew’s *Treatise* was certainly an inspiration to the openness of form, especially on the last page of the composition (Nonagon).

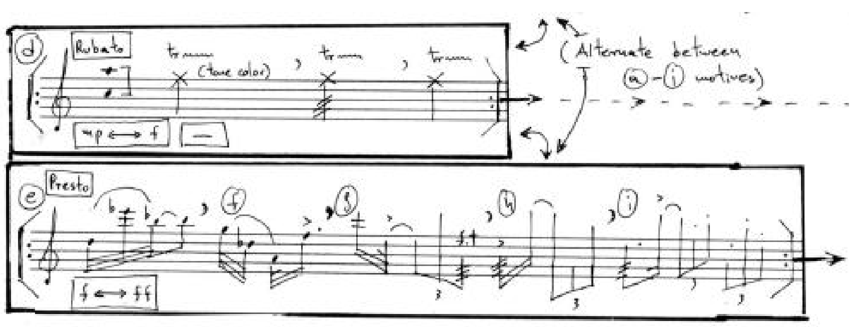


Figure 8: Blocks of sounds.

This Nonagon is actually a realization of a contingent event; an 'uncertain principle' that is impossible to determine beforehand. The performer can choose to start from any motive reading around the nonagon with no favouritism to any one of the nine, while the live looper (CanonLooper) sub patch records those sounds on 8-11 tracks routed through various audio processors. The same procedure is set out for the drops and pipes sounds, and when the live looper reaches the maximum of eleven tracks, it gradually fades them one by one. In this way, the end result is purely accidental; nobody can predict which sound has been performed and recorded on which track and using which audio effect (figure 9).

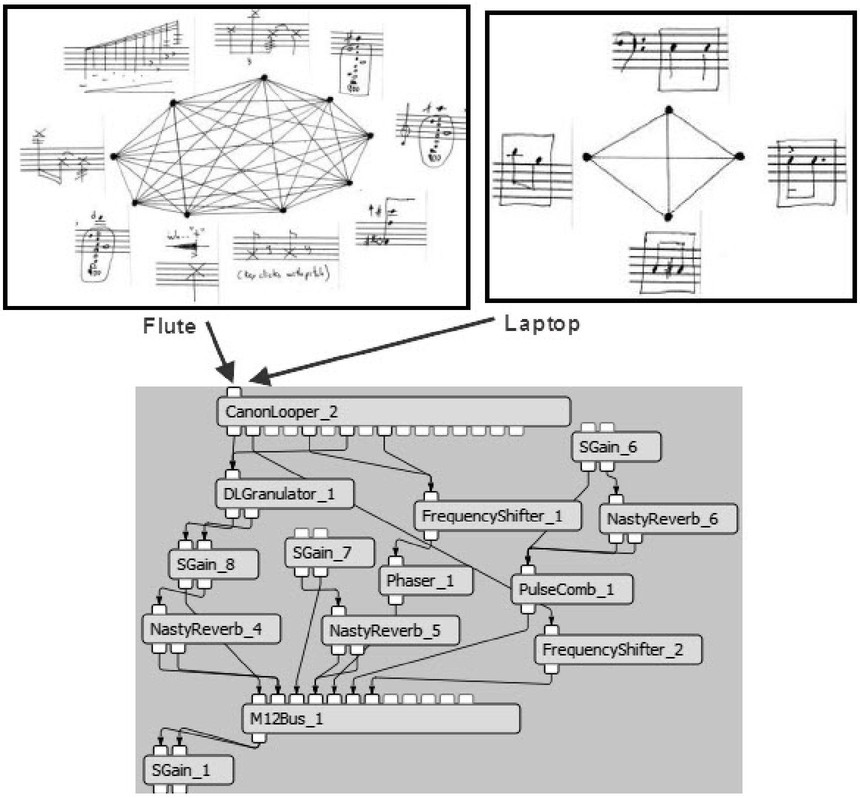


Figure 9: Nonagon and Live looper.

To conclude, the goal of the composition was to form a real-time environment in which event decisions are reciprocally intertwined between the computer and the performer with no temporal restrictions. The combination of a non-instrument with an acoustic instrument was formed and treated with the same manipulations so that their spectra would be fused into an amalgam of granular events that vary in intensity. Furthermore, I also wanted to resurrect the gestural energy which relates so much with the acoustical tradition. It was of greatest significance that no switching tasks would be automated, nothing would be hidden from the audience in an obscure click of a mouse, so every change of sound properties would correspond to a button, knob or key on the midi controller which sometimes is on the verge of virtuosic as the laptop performer is in charge of both the flute's audio processing and its own (figure 10a).

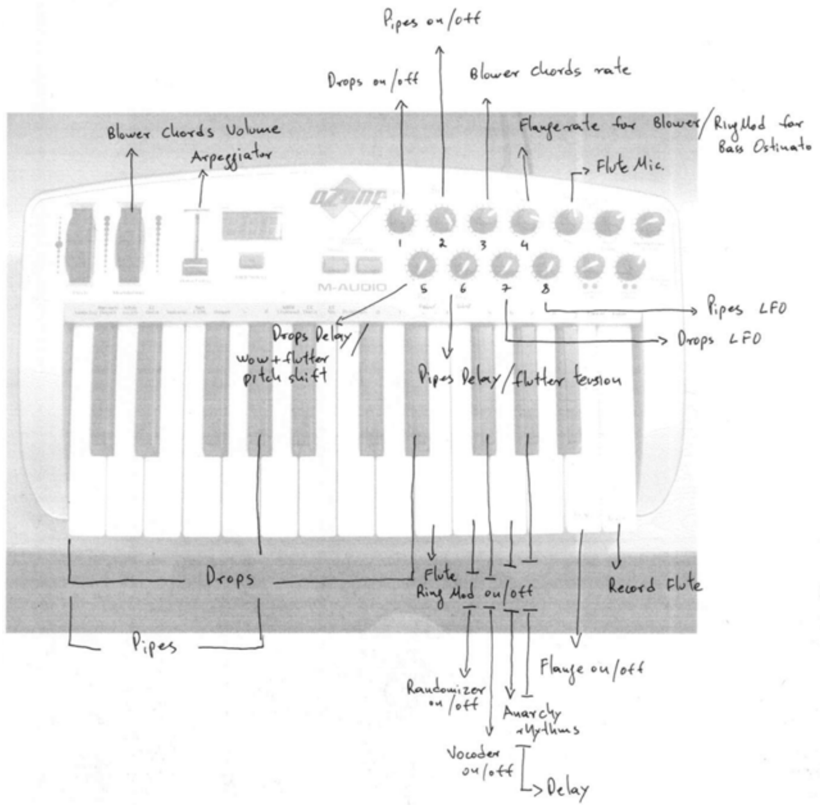


Figure 10a: Midi controller and its mapped parameters.

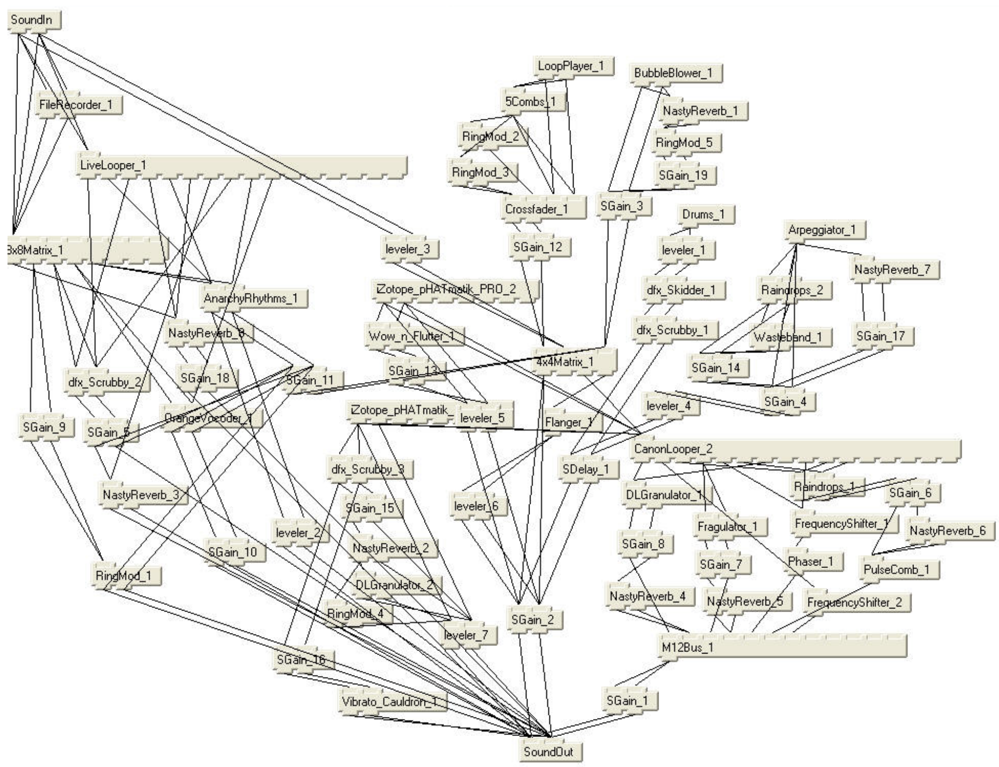


Figure 10b: Audiomulch Patch.

2.2 **Bushology**

The human voice has a special place in electro-acoustic music. One can draw examples dating back to 1955 with Stockhausen's *Songs of the Youth*, Berio's *Thema* (1958) as well as more 'recent' compositions such as Trevor Wishart's *Red Bird, Vox-5* and *Anticredos*. *Red Bird* deserves a special mention, since it has material with human utterances, animal and bird sounds transformed into a constant allegory of political messages (Wishart, 1996). Furthermore, the composers Peter Ablinger and Jacob ter Veldhuis have compositions with similar approaches as in Bushology, although they are not always politically derived. Another example of a strictly political composition based on the human voice is Luigi Nono's *La Fabbrica Illuminata* (for soprano and 4-track tape) where voices of the factory worker's struggles and concerns about the brutal working conditions are manipulated and fused with the soprano voice. These compositions were certainly an inspiration to see musical composition from a different point of view; as a vehicle of expression as well as a vehicle of realizing the social and political 'oppressions'. Therefore, *Bushology's* organization and significance stems out of the originality of its material and the conflict of the political messages it proclaims which is a discourse that is not favoured by the established social rationality.

The human voice can be thought of as a flexible and straightforward tool for manipulation. As seen in the above examples, it can be split up into phonemic objects, which can be manipulated based on their sound colour and formant characteristics. Winckel stresses the importance of formants in human sounds and asserts that the human brain scans the envelope of the spectrum in order to differentiate vowels and their tone colour (figure 11) (Winckel, 1967, p.15). This is why in the case of whispering (which consists only of formants) humans can still decipher its message (see the use of whispering in the 2nd section of *Bushology*). Formants and vowel differentiation were certainly an inspiration for the creation of the tape part in *Bushology*. President Bush's public speeches from 2001 to 2006 were the raw material (data cd: *A* folder)

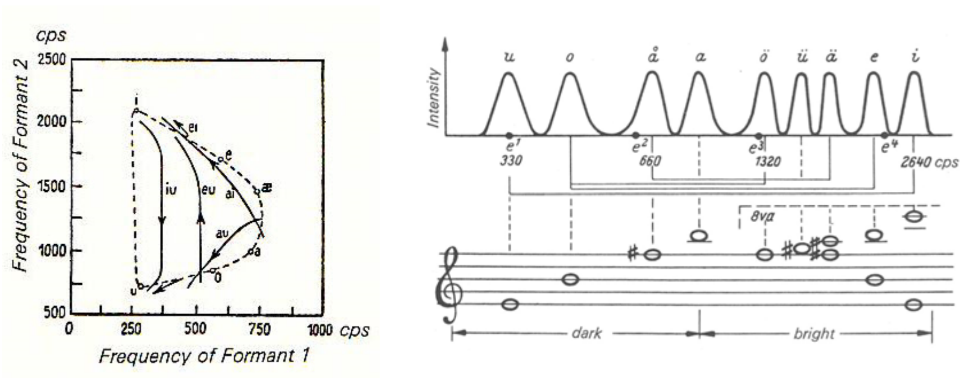


Figure 11: Two main vowel formant areas (left) and pitch identification (right) (Winckel, 1967).

Dennis Smalley also stresses the importance of *transcontextual interpretation*, in anecdotic or sample-based compositions (Smalley, 1996, p.99). He emphasizes that 'when sounds are taken from a cultural activity or where transformation does not destroy the identity of the original context, then the listener should be aware of the dual meaning of the source' (*ibid*., p.99); the original meaning of the sound source as well as the second meaning deriving from the phenomenology of our constructed material. In *Bushology*, the identity of the vocal sound material used is not destroyed, thus giving appropriateness to transcontextual interpretation. This may even form 'critical commentary', whether 'serious, ironic, social or political' (*ibid*., p.99). The sheer speed of the amalgamated phonemes and phrases of President's Bush speeches forms a direct link to political satire as well as implying social messages using ironic dualities of both the original speeches and the reconstructed text.

Bushology has a simple structure. Intro (0:00 - 0:38) / A section (a 0:39-1:35 / a' 1:36-2:01 / a'' 2:02-2:43) / B section (b 2:44-3:24 / b' 3:25-3:57) / A' section (3:58- 4:20) / Finale (4:21-end). The *Intro, A, A'* and *Finale* sections are based on metric rhythm where the saxophone is accompanying the tape part in a homophonic fashion, whereas the *B section* is in graphic notation and in an 'open' rhythmic structure where the saxophone is incorporating extended techniques and sound effects.

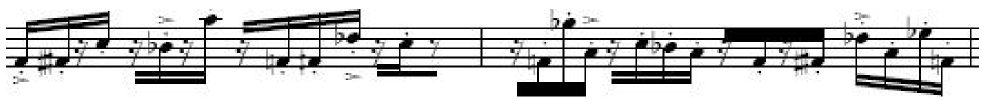


Figure 12: *Sax Intro*

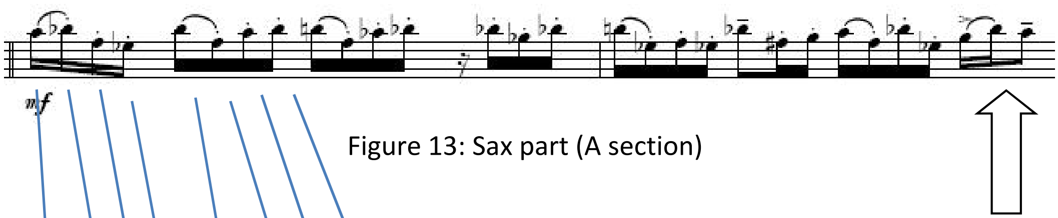


Figure 13: Sax part (A section)

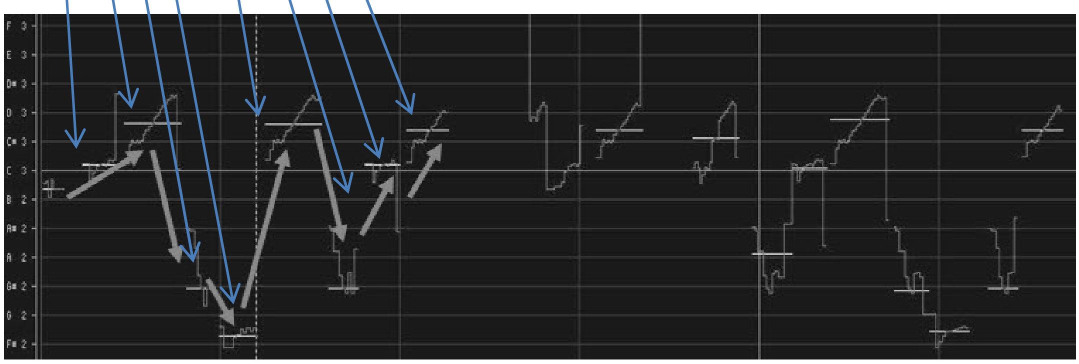


Figure 14: Pitch analysis of Bush's reconstructed voice (A section).

For a better explanation of its melodic derivations and connections, I'm using Allen Forte's set theory definitions. The saxophone (figure 12) starts with a quasi-pointillistic melody (Prime form: 0,1,3,4,6,8,9). This cluster of pitches has a similar relation with the pc set of the pitch analysis of Bush's reconstructed tape voice at the beginning of *section A* (figure 14: C,C#(+) ,D,F#(+),G#,A = Prime form: 0,1,2,5,6,8). The fluctuation of President Bush's speech material from high formant to low formant areas (and vice versa) as well as his idiolect manifestation of the word '*AND-a'*, was the base of the rhythmic formation of the tape part. Figure 13 (Sax part: *A section*. Prime form: 0,1,2,3,4,5,6,8) is a realization of the pitch analysis of the reconstructed text sound object. As can be explained from figure 14, the derived pitches of the saxophone part are the centre approximation of a formant analysis of the two strong formant areas of each vowel and not the actual formant frequencies, creating a 'virtual' cluster, with the tape part. The (0,1,2,3,4,5,6,8) set is encountered sporadically through the composition either in the tape or saxophone part and signifies either a start or closure of a section.

The underlying rhythmic structure of the *A section (a)* is a Fibonacci sequence (figure 15). Every two bars of 4/4 there is a gradual expansion of the time signature into 1/16, 2/16, 3/16, 5/16, 4/8 (8/16) bars. After this initial 'Golden' growth, the choice of injecting rhythmic cells in-between the 4/4 time bars is randomly chosen between the numbers 3,5,7 and 9.

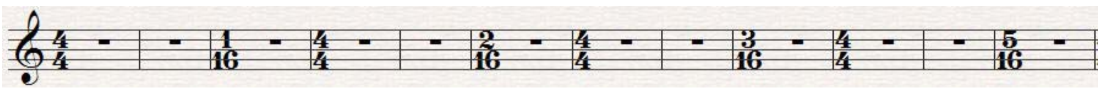


Figure 15: Fibonacci sequence every two 4/4 measures (A section)

Moving to the *A (a') section*, the rate of change of time signatures is denser giving a sense of irregularity and unevenness. The *A (a'') section* also uses metric modulation to further diffuse the regularity of 4/4 (characteristic of Elliot Carter). In *A section*, there are also a lot of extra-musical references, metaphors and ironies that require a thorough comprehension. They are listed below (figure 16) and are pretty much self-explanatory. Also, by using metric rhythm, it springs 'militaristic connotations' (in the case of Stockhausen) and associations with 'factories and machines' (in the case of Wishart) (Emmerson, 2007, p.68). In a postmodern era, metric rhythm can be a 'disadvantage' for some, but it works in our favour in *Bushology.* It further assists to absorb the war (militaristic) symbolisms, the 'factories and machines' that build the '20,000/200,000,000….bombs and shells'.

A man can be jailed in Afghanistan if his beard is not long enough	....and...thread to all
And/Build / Terrible weapons...	...and that is good
And War / Axis of Evil...	...thread to all
Terrorists / Zarqawi...	...be ready / die away
Thank you...	...with sympathy
22,000 / 200,000,000...	...bombs and shells
Bolder action against the killers...	...Afghanistan / bombs
Free Iraq / hopeful day has arrived...	...die away / Thank you
Thank you / die away / with sympathy...	...justice of this nation / terrible weapons
To promise tyranny / taxes / meet my veto...	....for every American / to renew Patriot Act
Nuclear chemical danger...	...weapons of mass destruction

Figure 16: Extra-musical references.

The *B section* is also different not just because the metric rhythm is alleviated, but also because the saxophone is no longer in a homophonic relationship with the tape part. The use of extended techniques allows the listeners to once again relate to extra-musical images. The gradual slow 'growling' glissando (figure 17) along with the distorted time-stretched 'grove' sample can suggest psychological images of horror/screams. The *rip*. of the saxophone along with the reverberated 'staccato' 'o' sound suggests bomb explosions in a time of war and the 'ta ka ta' spoken words/key clicks with a fading sax air note can imply a machine gun followed by the last breath of someone before dying. Also, this section rests on a bell-like drone which gives a liturgical/ceremonial atmosphere to the section (read below for the *why* it becomes ceremonial). Bear in mind that this is all 'implied' and that the listener's ear can create different associations and images from the composer's suggestions.

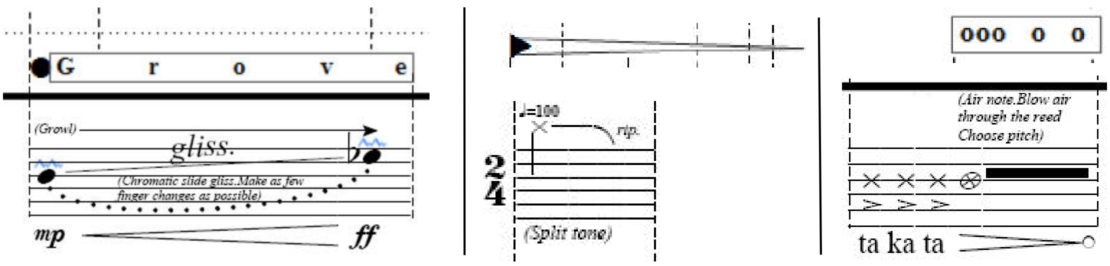


Figure 17: Extended techniques (extra-musical connotations)

As mentioned above, the *B section* tape part is composed from a minimal set of materials. Similar to an *acrostic* poem (acrostic is a poem such that a vertical phrase intersects lines of horizontal text) the listener must collage the snippets of sounds in order to realize the hidden message. 'B(ia)', 'B(e)', 'o-u', 'o', 'iii', 'mmm' , 'aan' and 'Grove' as well as 'New', 'World' ,'Order' are the only samples used (data cd: *B* folder). The snippets together form the phrase: 'Bo(h) emian Grove'. Bohemian Grove is a campground in California where once a year, allegedly, all of the socio-economic élite men of the world retreat (including former President Bush). Allegedly, they also take significant politico-economic decisions but also, and most importantly, engage in an ancient pagan ritual where they mock children sacrifices and worship Babylonian gods! Apparently, this is documented in the West German chancellor Schmidt's autobiography *Men and Powers* (Schmidt, 1990), in a Bohemian Grove infiltration video by journalist Alex Jones (Jones, 2000), and in Peter Martin Phillips's doctoral dissertation "A Relative Advantage: Sociology of the San Francisco Bohemian Club". In his doctoral thesis, Peter Phillips discusses what is seen in Alex Jones's infiltration video as the 'Cremation of Care' ritual (Phillips, 1994, p.44). This came as a shock to me and definitely was the main inspiration for creating *Bushology* and especially the *B section*.

In the *Finale section*, the voice samples are conflated into an r&b rhythmic background, while the saxophone is playing jazz/swing phrases. Both 'jazz' and 'r&b' are strictly American inventions. This 'Americanness' also explains the role of the saxophone in this composition. The saxophone is historically linked to America. Although the saxophone is not an American invention, it is still the most viable and pertinent instrument to accompany the tape part. But what is the 'frame role' of the saxophone in a composition like *Bushology* and what is the actual relationship with the tape part? (Emmerson, 2007, p.100).

Emmerson (2007) discusses a reverse frame 'role' of an instrument in certain electroacoustic compositions, which 'the instrument on stage can simply 'disappear' into a continuous field of sound' (Emmerson, 2007, p.100). In *Bushology*, the role of the saxophone is in a complete equalization with that of the tape. In most instances, the saxophone plays vestige of the formant analysis of the tape part, therefore the relationship is even more intimate; the composition becomes the sum total of the whole. There are no leading figures in the composition, no 'dictatorial' relationships (some can argue that the tape part itself *is* promoting a dictatorial rhythmic relationship by dictating to the saxophone what to play). But the intended focus of the listener is not only on the interaction between the material and the extra-musical images, but on the pure energy and 'struggle against the elements' of the composition, producing an 'expressive and dramatic result' (*ibid*., p.100) similar to a Greek tragedy, all complete with dramaturgy and a final catharsis of the audience through the ongoing satire. Furthermore, in Wishart's terms, this Bush-saxophone duet 'brings together normally unrelated visual objects in the virtual space', a technique which he categorizes under 'real-objects/real-space' but in a *surrealist* landscape (Wishart, 1996, p.146). A *real* Bush-saxophone duet would have been impossible in the real world but with the help of technology this can be realized in a concert space creating a surreal Bush-saxophone landscape.

To conclude, *Bushology* is a composition that bears the *zeitgeist*; the 'spirit of our time', the morals and political climate of an era. Its job is not only to inform our generation about the politico-economical situations we are in, but to function as a manifesto as well as a historical testament which I believe is missing from the majority of today's compositions. Quite simply, politics in music seems to be a taboo that is unfairly underexploited. This vision is also shared with the choreographer Elena Christodoulidou from Cyprus. Christodoulidou's collaborations mainly have a meta-political essence; how the humans relate to politics, what fundamental rights and laws should be protected and generally what is the relationship between the subject and the government. *Bushology* recently took part in the 16th European Dance Festival with the collaborative work *Bushes* (data cd: Bushology-video).

2.3 **Hz Discrimination**

The main inspiration behind this acousmatic piece comes from the use of microtonal inflections and alternative tunings and its social as well as perceptual role. The stimulus was further enhanced by the interview of the just intonation composer Ben Johnston in William Duckworth's book *Talking Music.* Ben Johnston believes that our society is corrupted by the 'Dionysian elements of music', those elements that 'stir up people' that lead them into the drug culture, further linking this with the imposed common culture of commercialized Rock and Pop (Duckworth, 1999, p.152). He believes that the 'fundamental acoustical poison' in our environment is the 'irrationally dissonant' tempered scale (*ibid*., p.151). As Kyle Gann (student of Ben Johnston) explains, 'it is our tuning that is responsible of much of our cultural psychology, the fact that we are so geared toward progress and action and violence and so little attuned to introspection, contentment, and acquiescence' (Gann, 1998). This interview inspired me and opened the way to think microtonally, controlling timbral and pitch space in a more precise way that has direct repercussions to our auditory perception of sound. The dominant psychoacoustic principles used in the composition, as the title implies, is that of pitch discrimination (the ability to distinguish between two nearly equal stimuli) as well as the ability to distinguish non-equal tempered intervals that are linked with non-Western traditions. Furthermore, the use of an augmented 4th sonority and its permutations through spectromorphological transformations and especially its harmonic vs. inharmonic transformation from a normal violin sound to an abstract bell-like hybrid is another prevalent characteristic.

The work is based on an audio recording of a violin and its spectrum manipulations. In the first fifty seconds of the composition there is a gradual shift of the open G string of the violin to an inharmonic bell-like spectrum. This is achieved by slightly shifting the partials of the violin analysis as well as distributing them spatially, half of them in the left channel and half in the right (data cd: Hz Discrimination). This creates a sort of 'spinning' sensation that is best experienced through headphones. The spatialization of partials also produces *binaural beats* which will be analysed later on.

In the intro, there is a constant play between harmonic and inharmonic spectra with variations on the amplitude of each partial but also omitting certain partials that changes the timbral characteristics of the violin sound (for example deleting the fundamental and 2nd partial changes the colour of the sound but does not change the perception of the pitch of the sound). Furthermore, a G 50 cents apart from the equal-tempered G is heard and proceeds to an A# (+40 cents higher, ratio: 128/125 from an equal tempered A#) finishing off to a B4 (figure 18).

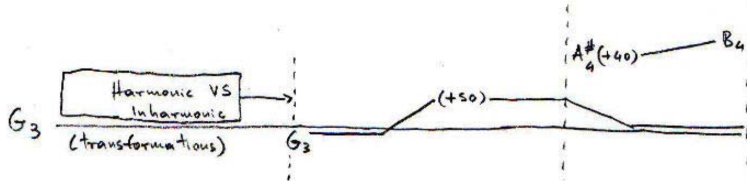


Figure 18: Intro

From an equal-tempered standpoint, this G - A#(+40) relation is what Hindemith mentions in his book *The* Craft of *Musical Composition* as having 'extraordinary significance' due the fact that the ear cannot register it as a known interval/sonority (Hindemith, 1947, p.79) (figure 19).

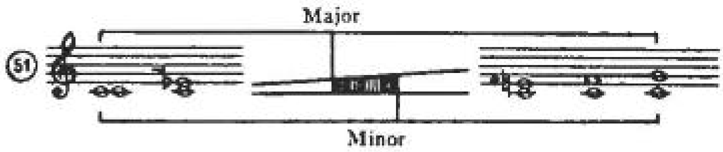


Figure 19: Hindemith's reference to the unknown sonority between a Maj. and Min. 3rd .

By hard panning certain partials that are really close in frequency, there is another psychological property that occurs which is called *binaural beats*. Binaural beats is a neural processing characteristic that happens when two tones of slightly different frequencies are presented separately to each ear, creating a pulsating sensation in the brain, a fluctuating rhythm at the frequency of the difference between the two auditory inputs appears to originate in the brain stem's superior olivary nucleus (Atwater, 1997, p.265). Atwater contends that binaural beats can 'provide potential consciousness-altering information to the brain's reticular activating system' which in turn interprets and reacts to this information by stimulating the thalamus and cortex, thereby inducing relaxed, meditative and creative states (Hiew, 1995; cited in Atwater, 1997, p. 266). This technique was inspired by the social ideals of Ben Johnston and the use of music creation as the means of instigating consciousness-altering meditative information to the brain.

From this time forward, the character of the composition shifts gradually towards the abstract. The violin sounds are slowly transformed making extrinsic suggestions. Smalley raises the issue of *source bonding*, 'the natural tendency to relate sound to supposed source and causes' (Smalley, 1997, p.110). As the piece progresses this source bonding is gradually diminished, making the violin sonority a distant aura.

At 0:50-0:60sec. a <0,1,6> chord with an undecimal tritone G-C(+50) (ratio: 11/8) otherwise known as the 11th harmonic is moving to a perfect fourth 10 cents sharper (43rd harmonic), and a Major 7th moving to an octave with an underpinning of a scratch tone mass (figure 20-1). At the next section (1:00-2:06sec) there is a repeated <0,1,6> chord followed by a low-pass and high-pass filter passage with some of the high partials (900-1000,2050,3100-3700,6500-7500Hz) either stretched or manipulated. There is also an expanded and contracted shape G (+35)-F (+88), followed by a Col legno mass that is slowly transformed into a raindrop texture with partial transpositions from 9000Hz to 14000Hz almost at the verge of hearing (2:07-3:26sec, figure 20-3). As Trevor Wishart describes, the ear simply is unable to function as a Fourier analyser above frequencies of around 4000Hz; we simply hear timbre as timbre (Wishart, 1996, p.54). At the end of this section there is a process of increasing remoteness, as Smalley defines, a *gestural remote surrogacy*. The source and cause become unknown and the human gesture behind the sound disappears (Smalley, 1997, p.112).

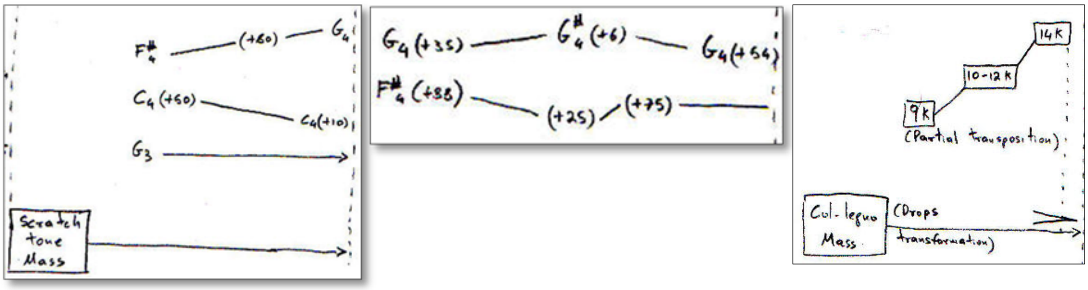


Figure 20: 1-3

From 3:27sec, we have a restoration of our source bonding. There is also an announcement of a few new sonorities (tailpiece bowing with a D3 undertone, body knocks, an iteration of the figure 20-1 sonority, and an 80Hz/D#2(+50) expanding bass mass). The most prominent of these is the expanding bass mass which opens up the spectral space, as this is the first time a low frequency object occurs. This low-frequency expanding object is also important due to the instigation of masking phenomena (the more intense it becomes the more it masks higher frequencies). Subjective loudness is dependent on the spectrum of the sound, so by expanding this sound mass into a broadband texture, when the frequency separation exceeds that of the critical bandwidth, the subjective loudness increases linearly (Rossing, 1990). Following this, the next salient moment is the gliding gesture F4 (+5) to D6 (+75) and C#4 to D3 (figure 21-1, 4:48sec) that produces another effect that of the combination and difference tones, succeeded by an extra-musical sonority I call the ‘doppler train horn’ (figure 21-2, 4:55sec). This sonority successfully simulates a train horn while it passes by an observer creating a Doppler effect.

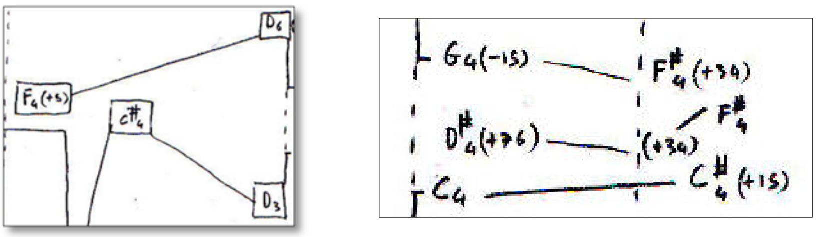


Figure 21 : 1-2

Next is a Col legno battuto mass that is firstly filtered, reversed and lastly reverberated (figure 22-1) followed by another 20-900Hz bass mass (6:00sec) with some extremely inharmonic high frequency Dadd6 chord (figure 22-2 and 22-3, 6:07 sec) repeated twice an octave lower (the extremity of range reminds us of the limitation of the human ear in terms of analysing sounds; inharmonicity in higher register is not perceived as well as in lower registers).

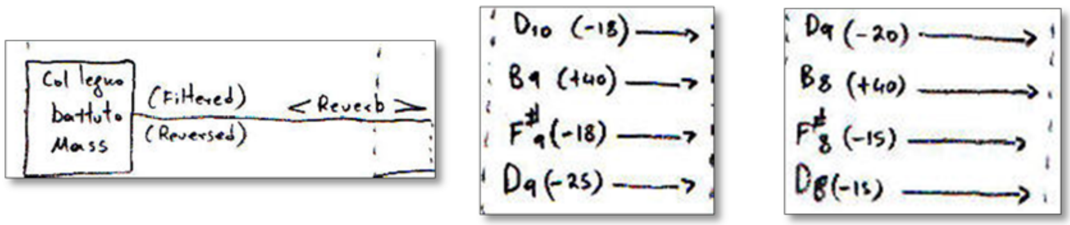


Figure 22 : 1-3

The composition finishes just like it started with an open G string drone (creating an A-B-A form) (figure 23-1). There is now an interplay between the G3 and C4 (-24) generating an unusual septimal fourth (ratio: 21/16) (6:54sec), followed by a cluster of G7(+37)-F7#(+30) (figure 23-2) that interlocks and transitions between ‘smoothness’ and ‘roughness’, once more challenging the limit of frequency discrimination in each of us.

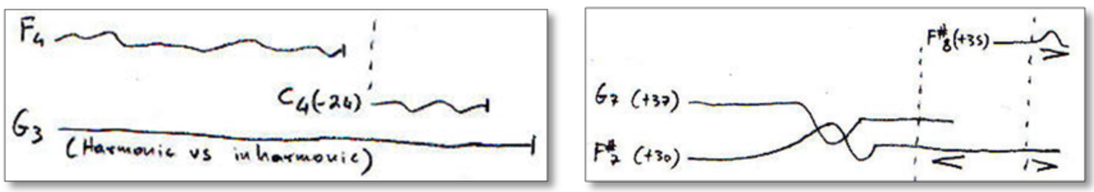


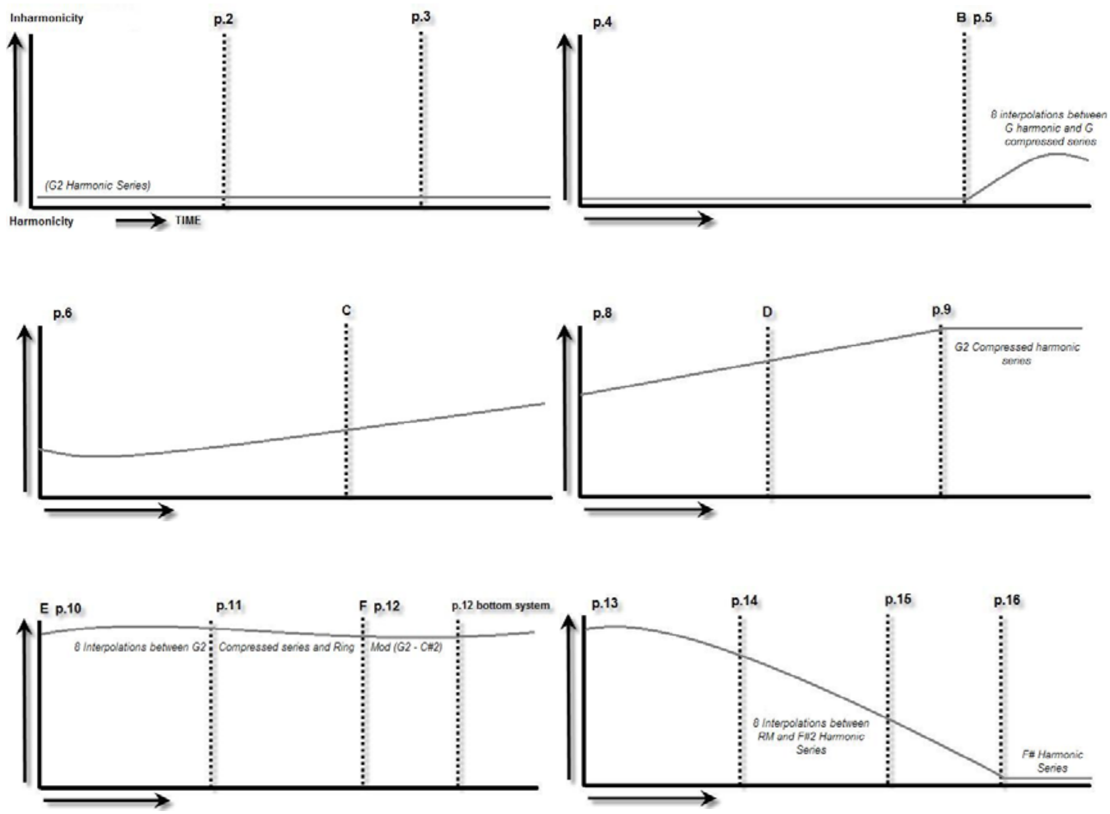
Figure 23 : 1-2

To conclude, *Hz Discrimination* is a composition that emphasizes the organic relationship between its parts; a hybrid between the world of equal-tempered tuning and just intonation, harmonicity and Inharmonicity. It also challenges our human nature with the limit of discrimination of tones (every human being has a different *difference limen*) and even touches upon other psychoacoustic characteristics like binaural beats, masking, combination and difference tones, the width of the critical bands and subjective loudness curves. Sound textures evolve into abstract entities losing their source bonding with their acoustic selves, creating distant timbral objects spatially distributed as their partials are panned left and right with different onsets and time envelopes, even creating localization paradoxes. Most importantly, this composition opened up the world of microtonal writing which can be found in my later compositional output.

2.4 **Metabolos**

Metabolos (from the Greek *μεταβολή; change*) as the name suggests, is a musical work that is based on a constant change of its constituent elements and especially of its frequency-based material to create its micro and macrostructures. *Metabolos* is a continuous mimesis of a living organism; just like a body needs a set of chemical reactions to sustain life and maintain its structure, so does *Metabolos,* trying to conflate its musical materials into a direct discourse with the listener by sustaining a process of metabolizing its material.

The overall macrostructure of the work is based on the interplay of its harmonic and inharmonic partials, which can be reduced down to a double arch pattern of ascending inharmonicity and descending harmonicity (figure 24). In figure 24, p.1 to p.21 correspond to the page numbers of the *Metabolos* score and capital letters to the rehearsal numbers. The G2 harmonic series of the first four pages is transformed into a G2 compressed/distorted series by p.9 (with eight non-linear interpolations in between). The same technique is used extensively transforming the G2 compressed series into an RM series, then into an F# harmonic series, an FM series and finishing up with a high pitched amalgam of natural harmonics on the G string of each of the instruments. Figure 24 is a 'virtual' harmonic/inharmonic chart as the actual levels of harmonicity and inharmonicity micro fluctuate based on various 'noisy' instrumental techniques (see Figure 25).



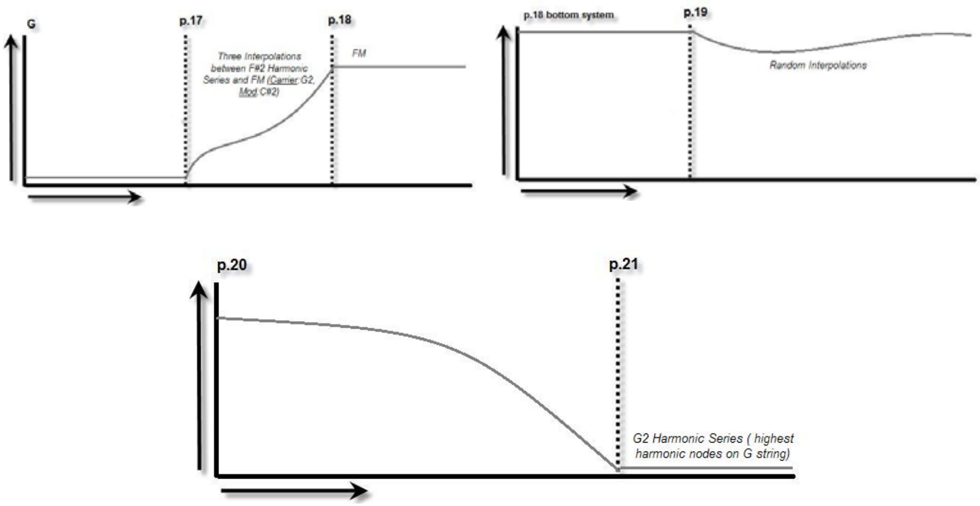
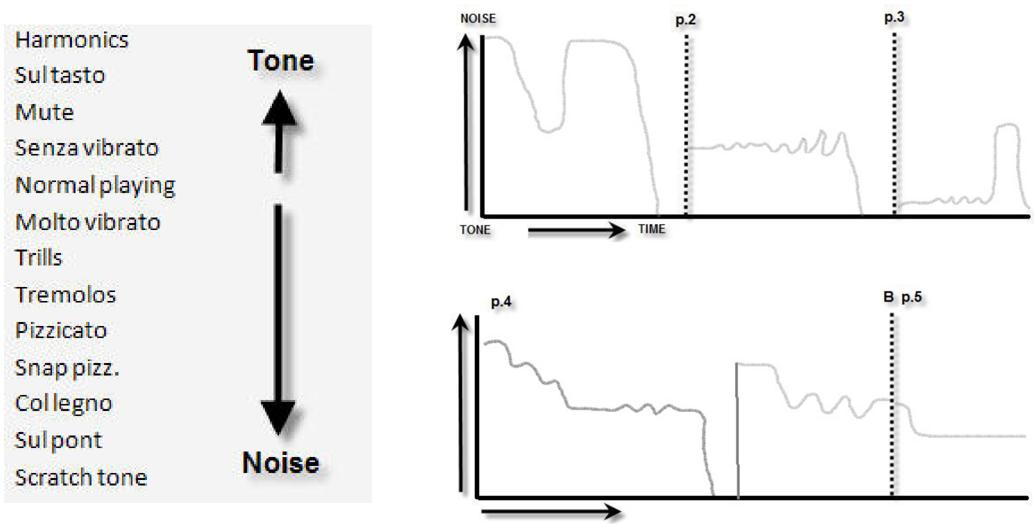


Figure 24: Macrostructure of *Metabolos* based on harmonicity and inharmonicity levels.

On the micro level scale though, the actual harmonicity and inharmonicity levels are constantly varied based on the purity and non-purity of sounds created by manipulating different instrumental techniques. Techniques like bowing pressure (normal/exaggerated), position changes (sul pont/tasto), pizzicato and scratch tones to name a few play a significant factor on the overall spectral fusion or fission (Figure 25a). O'Callaghan and Eigenfeldt utilized the same technique focusing on the gestural development in Saariaho's *Verblendungen* and *Lichtbogen* by mapping parametric changes over time (O'Callaghan & Eigenfeldt, 2010).



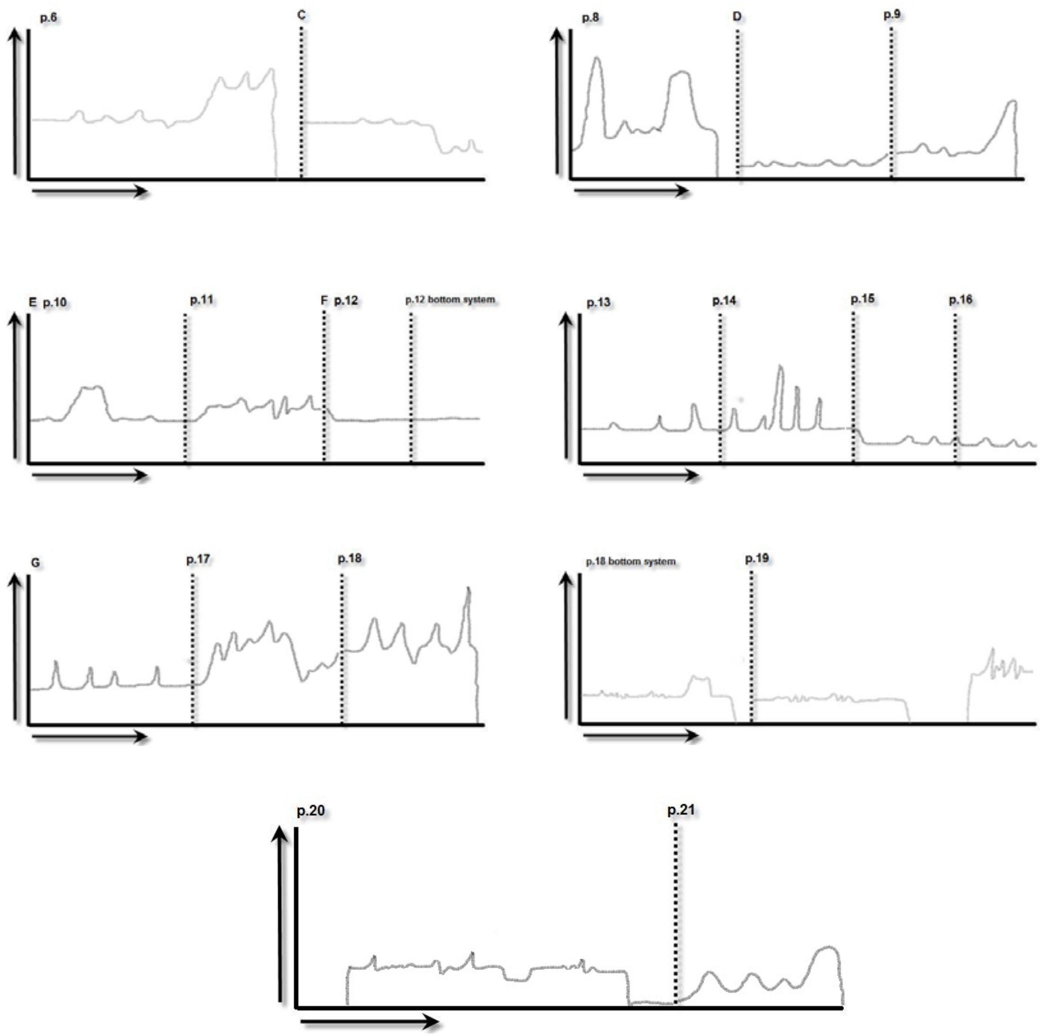


Figure 25a: Tone-noise axis in Metabolos

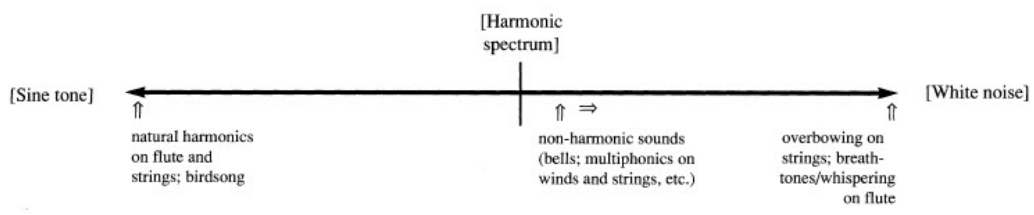
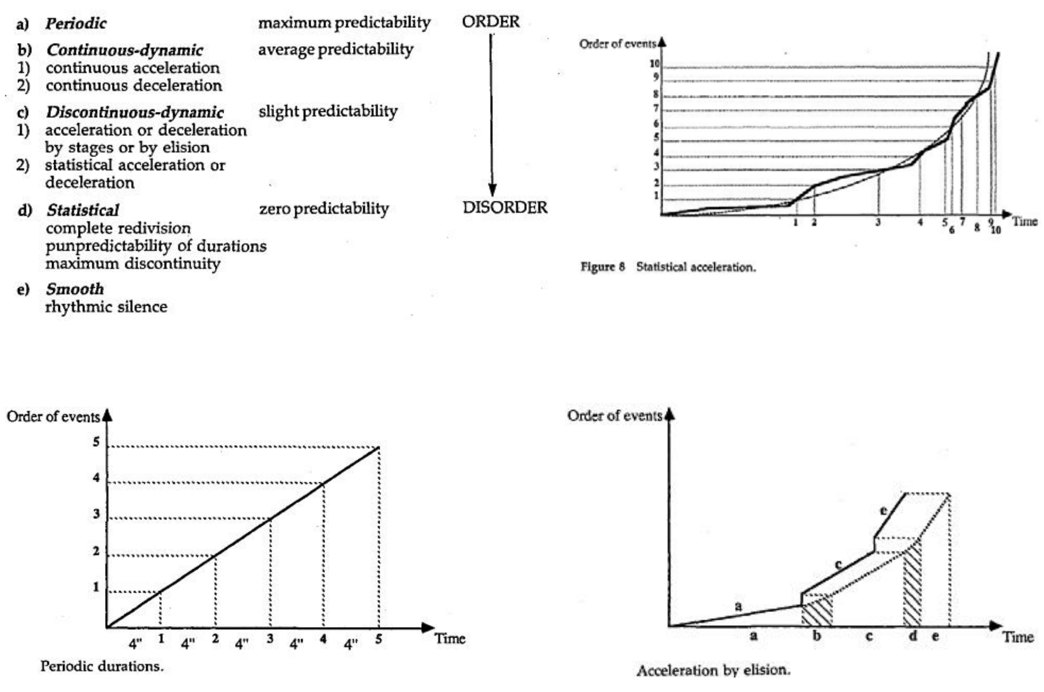


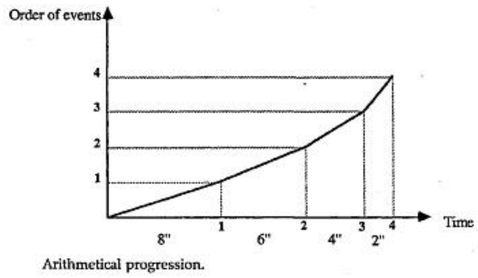
Figure 25b: Saariaho's Tone-noise axis

Saariaho's music is always based on the 'stability vs. instability' axis. For her, the spectrum is always articulated by the various extended techniques of the instrument. Take the strings for example. Sul tasto and senza vibrato always operate on the 'sine tone' axis (figure 25b), whereas the sul pont. and overpressure techniques excite higher partials that masks the fundamental, operating on the opposite side of the axis (white noise). Subsequently, the same happens with the flute sound. A low, breathy tone reinforces noisier spectrums, whereas a high bright tone has a characteristic 'sinusoid-like' character.

What we observe from figures 24 and 25a is that the tone-noise axis runs in conjunction with the harmonic-inharmonic axis, fusing together the two maps creating what Grisey describes as *liminal* music, music at the threshold of perception (Hervé, 2009, p.31). Harmonicity and inharmonicity levels are disturbed by these micro fluctuations of noisy textures. As can be observed from the first four pages of the work, even though its overall macro structure is based on a G2 series spectrum, which is highly harmonic, the 'noisier' micro fluctuations created by the instrumental techniques disturb its harmonic fusion.

Another axis that defines how a musical work is apprehended, proposed by Grisey, is a scale that spans from *periodicity* to the *white noise of durations* (figure 26) (Grisey, 1987). In other words, it shows the degree of predictability in the basic time structure of a work (Sandred, 1994, p.5). Cognitive memory also plays a significant role of how we respond to a composition. 'The repetition of an event helps and sometimes forces it to be memorized' (Grisey, 1987, p.273). Our ears are only able to grasp the outline of a complex texture, the macrostructure, whereas in a simpler texture the details of the texture become apparent. In *Metabolos*, as it will be analysed later on, there is a constant shift between periodic and aperiodic events, simple and complex textures.





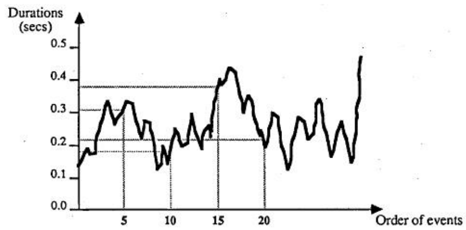


Figure 26: Grisey's *Scale of Complexity*

Metabolos starts with a scratch tone drone that gradually reveals its G2 fundamental frequency that lasts approx. 20 seconds. It is as if the whole macrostructure of the work (figure 24) is reduced to this very element that shifts from inharmonicity to harmonicity; an incubation of the fundamental frequency that creates the birth of the whole work. From now on, there is a constant process of instrumental additive synthesis fusing the partials of harmonic series into various timbral aggregates but also splitting these into independent textures as there is an interplay between interpolated, compressed and FM/RM spectra.

There is also no vibrato throughout the whole work. Vibrato is asked for occasionally (written down as 'vibrato beats per second') and it is always linked with the numbers 1, 2, 3 and 4. For example, having one instrument play a note with three vibrato beats per second with the other playing two, creates a 3:2 ratio which enhances and supports the lower partials of the harmonic series in this case the G3-D4 perfect 5th (see for example top of p.2). These rhythmic pulsations are proportionally related the same way the fundamental is related to its partials. This is what Henry Cowell describes in his *New Musical Resources* forming for the first time a theory relating rhythm and tone through overtone ratios (Cowell 1930, p.46).

Microtones are used in two ways. Some are written with the exact cent deviation from the equal tempered scale (James Tenney used this technique in KOAN) and some are approximated to the quarter-tone equivalent. Sections that are needed to be in exact intonation (RM, FM sections) are written in the first manner and sections that are interpolated and don't require high resolution to hear the ending result are written in the second manner.

Figure 27a: Chord No.1 (Natural Harmonic series on G2- odd partials) and No.10 (Distorted compressed series on G2 - 0.7 exponent) with eight nonlinear interpolations in-between (data cd: Metabolos OM Patch).

Figure 27b: Chord No.1 and its related partials

The pitch material of the first four pages of the work (including the upper system in p.5) is based on chord No.1 (figure 27a) which is a natural harmonic series with odd partials on a G2 fundamental. Figure 27b shows one of the many spatial arrangements of these partials. Notice that there are additional even partials in this arrangement (2nd partial G3, 10th partial B5, 12th partial D6 and 14th partial F6).

Some other sections fuse two harmonic series together (figure 28a). In this example partials from G2 and C#2 harmonic series are used. The first note of Violin I is the twenty-second partial of the G2 series, second note of Violin I is the fourteenth partial of the C#2 series, first note of Violin II is the twenty-third partial of G2 series and the second note of Violin II is the thirty-first partial of C# series. First and second note on the Viola are the fourth and third partial of G2 and C#2 series respectively. The C#2 fundamental appears in the cello as a C#1 pitch (one octave lower) which is outside the normal range of the cello. The player must detune its lower string from the peg until it reaches that pitch. The random *sff* dynamic marking on this loose string is shifting its timbral characteristics by conflating more inharmonic partials to the sound with a perceptual result of a ‘quasi-electronic timbre’ (similar to an electronic ring modulated sound). This resulting timbre is more obvious at a later stage as this low pitch is treated with various instrumental techniques (two that are especially important are the *sul pont* with bowing overpressure and left hand fingernail pizz. as close to the nut as possible - Figure 28b). The detuning of the C string is paying homage to Xenakis as it was used in *Charisma* for cello and clarinet as the last note of the work as well as in *Nomos Alpha* for cello.

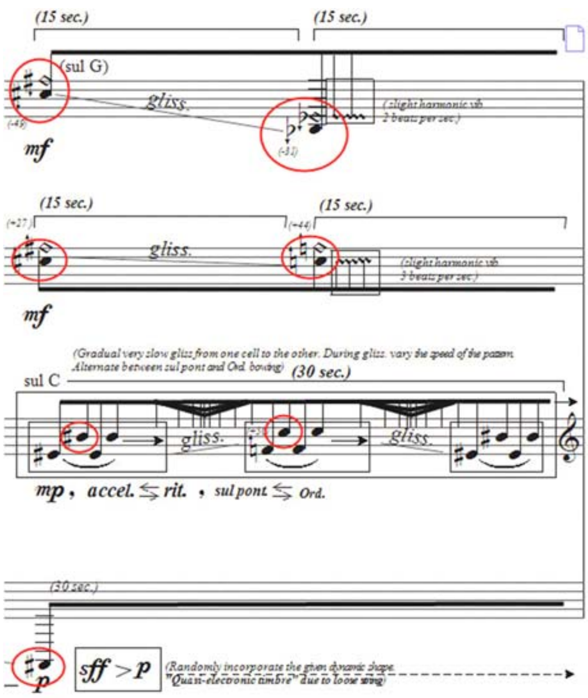


Figure 28a

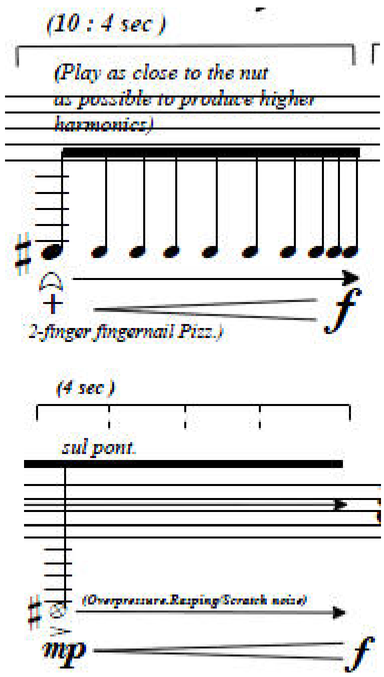


Figure 28b

From p.5 to p.9, there is a temporal as well as a harmonic shift to the composition. The G2 natural harmonic series (see chord no.1 in figure 27a) is subjected to a distortion process moving from harmonic to inharmonic (see chord no.10 in Figure 27a) and then interpolated eight times using the OPENMUSIC interpolation function. The following equation is used to calculate the compressed partials of chord no.10:

$$f(r) = f_0 \times r^d$$

Where $f(r)$ = the distorted frequency with partial rank r

f_0 = the fundamental frequency

r = the partial rank (an integer)

d = the distortion coefficient. An indicator of the amount of distortion. If $d < 1$ the spectrum is compressed. In our case d=0.7

Figure 29: First sixteen partials of the G2 compressed series (d=0.7).

As stated earlier, p.5-9 section presents a dynamic, temporal and gestural shift. Inspired by the idiosyncratic notation of Murail's *Territoires de l'Oubli* and Grisey's *Modulations* (especially at rehearsal number 37) this section conveys descriptive and prescriptive information regarding the desired effects and how they might be achieved by the performers (Nonken, 2008 , p.4). This descriptive and prescriptive information is given to the players as a set of written defined rules (figure 30).

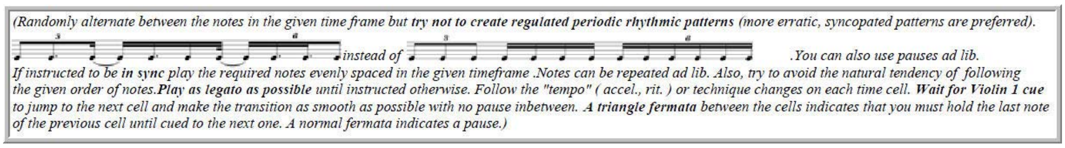


Figure 30: Set of performance rules for p.5-9

The focus of the players centres on the physical gesture and its acoustic consequence. Using limited aleatoricism there is a 'disciplined freedom, ordered chaos and controlled spontaneity' (Nonken 2008, *p.10*). Also the directional and predictable temporal plane of the previous section is now shifted reintroducing 'surprise, contrast and rupture' (Murail, 2005a, p.271).

This section also highlights Grisey's scale of complexity (see figure 26). One of many example of this would be the first system of p.5. Here the players have to follow the time cells and perform the given pitches (in our example partials of a G2 harmonic series) in various temporal complexities. Mini pockets of accelerando and decelerando appear as well. In our example (figure 31), periodic time cells of two seconds each become expanded into accelerated and decelerated events of six and ten seconds respectively. On the contrary, other sections are totally predictable and periodic as each instrument is in sync with the others (end of figure 31). This once again supports the notion of thresholds as described by Grisey and the exploration of 'stretched' and 'contracted' time (Grisey, G. & Fineberg, J. 2000, p. 2). At the same time, it differs due to the idiosyncratic notation that is been used (see Chapter One, 1.9).

Figure 31: Stretched and contracted time.

After a clear statement of the G2 compressed series at the 2nd system of p.9, the series reappears on the 1st system of p.10 with a mirroring up and down triplet movement on Violin I and Cello starting from the 10th partial of the series (figure 32a). In this section, we also have a gradual periodic contraction of our pitch bandwidth (figure 32b).

Figure 32a: Mirroring movement on Violin I and Cello

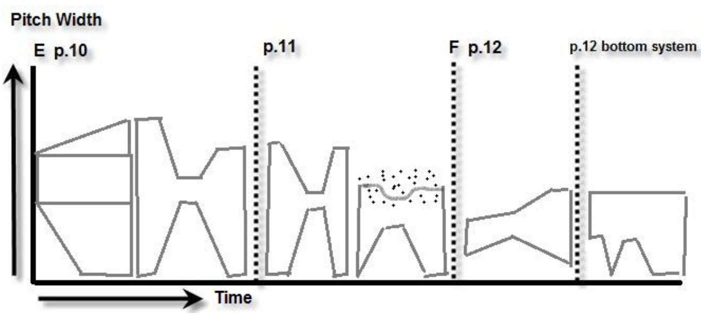


Figure 32b Pitch bandwidth contraction

Furthermore, from this moment on up until the top system on p.12, there is a gradual transformation of the G2 compressed series into a ring modulated timbre with an f1=98Hz (G2 carrier) and an f2=69.3Hz (C#2 modulator) with their multiplications 2a, 3a, 2b, 3b, 4b (see figure 33). The formula to achieve the resulting ring mod timbre is:

a+b (ff), a-b(ff), a+2b(f), a-2b(f), a+3b(mf), a-3b(mf), a+4b(mp), a-4b(mp),2a+b(f), 2a-b(f)

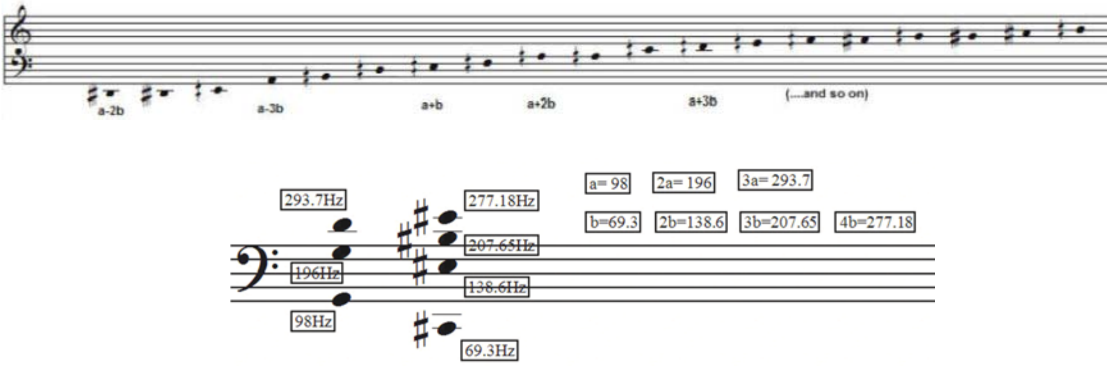


Figure 33: Ring modulation with a G2 carrier and C#2 modulator.

Eight nonlinear interpolations are created in between with the help of OPENMUSIC (figure 36) and only no. 1, 3, 5, 7 and 8 are used in this section. Also, the dynamic markings of Violin I and Cello are taken from the ring modulated series and are being used on the interpolated series as well. Furthermore, sudden dynamic fluctuations also define note accents and melodic phrases (figure 34).

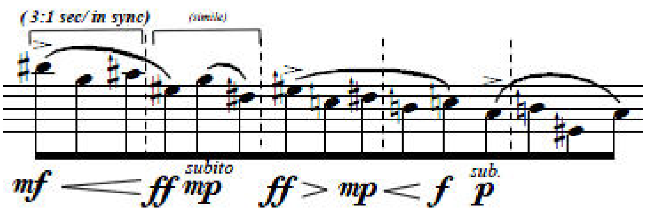


Figure 34: Dynamic fluctuations on the Cello and Violin I taken from the ring mod series.

This section also raises the issue of entropy as Violin II and Viola perform a finger tremolo between a normal pitch or a microtone and a microtonal natural harmonic that fluctuates in speed, dynamics and bowing technique (sul pont also changes the resultant harmonics into higher ones), and which is not at all in the realm of conventional techniques. This creates randomness and disorder with no predictable harmonic results, and can also be found at the ending section of the work (figure 35).

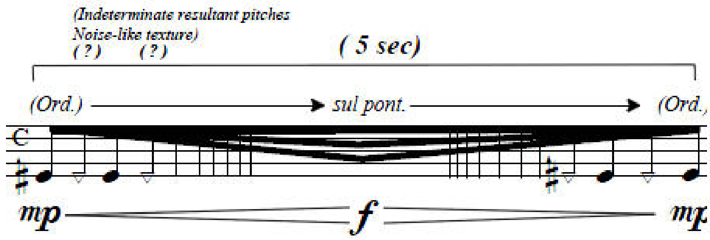


Figure 35: High entropy levels in Metabolos

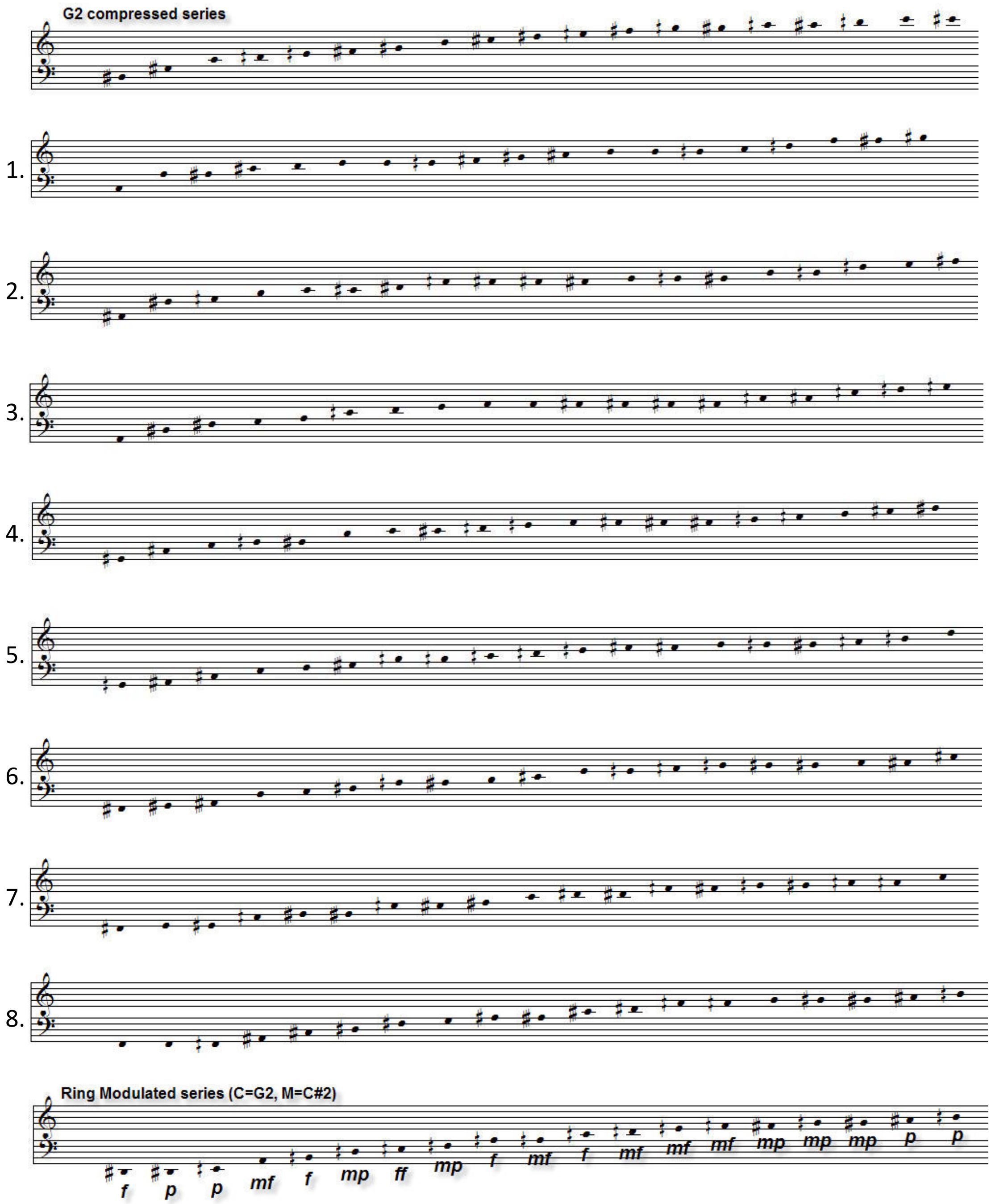


Figure 36: G2 compressed series to ring modulation timbre with eight nonlinear interpolations in between.

At the end of p.12 (figure 37), there is an RM aggregate section that uses all of the pitches of the RM series in a span of six seconds (figure 38, RM series). After this section, another process begins, transforming the RM series to an F# harmonic series with odd partials. Once again, eight nonlinear interpolations are calculated with an exponent of 0.6 (figure 38). Modifying the distortion exponent from 0.7 to 0.6, results in a different convex curve.

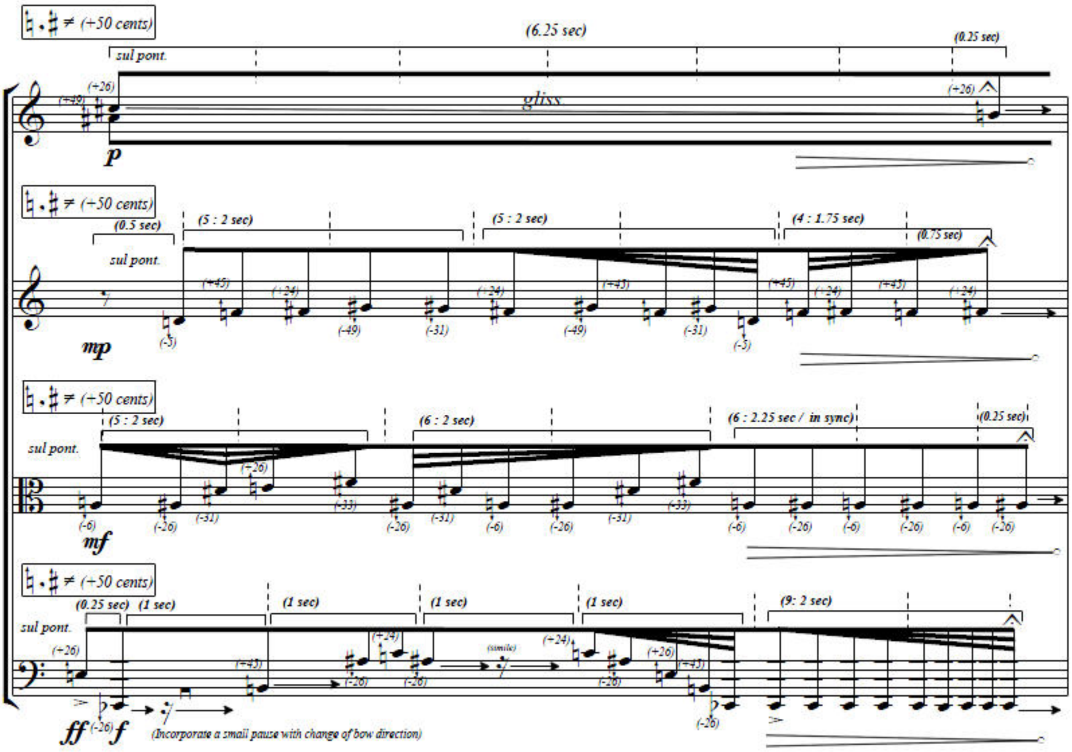
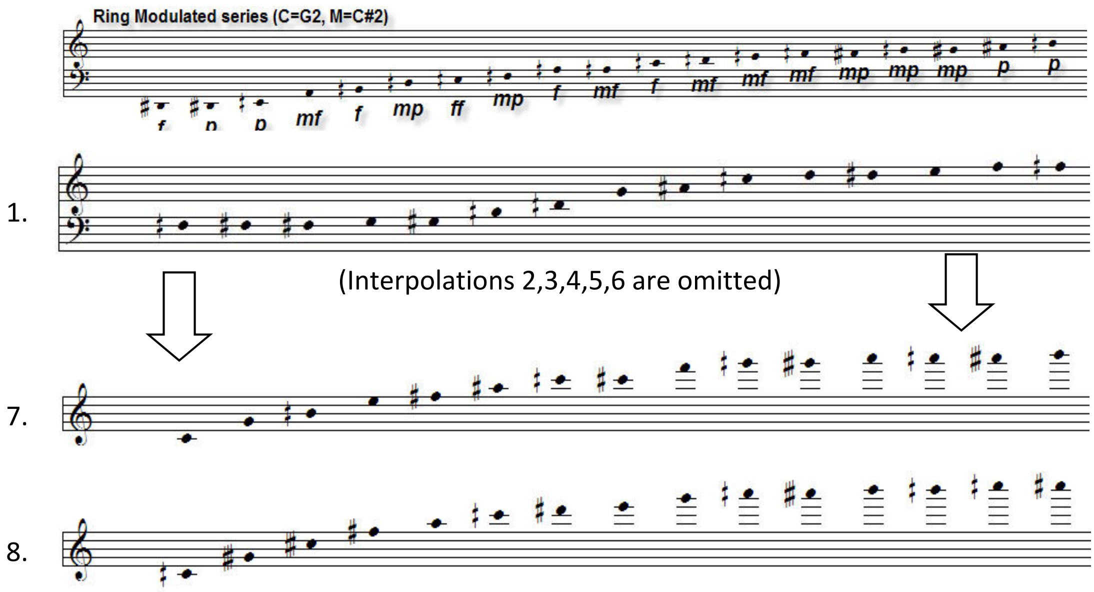


Figure 37: Ring modulation section



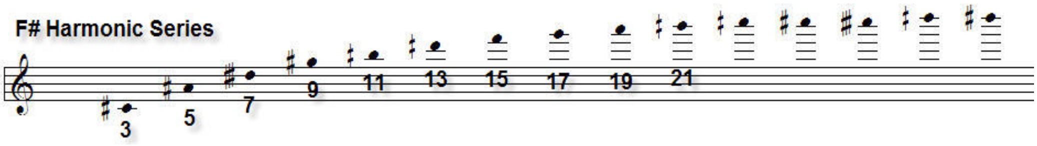


Figure 38: RM to F# harmonic series (eight interpolations in between).

Starting from the top system of p.13, a meta-process is starting to appear, a superposition of two layers, one that is purely periodic (Viola and Cello), slowly highlight moments of rhythmic 'arrhythmias', and the top layer (Violin I and II) that has a limited aleatoric context. All instruments are using material from figure 38 starting from interpolation no.1 and finishing on the bottom system of p.16 with an amalgamation of partials from interpolation no.8 and the F# harmonic series. Figure 39 shows vestiges of the F# fundamental in the cello part (that slowly increases in number) as well as rhythmic 'arrhythmias'. There is also a change on the 'frequency bandwidth' (lowest and highest frequency points) as this section started from low RM frequencies and ends up at the highest partials of the F# harmonic series (figure 38).

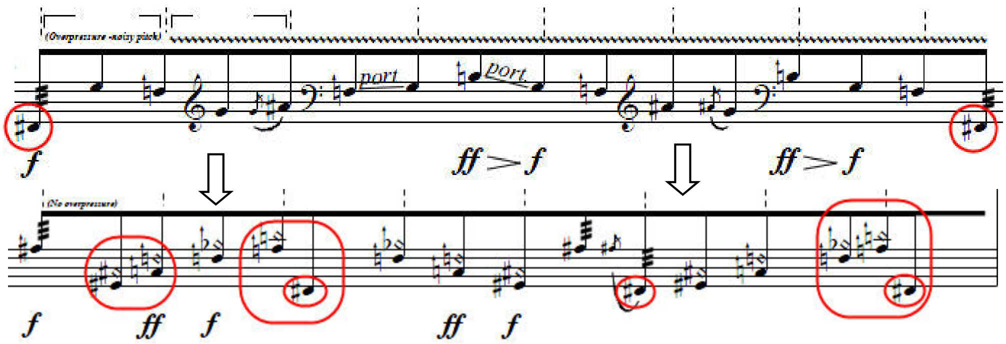


Figure 39: Vestiges of the F# fundamental and rhythmic 'arrhythmia' on the cello.

P.17 and p.18 go through three interpolated series between an F# harmonic series and a frequency modulation spectrum (G2=carrier, C#2 modulator) with a modulator index of 10 (figure 40a). Dynamics are calculated through Bessel functions (figure 40b). Sidebands are calculated with the following equation:

Frequency = carrier + and – (index x modulator)

(**c-m** and **c-2m** are omitted as they are outside of the cello range)

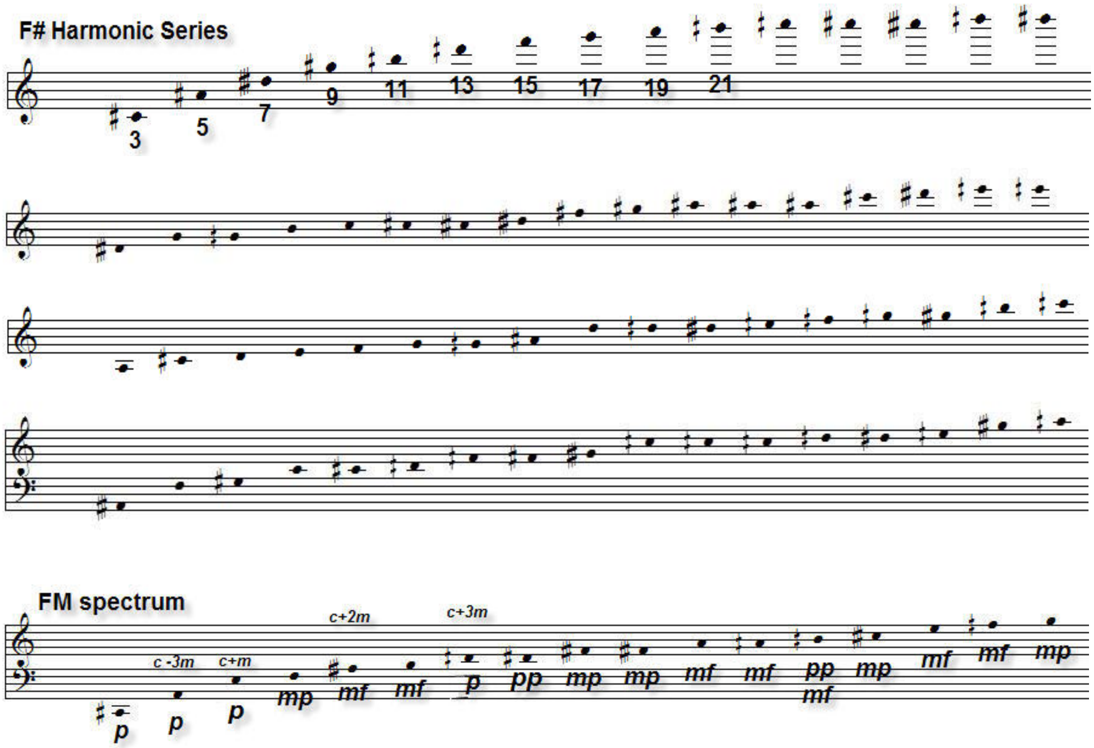


Figure 40a: F# series to FM spectrum with three interpolations in between (0.6 exponent)

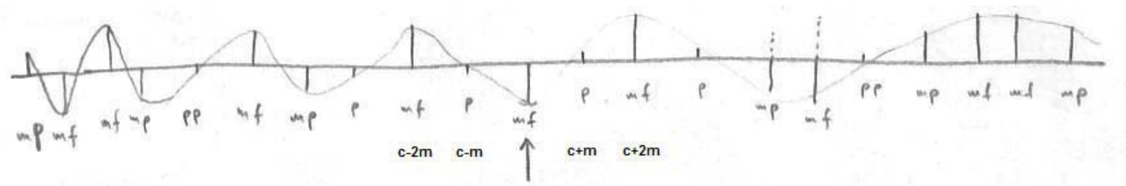


Figure 40b**:** Dynamics are calculated through Bessel functions

For example, one of the many realizations of the FM spectrum is given in figure 41. Here the microtones are written at the exact frequency of the FM sidebands with a plus or minus cent deviation from the equal tempered tuning. Also, the dynamics used are the ones calculated through Bessel functions as shown in figure 40b. On some of the notes of this section a three against two vibrato is asked for, metaphorically 'conflicting' with the non-integer ratio of the modulator and carrier that created this FM spectrum.

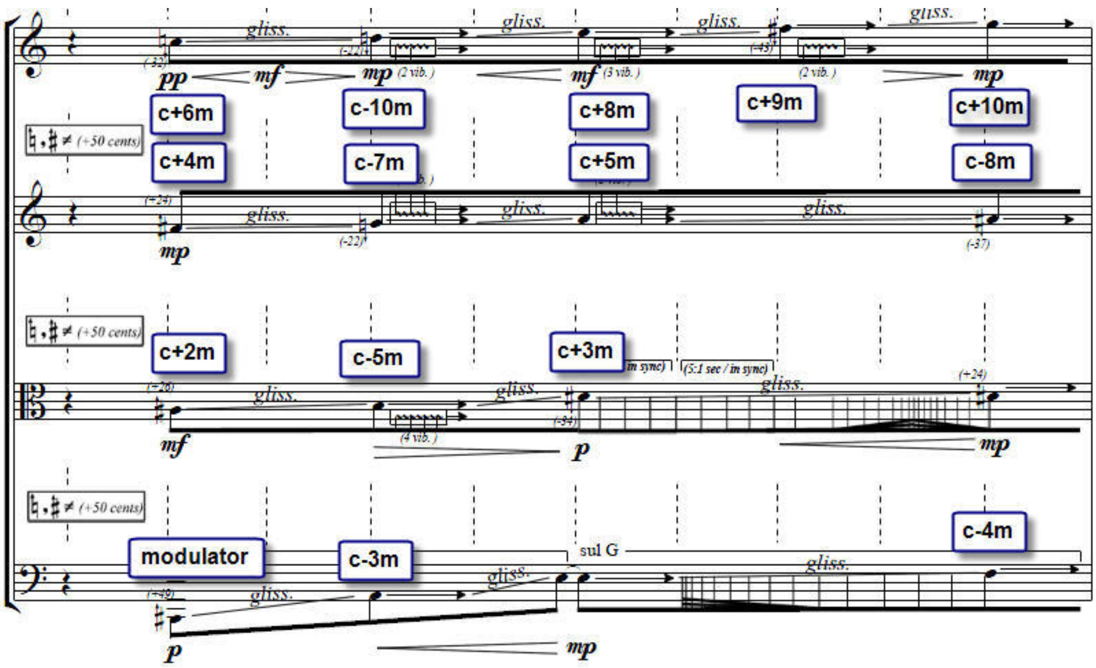


Figure 41: Realization of the FM spectrum

The spectrums used on p.19 and p.20 are randomly selected through all the calculated harmonic and inharmonic series. Some are taken from RM spectrums and some from random interpolated series. Specifically, the top system of p.19 is based on the RM spectrum; the bottom system on the 7th interpolated series of the G distorted-RM spectrum (figure 36); the top system of p.20 on the 3rd interpolated series (figure 36) and the bottom system on the G distorted series. P.20 finishes on a B - C# high register harmonic sound that prepares the listener for the next section.

For p.21 up to the end of the work, there is another long descriptive instruction of how the players should respond to this section. They are required to alternate between the given high register harmonic nodes on a single G string and follow the changes of the speed of the tremolo. Some of the harmonic nodes are not conventional and some even produce microtonal natural harmonics (for example, the no.7 Bb harmonic node produces a microtonal D). The chart and its resulting sound is quoted from Enzo Porta's *The Violin: Harmonics-Classification and New* Techniques (Porta, 1985).

Throughout this section, bowing should be sul pont. The ending result would be a chaotic amalgam of high register harmonics and noise-like textures as the resulting sound of these higher harmonics will fluctuate vastly depending on variables such as bow speed and position, bowing pressure, tremolo speed and so on (figure 42a). The players are specifically instructed to let the variables cause the resultant sound to fluctuate and not try to produce the specified sound and that sound only. The work ends in a directly opposite manner from the beginning. The slow directional spectral incubating period of the G2 fundamental becomes a spectral 'granular' synthesis of the string's constituent elements including its harmonic and noisy textures. Furthermore, this section is also in par with Radulescu's notion of the 'preferential phenomenology' of sound spectra (Radulescu, 2003, p.322). All the partials are part of the same fundamental so even though the players are instructed to instigate random parameters, there is a favourable chance of hearing a low G virtual fundamental. A similar example that uses the same technique would be Radulescu's *Das Andere* (1984). For example, in figure 42b, the nodes touched on the two adjacent strings are producing harmonics which are part of the same D spectrum. As Radulescu explains, his music is at the border between score and sound phenomenon, trying to create a state of trance, close to a *spiritism séance* (spiritism is the belief of the survival of the spirit after death) (Radulescu, 1984; program notes). In my example though, this technique doesn't have any teleological significance. It is purely a textural game between two opposite phenomena (pure harmonics and noise).

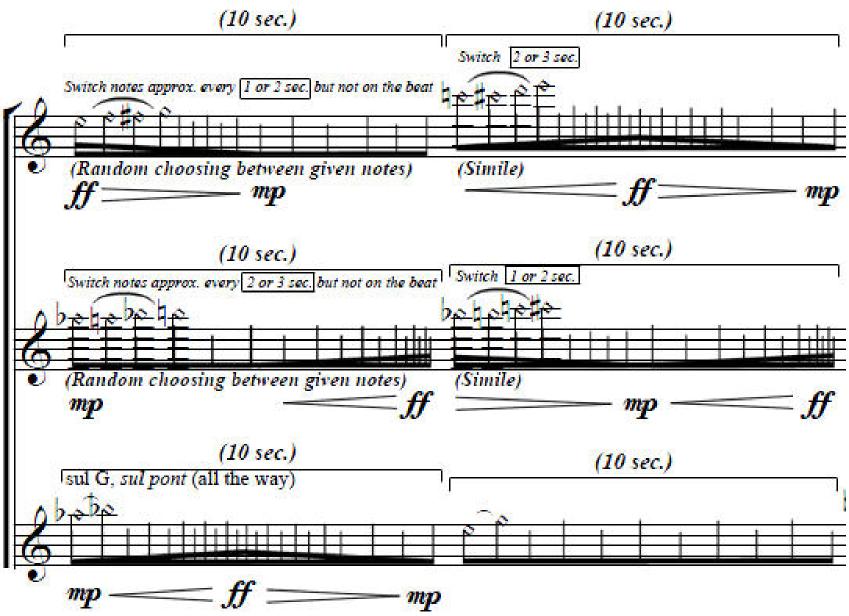


Figure 42: Ending section of *Metabolos*.

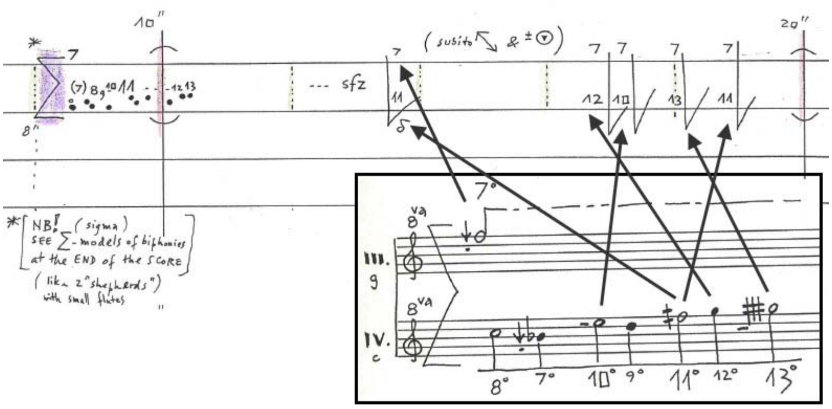


Figure 42: (Σ) module in the beginning of *Das Andere* (Score: Radulescu (1984) ; Chart: Radulescu (1984), program notes).

In *Metabolos*, the constant change of frequency-based material creates its formal structure. As Varèse asserts, 'form is a result - a result of process' (Varèse, 1966), and this process of transforming its spectral elements into harmonic and inharmonic timbres is how it sustains its form. The 'integration of all sounds' (Grisey & Fineberg, 2000) from scratch tones to harmonic aggregates and the use of 'thresholds between different parameters' (*ibid.,* 2000) are among the many characteristics of *Metabolos*. As Grisey concludes, 'the spectral adventure has allowed the renovation, without imitation of the foundations of occidental music, because it is not a closed technique but an attitude' (*ibid.,* 2000). But the works also shifts away from the orthodox spectral attitude. The entropic/idiomorphic 'open' writing of this work impinges the textural images projected, sometimes reminiscent of improvisatory paradigms.

2.5 **Transient**

Transient, as the name of the composition suggests, is something that exists briefly; temporary. This composition deals specifically with the attack transients of the piano serving as a model for the realizations and manipulations of its sinusoid partials.

In 1822, Fourier came forth with a mathematical proof stating that any waveform, no matter how complex, could be decomposed into a sum of sinusoidal waves by specifying precisely their relative amplitudes and phases (McAdams, 2000). Furthermore, a Fourier analysis of a complex periodic signal with truncated onsets won't be sufficient to distinguish its source. Winckel points out that formants and onsets and the decay transients are of equal importance in the recognition of the source and that many instruments have no stationary condition but consist entirely of transients (Winckel 1967, p.34). In the case of the piano, he argues that a light stroke results in a softer sound with fewer overtones, while a strong stroke gives the sound a bright timbre, even producing a swelling in intensity during the decay of some partials due to the multi-coupled resonant system of the piano (Vierling 1936; cited in Winckel 1967) (bottom of figure 43; discussed later in the composition).

What Winckel describes was confirmed by recording and observing the spectral analysis of an E2 piano string. Specifically, three recordings were made of the mentioned string on three dynamic levels: *p*, *mf*, and *f*.

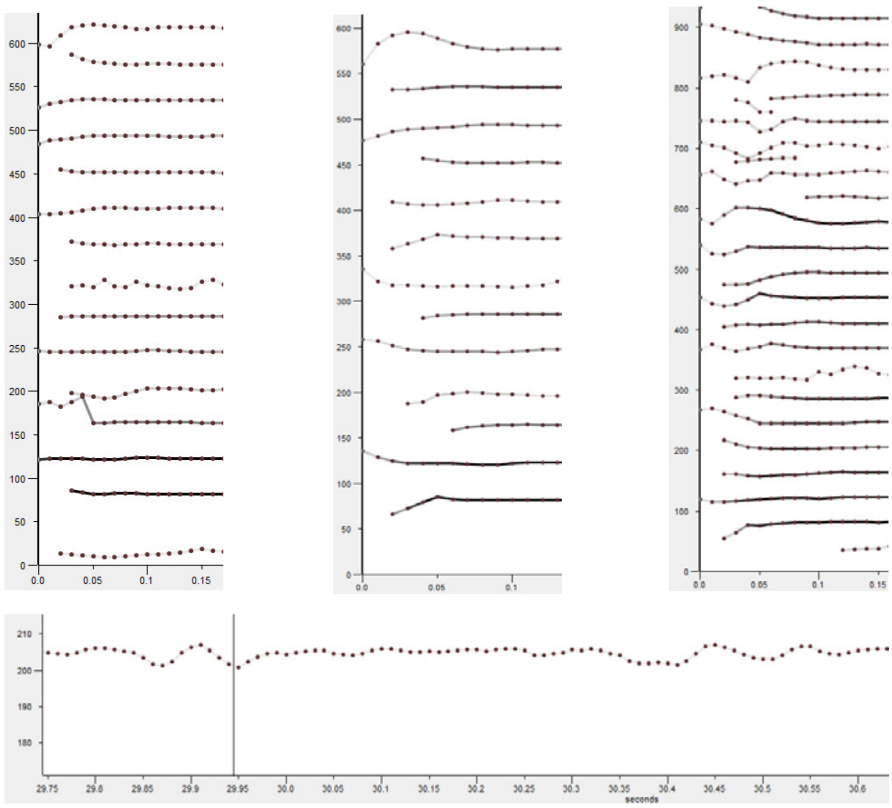


Figure 43: Recordings of the E2 piano string on three dynamic levels (p, mf and f). Bottom: swelling of a partial during the decay phase of the *f* audio sample (data cd: Transient piano samples).

What can be observed from figure 43 is that attack transients occur in less that 0.05 of a second with some partials appearing later than others (especially on the *mf* audio sample). The energy levels vary on all three with the *f* attack transient having more prominent inharmonic partials that deviate momentarily from its later steady-state phase. Furthermore, resonant frequency areas (spectral energy peaks or formants) are more prominent in the low register (first and second partials) of the *p* audio sample, while the *mf* sample adds the sixth and twelfth partials, with the *f* audio sample having the most noticeable peaks on various areas (1-3, 5-6, 10 and 12-13 partials; darker shaded lines). These dynamic properties of transients are very important to the distinction of one sound source from another but also to the overall timbral characteristics of the instrument. According to Grey (1977; cited in Bregman 1994), timbre is multidimensional, and it's correlated with the brightness of the spectrum, the simplicity of the harmonics and the 'bite' of the attack of the tone (p.481).

Revealing these intricate details of the onsets was the primary goal of this composition. The audio samples were analysed in SPEAR and exported as SDIFs in OPENMUSIC. They were then realized as a continuous stream of partials preserving their temporal order (figure 44).

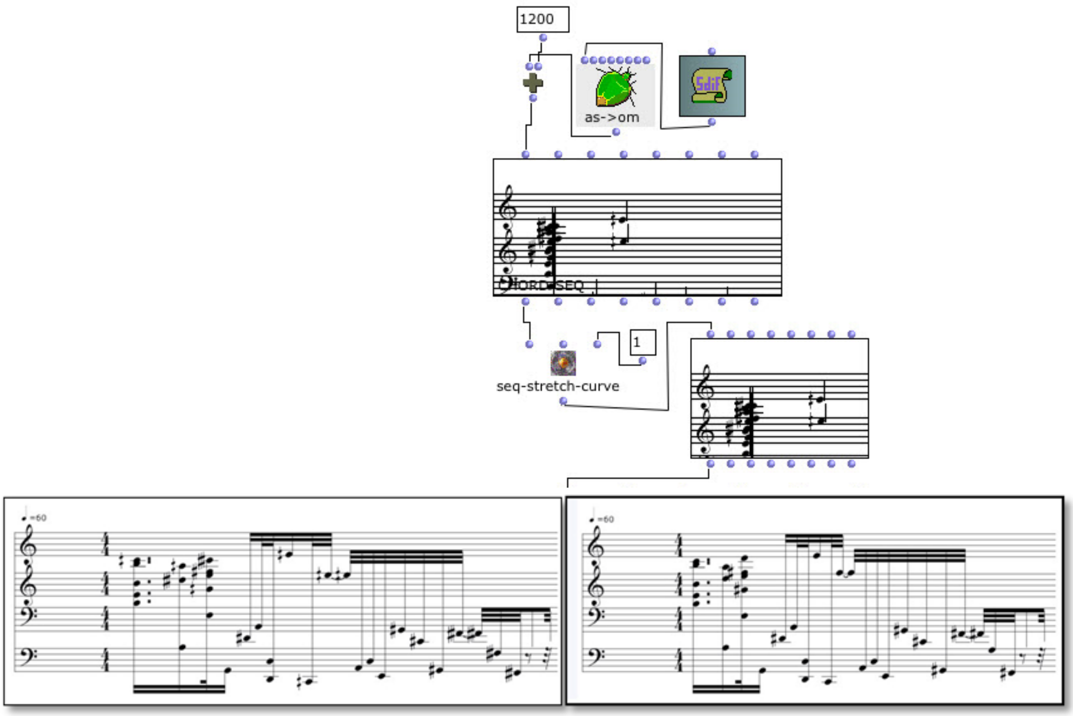


Figure 44: Analysis of the *p* audio sample. Quarter-tone resolution on the bottom left. Equal tempered realization on bottom right (data cd: Transient OM patch).

An equal-tempered version was created for the piano and a quarter-tone equivalent for the electronics (figure 44). Quarter-tone partials from figure 44 (left) were mapped in HIGHC and a graphic chart for each individual measure was exported in Sibelius for easy navigation and score following (figure 46).

Just to give an example of the procedure, in b.1, the piano is performing the equal tempered version of the spectral analysis of the p audio sample while the electronics are based on the quarter-tone version with partials having their own envelopes and occasionally using register and temporal shifts (figure 46). On the graphic score, connected partials with vertical lines mean there is a modulation event (FM, AM or RM) with one of the partials being the carrier and the other the modulator (figure 47). Noise bands of 4-20Hz are also utilized but there is no clear distinction from regular sinusoids in a black and white score (HIGHC uses green as the colour of noise bands).

Audio files are then created from the HIGHC score and stored on the computer, mapped on a QWERTY keyboard and triggered live with the use of SOUNDPLANT (figure 45). This was a conscious decision, to use a user friendly software that doesn't rely on any external hardware for sample triggering (midi keyboards, external soundcards) so that preparation and rehearsal time would be cut to a minimum as well as attracting performers that are not proficient with the use of technology. The aesthetic decision of using triggered sounds rather than live electronics lay to the simple fact that there are sections in the work that require precise synchronisation with the electronics to realise its texture and form. For example, this is evident on the last five minutes of the piece were we have two versions of partial tracking analysis that run simultaneously and gradually slowed down in a one to one linear fashion. Even if that was coded in software, it would have produced an artificial decelerando that does not relate to the inner timing of each partial of the original analysed sound. My aesthetic argument is that the concept of the piece creates its technological necessities and not the other way around (see also Chapter One: 1.4 for the aesthetics of live vs. non-live electronics).

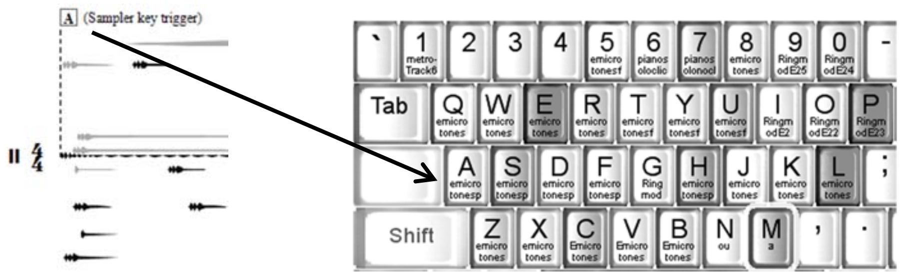


Figure 45: Audio triggering in SOUNDPLANT (data cd: Soundplant keymap).

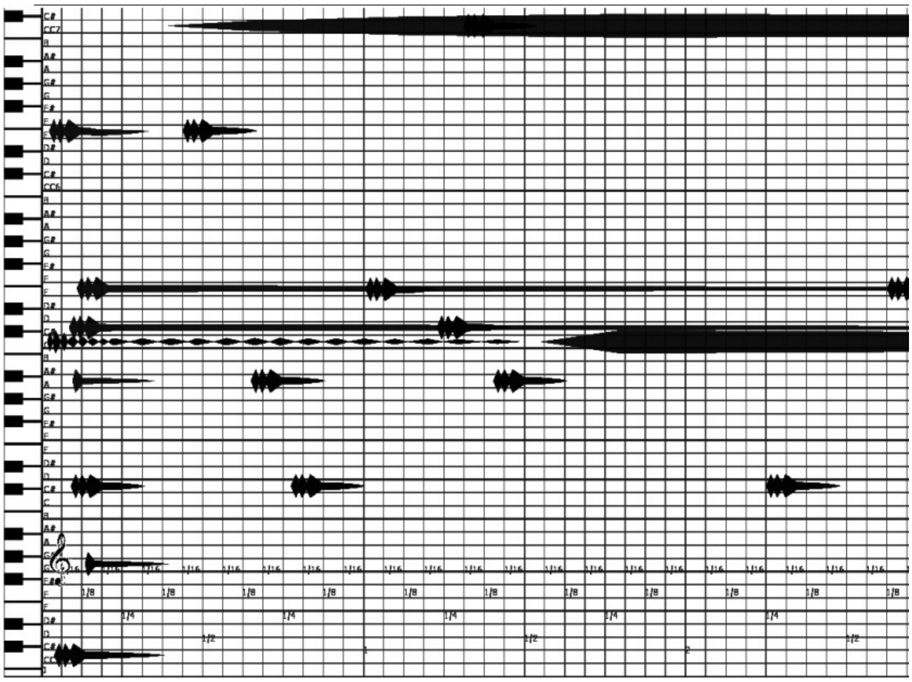


Figure 46: Construction of the graphic score in HIGHC (bar 1) (data cd: Transient score).

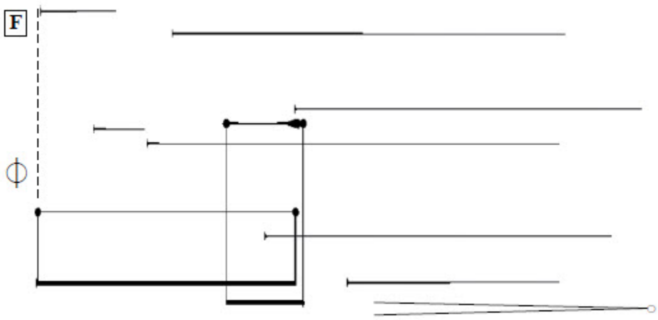


Figure 47: Two instances of Frequency Modulation on b.5

Following the score, the *p* audio sample (b.1-2) is stretched twice (multiplier=5 and 10) and realized in bb.3-5 and bb.6-9 respectively, while the *mf* audio sample (bb.11-20) is stretched only once (bb.21-54; multiplier=10). The *f* sample was stretched once (multiplier=5) and used in bb.55-67 which is also the most active section of the composition reflecting the potency of its partials (figure 43). Regarding this section, after a long decay of the *f* sample, we notice a rebirth of some of the partials similar to what Vierling highlights due to the multi-coupled resonant system of the piano (the multiple strings existing on the low range of the piano are creating a coupled oscillator transferring their energy to the sounding board at various rates creating the rebirth of the partials). This effect is reflected in the score starting from b.57 (bottom of figure 43; figure 48).

Figure 48: Swelling of the partials during the decay phase of the *f* audio sample (b.57-63).

From bb.68-73, some of the quarter-tone partials of the spectral analysis of the *p* audio sample (figure 49) were ring modulated with an E2 modulator using the *ring-sine* function in OPENMUSIC, producing the partials of figure 50 which were used in this section as the pitch material of both the piano and electronics.

Figure 49: Quarter-tone partials of the *p* audio sample spectral analysis.

Figure 50: Ring modulated partials (Mod=E2) (data cd: Transient OM patch).

For the last section of the composition, the *p* audio sample was ring modulated (Mod=E2) and then reloaded in SPEAR using two different options for the *minimum amplitude threshold* (-40db and -90db sensitivity). This produced two versions, one with fewer partials due to the difference in sensitivity (figure 51).

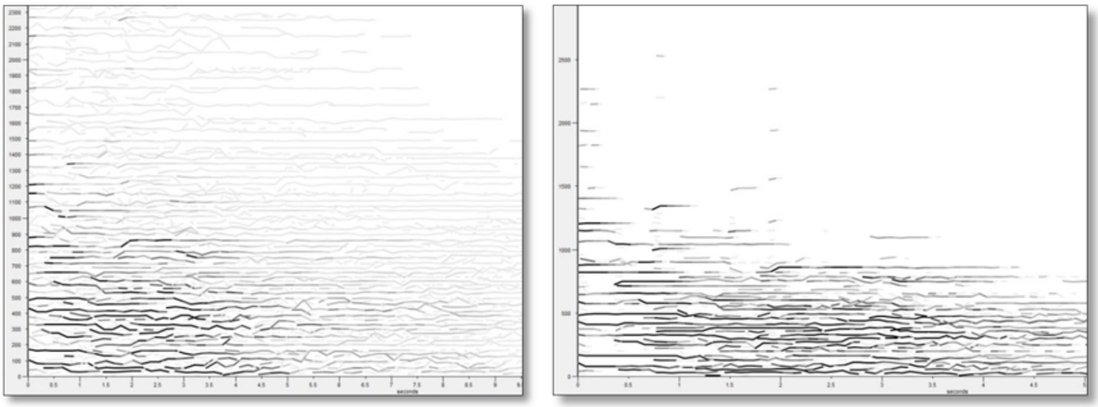


Figure 51: RM version of the *p* audio sample. Left: – 90db sensitivity. Right:-40db sensitivity.

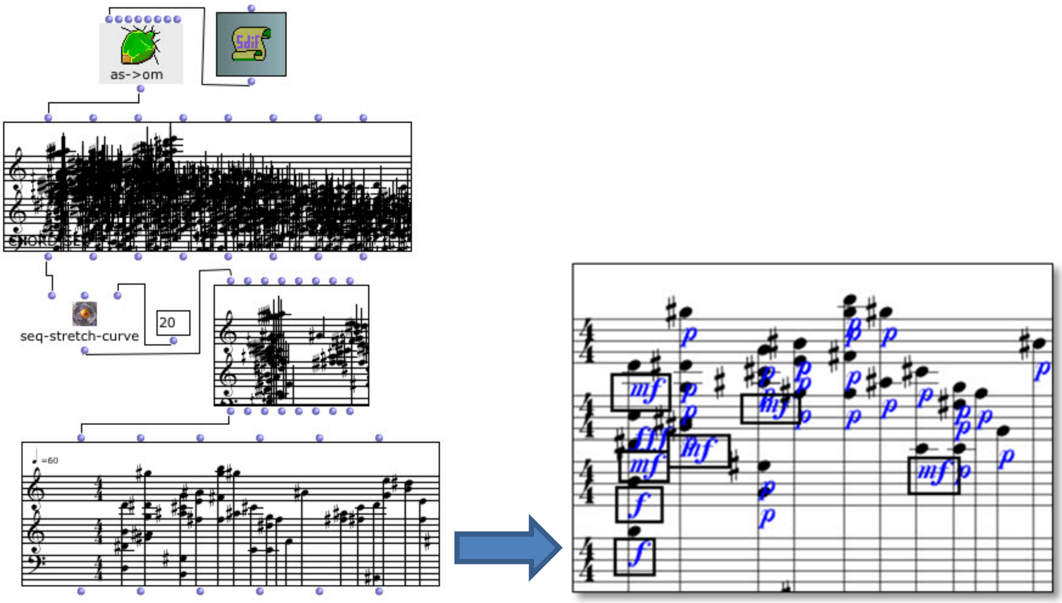


Figure 52: RM stretched version (multiplier=20) of the *p* audio sample used on the last section of the composition (electronics) (data cd: Transient OM patch).

These two versions were then exported in OPENMUSIC and stretched with the *seq-stretch-curve* function. Using a midi file export of figure 52, the file was loaded in SONAR X1 sequencer utilizing the Fazioli piano sample library to record an audio realization of the midi file (this is triggered in the score in b.76). Furthermore, the piano in b.76 uses the second RM version (figure 51, right) and is stretched using the *seq-stretch-curve* (multiplier=18). Metaphorically speaking, the last section is like the two sides of the same coin. Two slightly different tempos are superimposed based on the same audio sample with the triggered audio in b.76 being the most condensed, while the piano part is a more 'diluted' version using fewer partials because of the different amplitude threshold option used in SPEAR (figure 51). In addition, both versions use exact dynamic markings simulating as truthfully as possible the amplitude curve of the ring modulated sound (figure 52, bottom right).

What can be observed and concluded from the above is that the macrostructure of the composition is based on the OPENMUSIC non-linear stretching function (*seq-stretch-curve*) of the *p*, *mf* and *f* audio samples and the notation of their constituent partials, giving particular focus on the onset but also on the decay of the sound. A new world is revealed by gradually slowing the sound destroying its gestalt, its original envelope pattern, signifying a new timbral object and its intricate inner details. Bergman explains that 'a homogenous perceptual input contains no units. Only when it is broken up by some sort of discontinuity does it organize itself into units' (Bregman, p.70). This process of breaking the homogenous nature of sound into subunits is of high importance in this composition. Furthermore, the sustain pedal is fully depressed (or half depressed) throughout the whole composition, creating a halo of resonant frequencies, having a constant argument with the quarter-tone equivalent part of the electronics generating an artificial conglomerate of acoustic piano sounds and electronic sinusoids. It is a fact that we are adapted and conditioned to the equal-tempered tuning of the piano, but in this context (having an exact replica of the piano partials in quarter-tone intonation created from its own E2 string) actually creates quite an opposite psychological effect. The piano is being out of tune rather than the electronics as the ear 'prefers' a more precise approximation of harmonic aggregates producing less beatings as explained by Murail (see Chapter One, 1.8). This effect is augmented in the slow improvised sections that follow after each repeat of the onset sections (e.g. b.2), creating an 'inert space', an open template instigating focal points to the resonance that has passed moments before. This phenomenon is enlarged at the last section of the composition where the onset sections are replaced by an incubation and realization of sound's constituent elements as the sound object is extremely dilated, losing its original temporal envelope.

2.6 **The God Particle**

The God Particle was inspired by the discovery of the Higgs Boson particle at CERN on July 4th 2012. The Higgs Field (which is made out of Higgs particles and permeates the whole Universe) is responsible for giving mass to particles when they interact with it. As particles move through this field they slow down at various rates, which is what gives them a unique mass (this also explains our existence and everything else in the Universe) while a photon (a single quantum of light) doesn't interact with this field and therefore doesn't acquire mass and continue to move at the speed of light. The scientists at CERN took protons from the nuclei of atoms and collided them at almost the speed of light which in turn recreated all the elementary particles of the universe (what is called the Standard Model) including the famous Higgs Boson. All these particles were present less than a billionth of a second after the Big Bang.

Quantum mechanics came forward as a direct necessity, contradicting the principle of classical physics which states that measurement and predictions should always be exact and unique, while errors are caused by the imperfections of our measuring methods (Roederer, 2008). This statement is no longer defensible when we deal with subatomic particles. Heisenberg's *Uncertainty Principle* in physics (and thereupon Gabor's Uncertainly Principle in mathematics) states that 'the position and momentum of a particle cannot both simultaneously be known exactly' (Wishart, 1996, p.54). Roederer recognizes that no matter how much we try to improve our technique, most measurements will always be of limited accuracy because every time the system is being observed, the behaviour of the system changes (a classic example is the wave-particle duality observed in the double-slit experiment) (Roederer, 2008). This probabilistic nature of quantum mechanics is also true for Fourier analysis. As Winckel points out, time and frequency are bound together through the laws of nature; 'the more precisely we wish to perceive the pitch or frequency, the less precise will be the perception of the microduration' (an example of this would be the perception of a click sound rather than a pitch of a really short cycle of a sine wave) (Winckel, 1967, p.49). However, as Michael Klingbeil believes, every model has its drawbacks; perfect signal reconstruction is not guaranteed, but when considering compositional goals, perfect reconstruction is rarely the purpose (Klingbeil, 2009). Through a series of transformations or interpolations we can explore 'a vast space of synthetic variations' that clearly is a 'fertile territory for creative musical exploration' (*ibid.*, p.41).

The composition is split into four sections (bb.1-16, bb.17-33, bb.34-49, and bb.50-66) each based on a partial tracking analysis of a piano, flute and a suspended cymbal audio sample respectively with the last section being an amalgam of the onset partials of a clarinet, cello and violin analysis. Furthermore, RM and FM were used on small sub cells of 3-4 partials to produce difference and combination tones distributed throughout the sections. The work in a few words is a 'metaphorical transcription' (Emmerson, 2007, p.59) of the observations of the CERN scientists and specifically of the decaying/splitting patterns of the Higgs Boson into other elementary particles with less mass, including bottom quarks and *w* bosons (in the composition, the act of splitting the cells into ring or frequency modulated difference and combination tones is a reflection of the decaying patterns of the Higgs Boson into other elementary particles). Furthermore, the 'statistical anomaly' that the scientists were looking for in their data collection (the slightly more bottom quarks and *w* bosons) is reanimated as a textural obsession of a high G6/low G1 pitch cell hidden in the overly busy texture of the 2nd section of the composition.

The piece starts with an emerging gesture which can be further linked with the collision of the protons. The character of subsequent texture is purposely unstable and unpredictable (use of unstable whistle tones, overblown pitches, colour and microtonal trills with alternative fingerings, multiphonics, palm slaps and glissando inside the piano strings, increased drum skin pressure, unstable artificial harmonics and scratch tones), tracing the focus back to the sound object which is no other that the metaphorical representation of the unpredictable quantum world. Stretched and compressed time-frames are also utilized mimicking the Higgs field properties of slowing down particles at various rates while passing through the field.

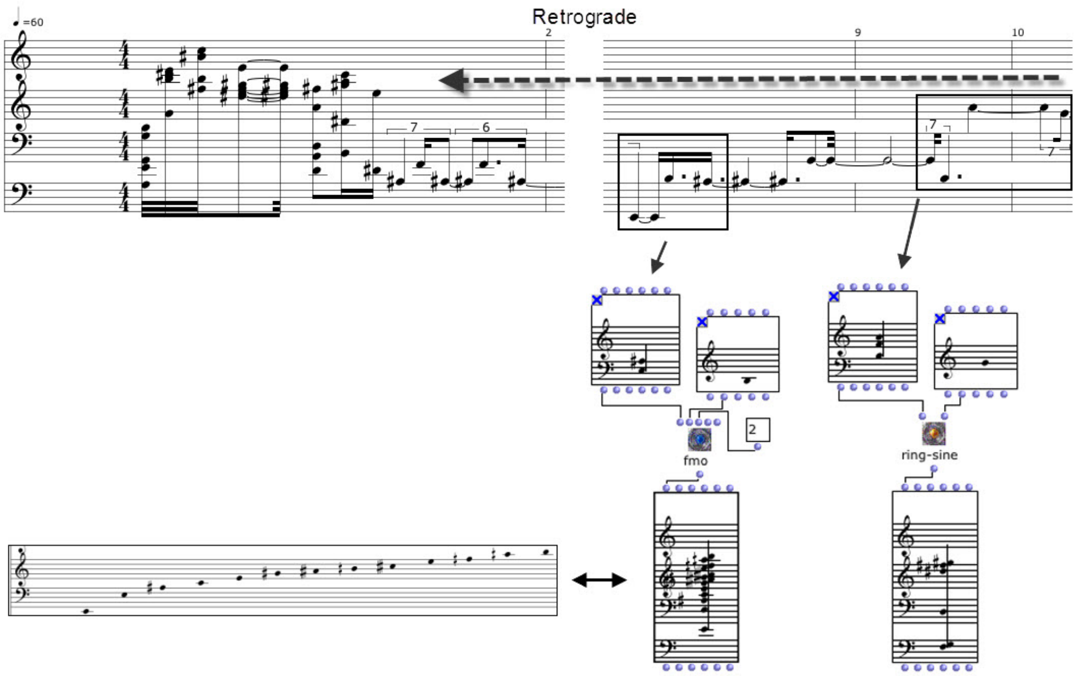


Figure 53: Partial tracking analysis and rhythmic realization of a G2 piano string (stretch function=10) and the use of RM and FM in partial subsets (data cd: The God Particle OM patch).

In the first section, the piano is using a retrograde version of its partial tracking analysis in proportional notation while the rest of the instruments are using the pitch material coming from the ring modulated subsets of the piano's partial tracking analysis (figure 53). For example, in bb.5-6, the flute, clarinet, violin and cello are performing pitches that derive from the FM analysis (index=2) of the B, E, A# piano subset (figure 53). This texture continues in a similar vein until it reaches the climax in b.11 which uses material from an RM chord with a G3 modulator and the piano pitches of beat three and four of b.11 as carriers (figure 54). In b.13, the original unaltered version of the piano's partial tracking analysis of its G2 string appears in the piano part (figure 53 – top) with no stretching functions and fades out reaching the end of the first section.

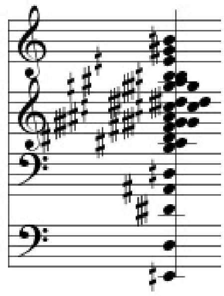


Figure 54: RM chord used on b.11 (mod=G3, Carriers= piano pitches of b.11, 3rd and 4th beat).

The second section (bb.17-33) is based on a partial tracking analysis of a flute playing a G4 pitch with vibrato. Due to the vibrato, the partials are rapidly fluctuating creating a horizontal permutation of the same partials rearranged differently in each of the chords (3rd and 4th beat – figure 55), which is a characteristic of the texture of section two.

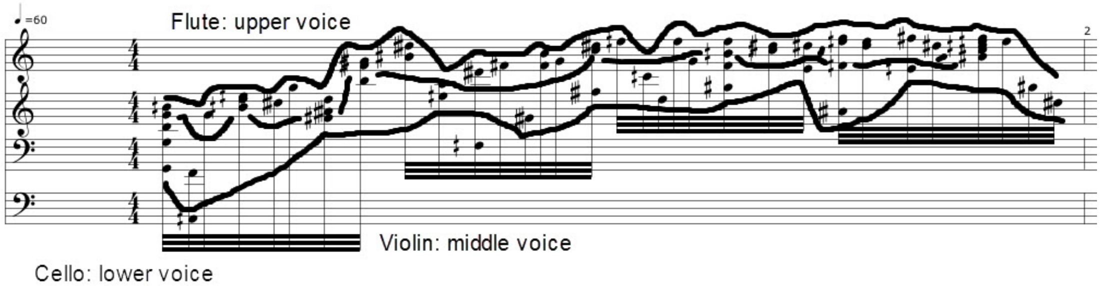


Figure 55: Partial tracking analysis of a G4 flute audio sample with vibrato and its instrumental distribution (data cd: The God Particle OM patch).

The flute, violin and cello produce a declamatory texture that is based on figure 55, while the clarinet, percussion and piano give rise to a textural obsession of a high G6/low G1 pitch cell which as discussed earlier is used as a metaphor for the sought-after 'statistical anomaly' data in order to verify the existence of the Higgs Boson (figure 56).

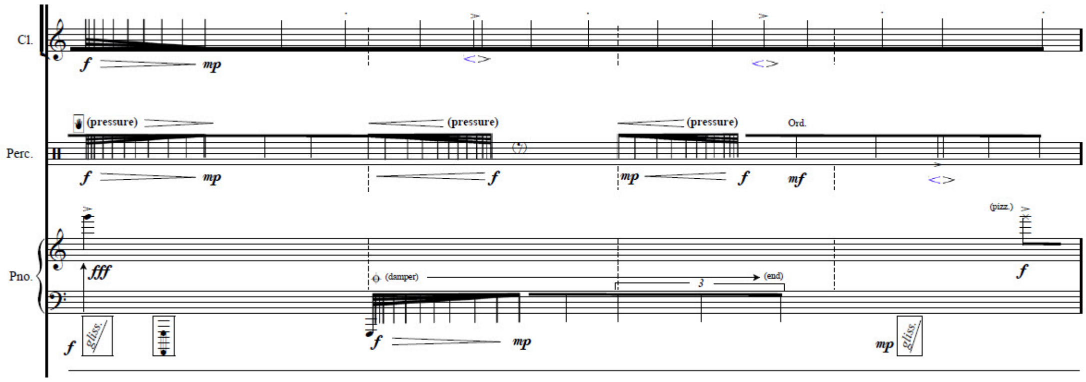


Figure 56: High G6/G1 pitch cell texture in section two.

Ring modulation is also used in section two (e.g. bb.30-33). Partials from the flute sample are ring modulated and used as the core materials for the inner instruments (figure 57 – clarinet and piano) while the outer instruments are still based on the original unaltered partials of the audio analysis (figure 55).

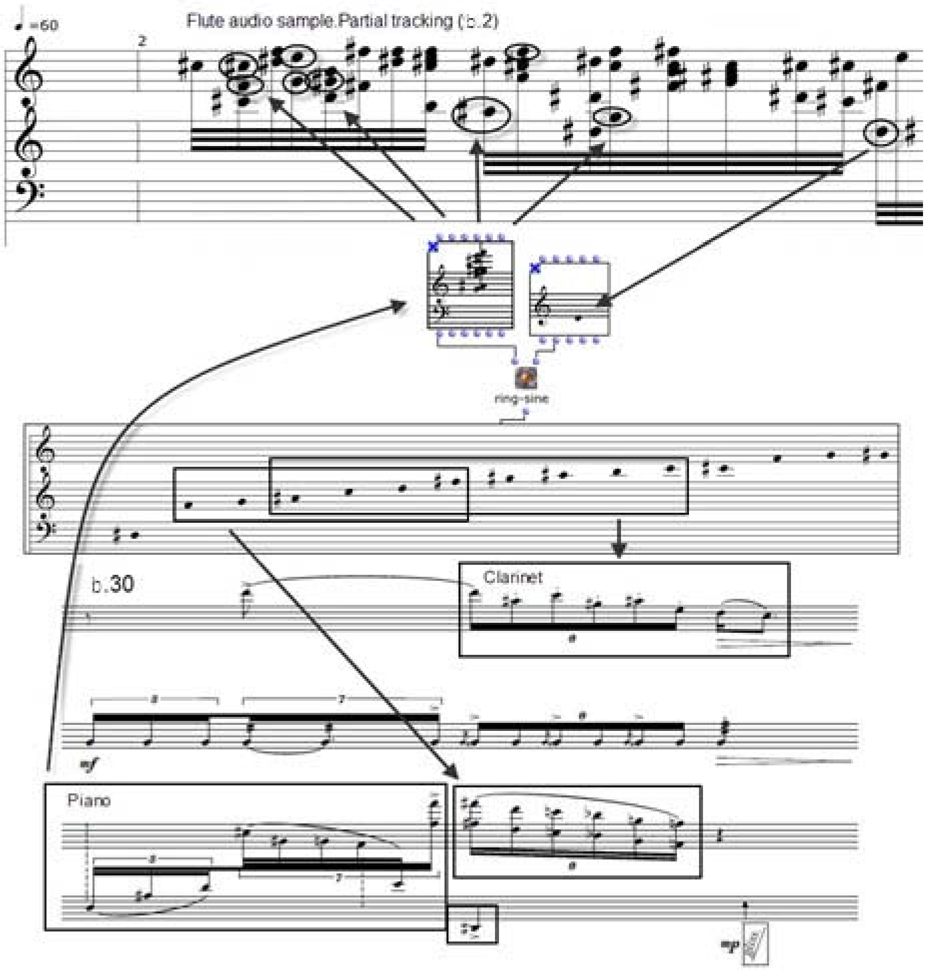


Figure 57: RM section in b.30 (data cd: The God Particle Om patch).

Furthermore, the flute's micro fluctuations of its vibrato are being translated into alternating rhythmic patterns of expansion and contraction of 1/64 notes, septuplets, sextuplets, quintuplet and 1/16 notes that gradually decelerate and by the end of section two (bb.31-33) it reveals the overall temporal envelope of this section which is a reflection of the flute's sound envelope (figure 58).

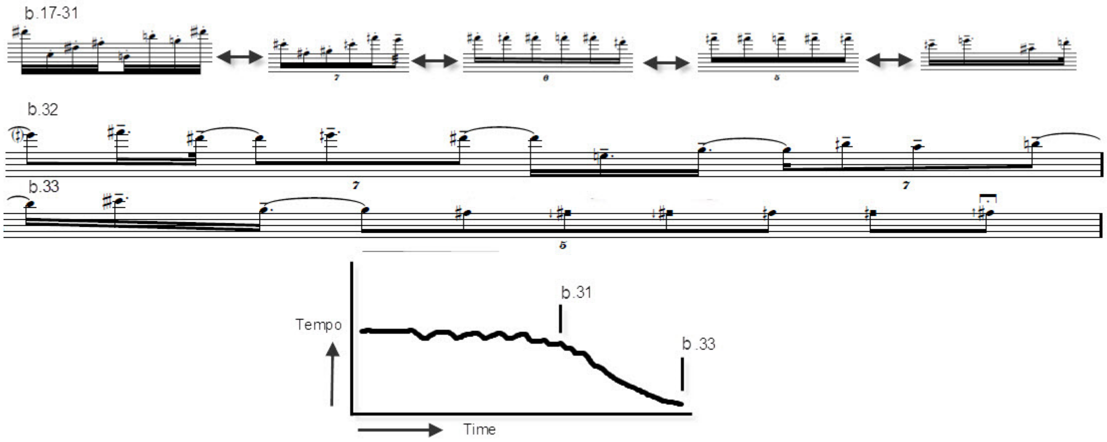


Figure 58: The tempo of section two reflects the overall sound envelope of the G4 audio sample of the flute.

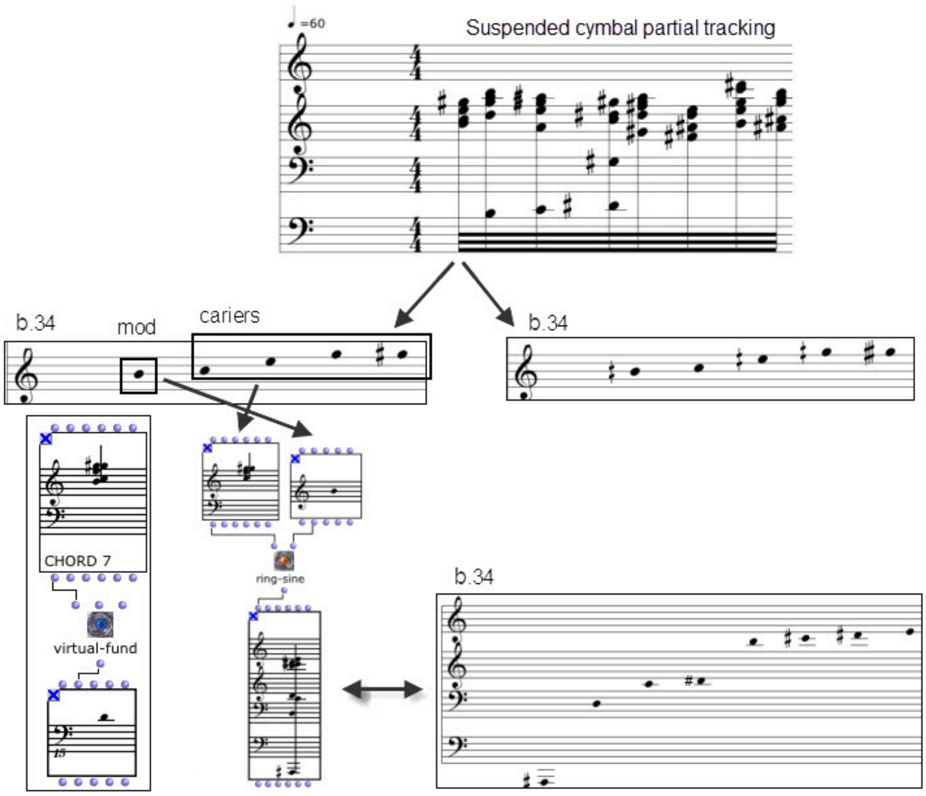


Figure 59a: Suspended cymbal partial tracking analysis, RM and virtual fundamental (data cd: The God Particle OM patch).

The third section of composition (bb.34-48) is based on the partial tracking analysis of a suspended cymbal. Each chord of the analysis has two versions, one that is in equal-tempered tuning and its quarter-tone constituent. The equal-tempered chords are ring modulated with the lowest note being the modulator and the highest notes the carriers (figure 59a). The *virtual-fund* function is also utilized to calculate the virtual fundamental of each chord respectively. It has been often used by spectral composers to measure the presence or lack of tension in a chord (Fineberg, 2000). A lower virtual fundamental indicates that the partials of the chord are more inharmonic, whereas a higher virtual fundamental indicates partials that are more inharmonic. For example, scanning the score on b.34 (figure 59b), all the instruments are using pitches deriving from figure 59a. The same calculations are used measure by measure for each individual chord of the suspended cymbal analysis up until b.49. Furthermore, the macrostructure of the third section is based on the first fifteen numbers of *Phi* (618033988749895), which are translated as a consecutive change of time signatures.

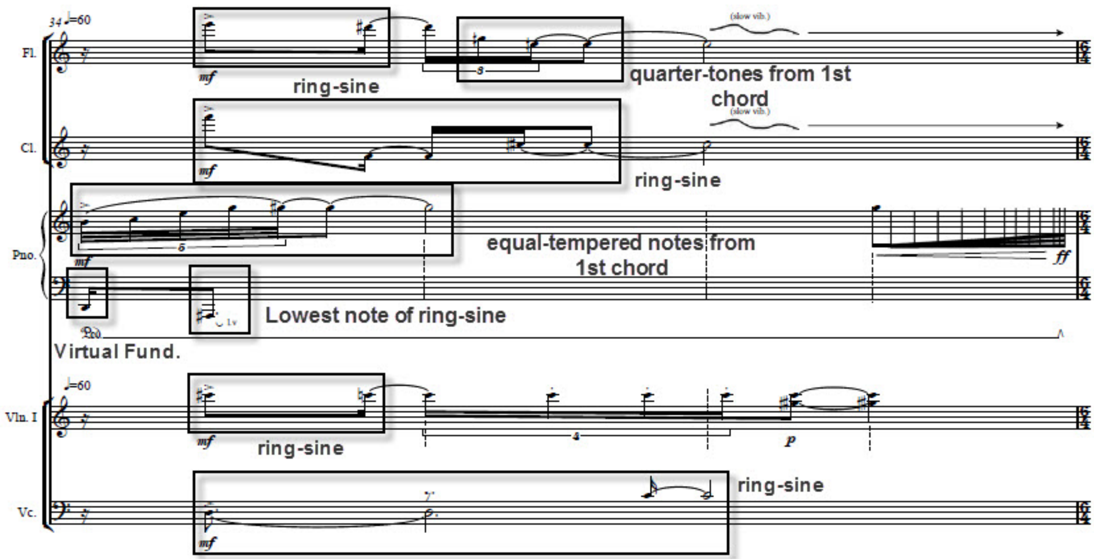


Figure 59b: b.34. Realization of figure 59a.

After the ‘cataclysmic’ three sections, a solemn chorale emerges (bb.50-64) as if it marks the ending of the quantum experiment (figure 60). The ‘jolt’ of the previous sections leaves a ‘violent impression in our memories; makes us less likely to grasp the shape of the musical discourse’ (Grisey, 1987, p.259). That is why ‘moments of readjustment’ (long silences) are offered in-between each section to ‘regain a relative equilibrium’ (*ibid*., p.259). The contracted time of the previous sections gives its place to the expansion of time, the ‘microphonic structure of sound’, ‘bringing us closer to the internal structure of sounds’ (ibid., p.259). Here, the onsets of the clarinet, cello and violin (the remaining instruments of the group that have not yet been analysed) are distributed to the instruments creating a dilated timespan focusing on the timbral fluctuations of each individual analysed onset. The sonorities are further enhanced by the microtonal inflections and the dry sound of the instruments (con sordina and no vibrato). This enriches the beatings created by the microtonal clusters which are more intensified releasing a perceptual 'vertigo' (due to the non-tempered character of the chords).

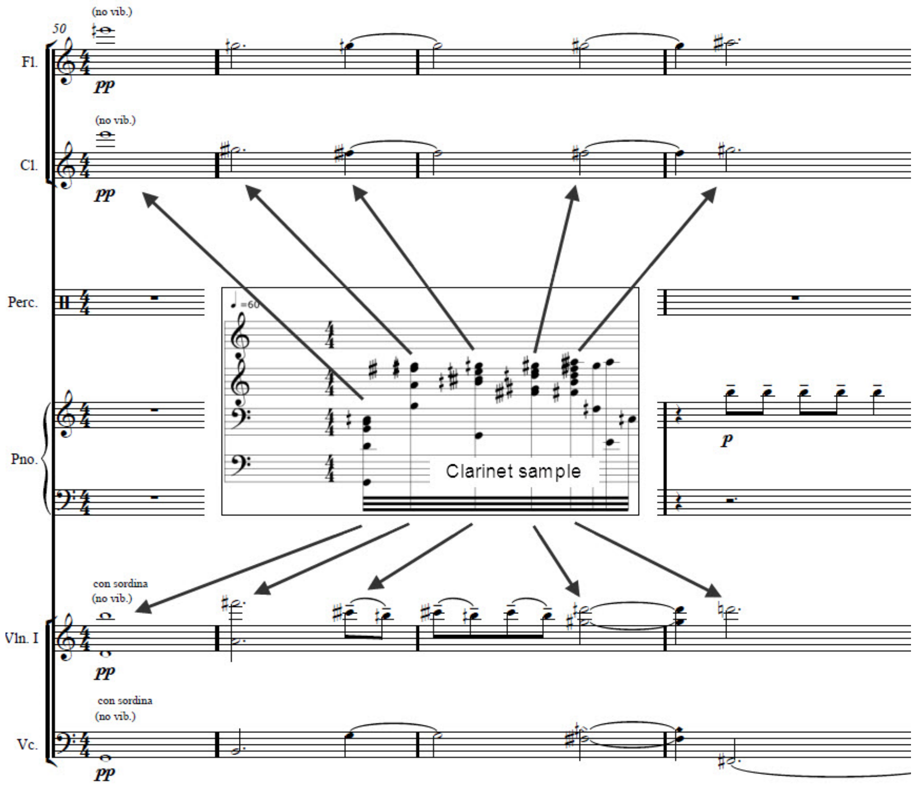


Figure 60: Onset of the clarinet audio sample distributed to the instruments.

To conclude, the last section raises a lot of questions, one of which is the never-ending question of where it all began. Will we one day be able to finally break the code of the Universe? The atomic physicist Russell Stannard believes otherwise. He asserts that complete knowledge is not feasible because of the limits of our physical brain; we discover everything that is *open* for us to understand (Stannard, 2010). It seems plausible considering that discovering new particles or dealing with the microscopic universe becomes even more difficult, incorporating probabilistic narratives, with each new experiment becoming even more grandiose in scale than the previous one. Answering these intrinsically unanswerable questions will be the epitome of the human race.

2.7 **Cicada**

The initiative behind this work came after my repatriation back to Cyprus. During the months of late July to early August, local male cicadas produce their characteristic chorus singing aggregates to attract their female counterparts. According to Colley, Marshall and O'Brien (2012), male signals are divided into five categories: alarm calls, calling songs, court I (CI) songs, court II (CII) songs and court III (CIII) songs. Calling songs are about 1.5-3 seconds long and are separated by silent gaps of about 1-2 seconds. CI-III songs are produced when courting a nearby female with the most characteristic being the CIII song consisting of uninterrupted short staccato buzzes (about four to six per second) while attempting to mount the female. CI-II are constructed similarly with phases being shortened.

Through field recordings, I had managed to reproduce all the cicadas' songs except the alarm call which is only possible if you startle or handled the cicadas (Colley et al., 2012). The inspiration for the macrostructure of the composition came after reading Xenakis's *Formalized Music*. He describes that stochastic laws can be used in various situations for example 'natural events such as the collision of hail or rain with hard surfaces, or the song of cicadas in a summer field' (Xenakis, 1992, p.9). In 1957, in his composition *Achorripsis* ('jets of sound'), he utilised probability distributions to realise the overall macrostructure of the work by distributing sound events in time/space.

In *Cicada*, the same procedure has been used to distribute individual partials of a partial tracking analysis of the cicada's field recording into a probability matrix. I have chosen a 30-second audio sample which includes a superposition of the four singing categories mentioned above, with the CIII category being the most prominent (figure 61). Analysing the audio sample in SPEAR, a narrow spectral bandwidth of two octaves emerges (1500-7000Hz). The 30-second audio sample was then exported as an SDIF file format in OPENMUSIC. Through the *as->om* function I converted the SDIF data into a stream of sinusoids (figure 62).

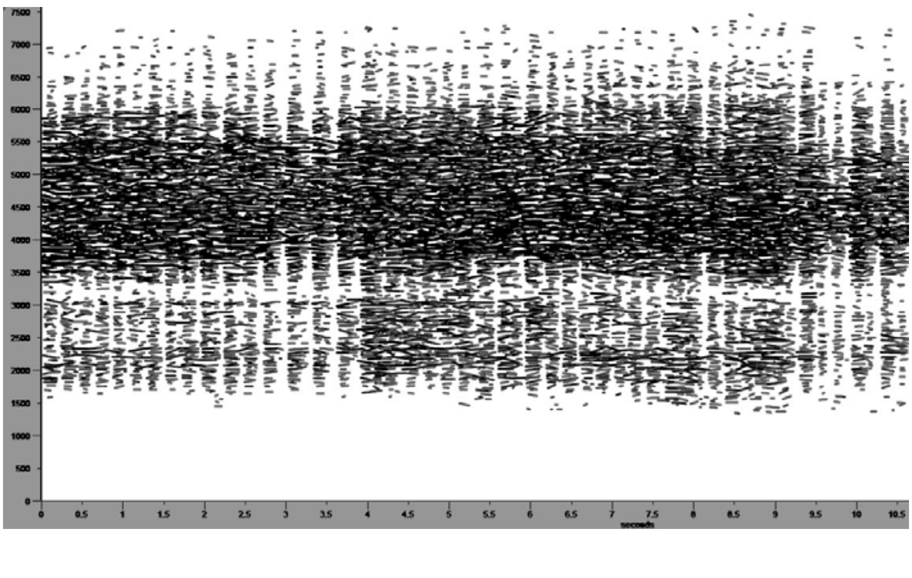


Figure 61: Spectral analysis of Cicadas chorusing (data cd: Cicada – spectral analysis).

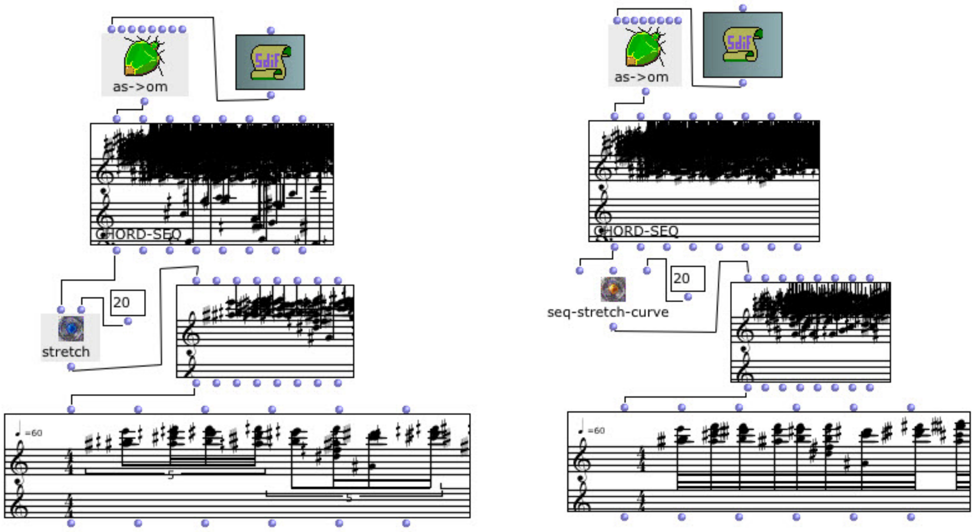


Figure 62: Analysis, stretching and rhythmic structure (data cd: Cicada OM patch).

The *stretch* function was used (multiplier=20) creating a linear stretch of the audio sample to 10 minutes and the *voice* function (last function of figure 62) to convert the chord sequence to a rhythmic structure (figure 63 and 65). The *Seq-stretch-curve* function was also used (multiplier=20); this multiplies onsets, durations and offsets by the *Lcurb/2* and *Lcurb/3* function, which produces a non-linear rhythmic structure (figure 64 and 65). Both structures were transposed three octaves down as well as using the *npoly* argument on the *as->om* function, to reduce the polyphony down to the five loudest partials per chord. A higher amplitude threshold was utilized in SPEAR in order to incorporate more partials in the spectral analysis (figure 64).

Figure 63: Linear expansion of the 30 second sample to 10 minutes (*Stretch* function) (data cd: Cicada OM export – linear).

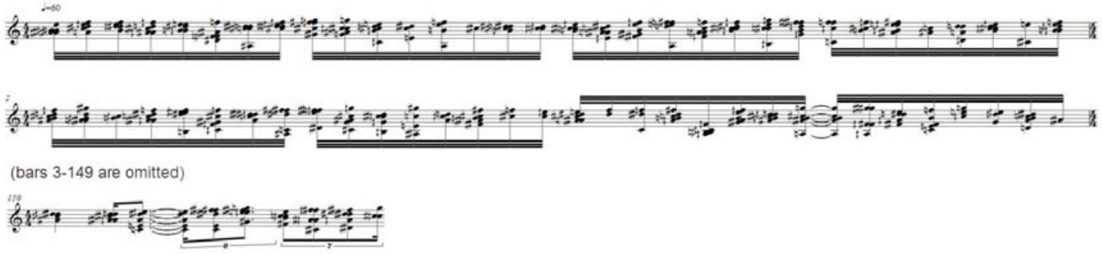


Figure 64: Non-linear expansion of the 30 second sample to 10 minutes (*Seq-stretch-curve* function). (data cd: Cicada OM export – non-linear).

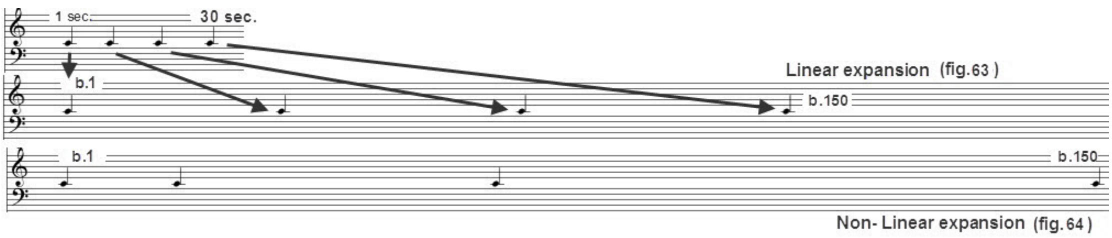


Figure 65: Visualization of the linear and non-linear expansion of figure 63 and 64.

Attention is shifted to the distribution of the material, creating the macrostructure of the composition (figure 66). Xenakis refers to the Poisson formula as a helping hand to the 'process of manufacturing a template in which music is to be placed' (Arsenault, 2002, p.58). The composition is set to a fixed period of 10 minutes and consists of a matrix of 30 columns (each column represents five 4/4 bars at a tempo of quarter note=60 or 20 seconds) and seven rows (each representing a different instrument). For the instrumentation, eight instruments are used (flute, clarinet, bassoon, percussion, piano, violin, cello and double bass) with a minimal percussion section (cabasa and tam-tam). The use of the cabasa has a special meaning as it's not part of the distribution matrix. Its spectrum and formant energy is similar to a cicada spectrum so it's being used metaphorically as the leader of the chorus aggregates, cueing entrances or fading out sections. In addition, the piano's harmonic material is an equal-tempered equivalent of the chart of figure 63 and 64. Furthermore, the piccolo uses the same equal tempered chart as its holes are covered entirely with keys making microtonal inflections extremely difficult, especially in fast passages. The rest of the instruments are using quarter-tone inflections.

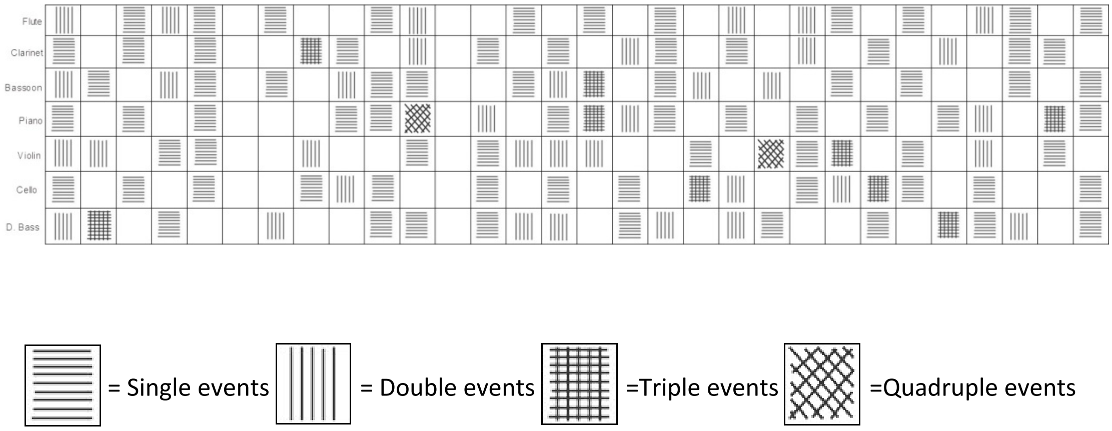


Figure 66: Sound distribution

By using Poisson's distribution formula, the probability of having 0, 1,2,3,4 or 5 events in any given cell was calculated (Childs, 2002). 'Single events' have an average of 40 sounds per five bars (average of 8 sounds per bar), 'double events' have an average of 80 sounds per five bars (average of 16 sounds per bar),'triple events' have an average of 120 sounds per five bars (average of 24 sounds per bar), and 'quadruple events' have an average of 160 sounds per five bars (average of 32 sounds per bar).

In *Achorripsis*, Xenakis uses λ=0.6 (λ is the average number of events per cell). In our example, this was producing quite a thin texture which wasn't appropriate for this work so λ was raised to 0.9. In the Poisson formula, k represents the number of events, e is the base of natural logarithms (=2.71828) and $k!$ is the factorial. So the probability of having 0,1,2,3,4 and 5 events in a cell is:

$P_k = \frac{\lambda^\kappa}{\kappa!} e^{-\lambda}$, $P_0 = \frac{0.9^0}{0!} 2.71828^{-0.9}$ =0.40657 x 210 (30 columns x7 rows) cells= 86

P_1 =77, P_2 =35, P_3 =10, P_4 =2, P_5 =0

Following Xenakis's thought, the 77 single events must now be distributed once more to find out how many columns will have 0,1,2,3,4,5,6 or 7 single events. Our new λ is 77/30=2.56 hence:

$P_0 = \frac{2.56^0}{0!} 2.71828^{-2.56}$ =2, P_1 =6, P_2 =8, P_3 =7, P_4 =4, P_5 =2, P_6 =1, P_7 =0

Double checking the chart in figure 66, there are two columns that don't have any single events, six columns that have one single event, eight columns that have two single events, seven columns that have three single events, four columns that have four single events, two columns that have five single events, one column that has six single events and no columns with seven single events. The same procedure was used for the distribution of double, triple and quadruple events.

Xenakis goes a step further and calculates the exponential distribution that govern the time between successive events, the linear distribution that govern the intervals between successive pitches and the normal distribution that govern the glissando ‘speed’ (Childs, 2002). These are not applicable in our example as the rhythmic and harmonic structure is already calculated from the spectral analysis of the cicada recordings (figure 85 and 86).

The composition starts with an open aleatoric form (contrary to stochastic principles), giving choices to the players to improvise on a fixed set of rules. The flute is using pitches from the first five chords of figure 63, clarinet (from chord 6-12), bassoon (13-19), piano (20-29), violin (30-36), cello (37-42), and the double bass (43-48). From bb.1-151, the distribution matrix is responsible for the structure of the composition (what instruments and how many sounds per measure are going to be performed). The five-chord clusters of the cicada’s partial tracking analysis are orchestrated and distributed to the instruments with a shift of registers accommodating the specific range of the instrument. For single events (8 sounds per bar), a procedure of thinning out the original texture is followed (figure 67). Consequently, the musical object (in our case the homophonic five-note aggregate texture) stays unaffected on most down beats which retains the original rhythmic structure of the analysis (figure 62).

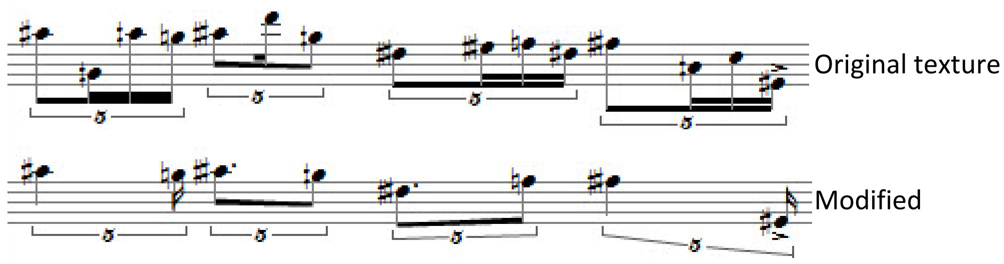


Figure 67: Cello b.14. Thinning the original texture to fit the instructions of the distribution matrix.

The spectral analysis also reveals a slow shift of the original quintuplet rhythm. From b.31 there is a 16th note added to the quintuplet rhythm and from b.61 two 16^{th} notes are added (figure 68).

Figure 68: Forward shifting of the original rhythm.

In fast sections (24 and 32 sounds on average per section), materials from figure 64 are employed as well as using cross-rhythms (8:5:4, 7:6:5). For example in b.78 (figure 69), the bassoon and piano are using elements from the non-linear sample expansion (figure 64), while the violin is using the linear version (figure 63) at the same time creating what is called a *mensuration cano*n, which is a compositional form of the Renaissance composers but also a major characteristic of twentieth century composers, especially Conlon Nancarrow (see also figure 65 for a better visualization of the two superimposed textures/tempi).

Figure 69: b.78. Cross-rhythms, superimposed tempi and average sound distribution.

Slower and faster tempos are also being employed inspired by the tempo fluctuations of cicada's singing (using metric modulations). Whenever there is an upward tempo fluctuation there is always a counterbalancing slower tempo in the next section and vice versa so that the composition ends exactly on the 10 minute mark (this is also why the composition ends on b.151 rather than on b.150 because of the tempo change on b.146).

From a perceptual standpoint, we can think of each individual partial of the five-note cluster chords as a grain of sand. Wishart argues that 'it is important to realize that there is a perceptual threshold at which we cease to perceive individual events as individual events and begin to experience them as contributing to the grain of a larger event' (Wishart, 1996, p.68). At a sufficiently high speed, 'any sequence of sound-objects may become fused into a larger object' (*ibid.*, p.68). Christensen raises the same issue. He asserts that 'when a sufficient number of tones are played close together, the single tones lose their distinctness, merging in a diffuse quality of harmonic colour' (Christensen, 1996, p.77). This dualistic approach of fusion vs. segregation, approach vs. receding of pulsating streams, blending vs. dividing of material is what is prominent in this composition (*ibid*., p.78). Even though the global structure was defined by the distribution matrix (some spectral composers would disagree with this monolithic approach), still, the 'musical object' (defined by Murail as a short entity which stays recognized even after transformed by various musical parameters) stays unaffected (Hirs, 2009, p.47). By using partial tracking and stretching of the 30-second sample into a 10-minute framework, the whole structure reflects back to itself as Rozalie Hirs defines as an 'intensified experience of time' (*ibid.*, p.47). In a sense, and as Emmerson contends, this natural world is being *reanimated* using models; models which are 'the doorways to the use of any observable phenomenon as a generator of music' (Emmerson, 2007, p.53-59).

Conclusions

In 1970s France, the spectral ideal formed as a reaction to the Darmstadt aesthetics. The fracturing of social norms made the 'autonomous art' of the early 50s crumbled down under the influence of populist movements (e.g. minimalism). This pessimistic vision should not blind one to the possibility that such middle terms do exist (Hamilton, 2007). It is not always a black and white vision of a self-reflective music on the one hand that resists commodification, and a regressive, assimilated music on the other (*ibid*., 2007). Spectralism seems to be in the middle; a 'naturalistic' view of the harmonic series, with a scientific 'parametric' approach on its manipulations, reminiscence of algorithmic approaches of the past. My compositions, for example *Bushology* or *Cicada,* have this 'middle ground' approach to them; a unification of characteristics taken from antithetical musical paradigms. Generating compositional ideas might stem out of a concept (quantum particles), a narrative (political story), a form (a distribution matrix) (Robin, 2006) or from the observation of the natural resonances of sound (piano onsets) and its temporal distortion through spectral analyses. This *experienced sound* is what my music aspires to and is reflected in my compositions as an instigator of dynamic, formal, timbral, pitch and rhythmic anamorphosis achieved through meticulous spectral analyses of sound events.

List of included material

1. CD

[Track 1: *Drops and Pipes* – 4 min. of synth patch Improvisation only]
-Premiere: EMS Concert – Goldsmiths University on Dec. 13th 2006.

[Track 2: *Bushology*]
-Premiere: 'The Electronic Saxophone' - Bowling Green University. Feb. 3rd 2008.
(Sax: William Conn)
-May 3rd 2008 - Lugano Switzerland. (Sax: Luca Bariffi)
-Feb. 3rd 2012 – 'Clarinet and Electronics', ETHAL, Limassol, Cyprus.
(Clarinet transcription: George Georgiou)
-Dec. 23rd 2012 - 'Electronic Music Concert', Skali Aglantzia, Nicosia, Cyprus.
(Clarinet transcription: George Georgiou)
-June 9th 2013 – '16th European Dance Festival', Pallas Theatre, Nicosia, Cyprus.
(Amfidromo Dance Company)

[Track 3: *Hz Discrimination*]
-Premiere: 'Spectral Music Seminars' – ARTE, Nicosia, Cyprus. Jan. 15th 2012.

[Track 4: *Metabolos*]
-Premiere: 'TANA String Quartet concert' – Melina Merkouri Theatre, Cyprus. May 29th 2013. (TANA String Quartet)

[Track 5: *Transient*]
-Premiere: 'Center of Cypriot Composers Concert' – PA.SY.DY, Cyprus. May 23rd 2012. (Piano: Ermis Theodorakis)

[Track 5: *The God Particle*]
-Premiere: '1st Festival of Contemporary Music' – PA.SY.DY, Cyprus. Sept. 23rd 2012. (Moscow Contemporary Music Ensemble)

[Track 7: *Cicada*]
- Partial MIDI realization. Premiere TBA.

2. Data CD

- Software folder (subfolder: OmTristan3 library)
- Bushology (subfolders: Bush Samples, Video)
- Cicada
- Drops and Pipes
- Hz Discrimination
- Metabolos
- The God Particle (subfolders: OpenMusic Patch, Samples)
- Transient (subfolders: Soundplant keymap, Transient Open Music Patches, Transient piano samples, Transient score).

3. Scores

1. *Drops and Pipes* [for flute and live electronics]
2. *Bushology* [for alto sax and tape]
3. *Hz Discrimination* [acousmatic composition]
4. *Metabolos* [for String Quartet]
5. *Transient* [for Piano and electronic]
6. *The God Particle* [for Fl., Cl., Perc., Pno., Vln., Vc.]
7. *Cicada* [for Fl., Cl., Bsn., Perc., Pno., Vln., Vc., Cb.]

Bibliography

Adorno, T.W (1997) *Aesthetic Theory,* trans. Robert Hullot-Kentor. London: Athlone Press.

Anderson, J. (2000) 'A Provisional History of Spectral Music'. *Contemporary Music Review*, 19, Part 2, p. 7-22.

Arsenault, L. M. (2002) 'Iannis Xenakis's "Achorripsis": The Matrix Game. *Computer Music Journal*, 26, no.1, p.58.72.

Atwater, F.H. (1997) 'Accessing Anomalous States of Consciousness with a Binaural Beat Technology'. *Journal of Scientific Exploration*, 11, no.3, p.263-274.

Bandur, M. (2001) *Aesthetics of total serialism: contemporary research from music to architecture*. Basel; Boston; Berlin: Birkhauser.

Békésy, G. von (1960) *Experiments in Hearing*. New York: McGraw-Hill.

Berger, K. W. (1963) 'Some Factors in the Recognition of Timbre'. *Journal of the Acoustical Society of America,* no.36, p.1888.

BileEnsemble (2012) *Manifesto*.
Internet WWW Page at URL: http://bilensemble.wordpress.com/manifesto/
(Accessed 18/10/12)

Bregman, A. S. (1994) *Auditory Scene Analysis: The Perceptual Organization of Sound*. London: MIT Press.

Childs, E. (2002) 'Achorripsis: A sonification of probability distributions'. *Proceedings of the 2002 International Conference on Auditory Display*. Kyoto, Japan, July 2-5.

Cendo, R. (2012) Program notes for FORIS. Cited in Deforce, A. (2012). Internet WWW Page at URL: http://www.arnedeforce.be/agenda.htm (Accessed 17/11/12)

Colley, J. , Marshall, D. & O'Brien (2012) 'Periodical Cicada Page'. University of Michigan Museum of Zoology. Internet WWW Page at URL:
http://insects.ummz.lsa.umich.edu/fauna/michigan_cicadas/Periodical/
(Accessed 20/11/12)

Cornicello, A. (2000) 'Timbral Organization in Tristan Murail's Desintegrations'. Ph. D. Brandeis University.
Internet WWW Page at URL: http://www.anthonycornicello.com/DissIndex.htm
(Accessed 20/07/08)

Cowell, H. (1996 [1930]). *New Musical Resources*. Annotated, with an accompanying essay, by David Nicholls. Cambridge, New York, and Melbourne: Cambridge University Press.

Daubresse, E. , Assayag, G. , Fineberg, J. (2000) 'Technology and creation – The creative evolution'. *Contemporary Music Review,* 19 , no.2, 61-80.

Davino, N. (2010) 'Gerard Grisey: Time and Process' Proceedings of the International Conference: *Beyond the Centers: Musical Avant-Gardes since 1950.*
Internet WWW Page at URL: http://btc.web.auth.gr/_assets/_papers/DAVICO.pdf
(Accessed 14/06/10)

Deliège, C. (2010) ' A period of Confrontation: The Post-Webern Years'. In Paddison M. & Deliège C. , eds. *Contemporary Music: Theoretical and Philosophical Perspectives.* Burlington: Ashgate.

Drott, E. (2005) 'Timbre and the cultural Politics of French Spectralism'. *Proceedings of the Conference on Interdisciplinary Musicology (CIM05).* Montreal, Canada, 10-12/03/2005.

Duckworth, W. (1999) *Talking Music: Conversations with John Cage, Philip Glass, Laurie Anderson, and* Five Generations of American Experimental Composers. New York: Da Capo Press.

Ellis, W. (1938) *A source book of Gestalt psychology***.** London: Routledge & Kegan Paul. p.71-88.

Emmerson, S. (2007) *Living Electronic Music*. Aldershot: Ashgate.

Ernst, D. (1977) *The Evolution of Electronic Music*. New York: Schirmer Books.

Fineberg, J. (2000) 'Guide to the Basic Concepts and Techniques of Spectral Music'. *Contemporary Music Review*, 19, Part 2, p.81-113.

Garnett, E. (2001) 'The Aesthetics of Interactive Computer Music'. *Computer Music Journal,* no. 25:1, p.21-33.

Gann, K. (1998) *Just Intonation Explained*. Internet WWW Page at URL: http://www.kylegann.com/tuning.html#tune4 (Accessed 08/09/10)

Gilmore, B. (2003) 'Wild Ocean: An Interview with Horatiu Radulescu'. *Contemporary Music Review*, 22, no. 1/2, p.105-122.

Gilmore, B. (2009) 'On Claude Vivier's Lonely Child '. In Hirs, R. & Gilmore, B., eds. *Contemporary Compositional Techniques and Openmusic*. Paris: IRCAM/Editions Delatour

Goldstein, J. L. (1973) 'An optimum processor theory for the central formation of the pitch of complex tones'. *Journal of the Acoustical Society of America,* no.54, p.1496-1516.

Grimo, S. (1991) ' A Conductor's Guide to the Performance of Edgar Varese's Wind and Percussion Music'. Ph.D. Catholic University of America.
Internet WWW Page at URL: http://www.stevengrimo.com/varese/table_of_contents.html
(Accessed 2/09/12)

Grisey, G. (1985) *Talea*. Editions Ricordi: Paris.

Grisey, G. (1987) 'Tempus ex Machina: A composer's reflections on musical time'. *Contemporary Music Review*, 2, no.1, p. 239-275.

Grisey, G. (1996) 'Interview with David Bundler'. *20th-Century Music*, March 1996. Internet WWW Page at URL: http://www.angelfire.com/music2/davidbundler/grisey.html (Accessed 15/09/10)

Grisey, G. & Fineberg, J. (2000) 'Did you say Spectral?'. *Contemporary Music Review*, 19, Part 3, p. 1-3.

Hall, M. P. (2007) *The Secret Teaching of All Ages*. USA: Penguin Group.

Hamilton, A. (2003) 'The primer: spectral composition'. *The Wire,* Issue 23, November.Internet WWW Page at URL: http://www.andyhamilton.org.uk/andy_pdfs/Spectral_Composition.pdf (Accessed 14/07/10)

Hamilton, A. (2007) *Aesthetic and Music*. London: Continuum.

Harvey, J. (1999) *In quest of spirit: thoughts on music*. California: University of California Press.

Harvey, J. (2001) 'Spectralism'. *Contemporary Music Review*, 19, Part 3, p. 11-14.

Hasegawa, R. (2006) 'Tone representation and just intervals in contemporary music'. *Contemporary Music Review*, 25, no.3, p.263-281.

Helmholtz, H. von (1877) *On the Sensation of Tone as a Psychological Basis for the Study of Music*, 4th ed. Trans., A.J. Ellis. New York: Dover, 1954.

Hervé, J.-L. (2009) 'Quatre chants pour franchir le seuil'. In Hirs, R. & Gilmore, B., eds. *Contemporary Compositional Techniques and Openmusic*. Paris: IRCAM/Editions Delatour.

Hiew, C. C. (1995) 'Hemi-Sync into creativity'. *Hemi-Sync Journal, 13, 1, 3.*

Hindemith, P. (1942) *The Craft of Musical Composition*. Volume 1 (1937; trans. Arthur Mendel, 1942).

Hirs, R. (2009) 'Frequency-based compositional techniques in the music of Tristan Murail'. In Hirs, R. & B. Gilmore, eds. *Contemporary Compositional Techniques and Openmusic*. Paris: IRCAM/Editions Delatour.

Hirs, R. (2009b) 'Interview with Tristan Murail, April 10, 2007'. In Hirs, R. & Gilmore, B., eds. *Contemporary Compositional Techniques and Openmusic*. Paris: IRCAM/Editions Delatour.

Hodgkinson, T. (1997) *Iancu Dumitrescu*. Internet WWW Page at URL: http://furious.com/perfect/iancu.html#notes (Accessed 15/06/ 13)

Hurel, P. (2007) *Spectral music: long-term perspectives*. Internet WWW Page at URL: http://www.philippe-hurel.fr/en/musique_spectrale.html (Accessed 16/7/ 09)

Jones, A. (2000) Bohemian Grove. Internet WWW Page at URL: http://www.infowars.com/bg_story_template.html (Accessed 13/6/ 08)

Koumenteris, A. (2007) 'Presendation of the second generation composers of spectral music and the composition of pieces with references to spectral music'. Ph.D. Ionian University. Internet WWW Page at URL:
http://thesis.ekt.gr/thesisBookReader/id/15683#page/1/mode/2up
(Accessed 17/03/ 12)

Klingbeil, M. (2009) 'Spectral Analysis, Editing, and Resynthesis: Methods and Applications'.Ph.D. Columbia University. Internet WWW Page at URL:
http://www.klingbeil.com/data/Klingbeil_Dissertation_web.pdf
(Accessed 12/05/ 11)

Lelong, G. (1994) *Les cahiers de l'Ircam: Compositeurs d'aujourd'hui: Philippe Hurel*. no.5, Paris: IRCAM.

Lippe, C. (1996) 'A look at Performer/Machine Interaction Using Real-Time Systems'. *Proceedings of the International Computer Music Conference,* p. 116-117. San Francisco: Computer Music Association.

Ledoux, C. (2000) 'From the Philosophical to the Practical: An Imaginary Proposition Concerning the Music of Tristan Murail'. *Contemporary Music Review*, 19, Part 3, p.41-65.

Levinas, M. (2006) *La Chanson du souffle, une Èpiphanie du visage*. Internet WWW Page at URL: http://www.michaellevinas.com/entretien.html (Accessed 19/08/ 12)

Ligeti, G. (1983). *Gyorgy Ligeti in conversation with Peter Varnai, Josef Hausler, Claude Samuel, and himself*. London : Eulenburg

Maconie, R. (1989) *Stockhausen on Music: Lectures and Interviews*. London and NewYork: Marion Boyars.

Mannel, R. (2008) *Theories of Hearing*. Internet WWW Page at URL:
http://clas.mq.edu.au/perception/psychoacoustics/hearing_theory.html
(Accessed 21/07/ 12)

Manoury, P. (1992) *Jupiter*. Paris: Editions Durand.

Mathews, M. (1999) 'The Auditory Brain'. In Cook, P., ed. *Music, Cognition, and Computerized Sound: An Introduction to Psychoacoustics*. Cambridge: The MIT Press. p.11-20.

McAdams, S. (1982) 'Spectral Fusion and the creation of Auditory Images'. In *Music, Mind and Brain* (Clynes, M., ed.). New York: Plenum Press. p.279-298.

Messiaen, O. (1956) *The Technique of my Musical Language.* Translated by J. Satterfield. Paris: Alphonse Leduc.

Messiaen, O. (1986) *Musique et Couleur, Nouvelles Entretiens Avec Claude Samuel.* Paris: Belfond.

McNabb, M. (1986) 'Computer Music: Some Aesthetic Consideration', in Emmerson, S., ed. *The Language of Electronic Music*. London: McMillan Press.

Morgan, R. (1991) *Twentieth-Century Music: A History of Musical Style in Modern Europe and America.* London and New York: W. W. Norton & Company, Inc.

Moscovitch, V. (1997) 'French Spectral Music: An Introduction'. *Tempo, New Series*, no. 200, p. 21-27.

Murail, T. (1976) *Mémoire/Erosion*. Paris: Editions Musicales Transatlantiques.

Murail, T. (1984) 'Spectra and pixies'. *Contemporary Music Review*, 1,1, p.157-170.

Murail, T. (1996) Livret du disque *Tristan Murail*, Compositeurs d'aujourd'hui. Paris: Ensemble Intercontemporain/IRCAM

Murail, T. (2004) *Désintégrations*. Paris: Editions Henry Lemoine.

Murail, T. (2005a) 'After-thoughts'. *Contemporary Music Review*, 24, no.2, p. 269-272.

Murail, T. (2005b) 'Scelsi, De-composer', trans. Robert Hasegawa.
Contemporary Music Review, 24, no. 2/3, p. 173-180.

Murail, T. (2005c) 'The revolution of Complex Sounds'. Contemporary Music Review, 24, no.2, 121-135.

Murail, T. (2005d) 'Villeneuve-lès-Avignon Conferences, Centre Acanthes, 9-11 and 13 July 1992'. *Contemporary Music Review*, 24, no. 2-3, p.187-267.

Nonken, M. (2008) 'La notation ne peut render compte du fait': performing Murail's 'Territoires de l'Oubli'. *Tempo* 62 (244) 2-10 : Cambridge University Press.

Northwestern University (1999) 'Block Museum of Art, Cornelius Cardew: An animated Analysis'. Internet WWW Page at URL:
http://www.blockmuseum.northwestern.edu/picturesofmusic/pages/anim.html
(Accessed 21/07/10)

Nyman, M. (1999) *Experimental Music: Cage and Beyond* **.**2nd Ed. Cambridge: Cambridge University Press.

O'Callaghan, J. & Eigenfeldt, A. (2010) 'Gesture transformation through electronics in the music of Kaija Saariaho'. *Electroacoustic Music Studies Network Conference 2010*, Shanghai. Internet WWW Page at URL:
http://www.emsnetwork.org/IMG/pdf_EMS10_OCallaghan_Eigenfeldt.pdf
(Accessed 20/08/ 11)

Paddison, M. (2010) 'Postmodernism and the Survival of the Avant-garde'. In Paddison M. & Deliège C. , eds. *Contemporary Music: Theoretical and Philosophical Perspectives.* Burlington: Ashgate.

Phillips, P. M. (1994) 'A Relative Advantage: Sociology of the San Francisco Bohemian Club'. Ph.D. University of California. Internet WWW Page at URL: http://library.sonoma.edu/regional/faculty/phillips/bohemianindex.php (Accessed 10/04/ 09)

Plomp, R. (1967) 'Pitch of complex tones'.*Journal of the Acoustical Society of America*, no.41, p.1526-1533.

Polfreman, R., Sheppard, D. and Dearden, I. (2005) 'Time to re-wire? Problems and strategies for the maintenance of live electronics'. *Organised Sound*, 11, no.3, p.229-242.

Porta, E. (1985) *The Violin: Harmonics - Classificaion and New Techniques*. Milano: Ricordi.

Pousset, D., Fineberg, J., Hyacinthe, R. (2000) 'The works of Kaija Saariaho, Philippe Hurel and Marc-Andre Dalbavie-Stile concertato, stile concitato, stile rappresentativo'. *Contemporary Music Review*, 19, no.3, p.67-110.

Pressnitzer, D., McAdams, S. (2000) 'Acoustics, psychoacoustics and spectral music'. *Contemporary Music Review,* 19, no.2, p.33-59.

Pugin, T. (2001) 'Through the Spectrum: The New Intimacy in French Music (II)'. *Tempo*, New Series, no.217 , p.38-44+47.

Radulescu, H. (1984) *Das Andere*. France: Lucero Print.

Radulescu, H. (2003) 'The World of Self-Generative Functions as a Basis of the Spectral Language of Music'. *Ann. N.Y. Acad. Sci. 999*, p.322-363.

Reigle, R. (2008) 'Spectral Musics Old and New'. *Spectral World Musics: Proceedings of the Istanbul Spectral Music Conference*, ed. Reigle, R. and Whitehead, P. Istanbul: Pan Yayincilik.

Risset, J. (1999) 'Composing in Real-time?'.*Contemporary Music Review*, 18, Part 3 , p.31-39.

Robin, Y. (2006) 'Writings: Creation'. Internet WWW Page at URL: http://www.yannrobin.com/spip.php?rubrique5&lang=fr

Roederer, J. (2008) *The Physics and Psychophysics of Music. An Introduction.*4th ed. New York: Springer.

Rossing, Thomas D. (1990) *The Science of Sound*. 2nd ed. Massachusetts: Addison-Wesley.

Sandred, O. (1994) Temporal Structures and Time Perception in the music of Gerard Grisey. Internet WWW Page at URL: http://www.sandred.com/texts/Temporal_Structures.pdf (Accessed 23/9/ 10)

Schmidt, H. (1990) *Men and Powers: A political Retrospective.* Michigan: Random House.

Schouten, J. F., (1940) 'The residue and the mechanism of hearing'. *Proceedings of the Koninklijke Akademie vam Wetenschap*, no.43, p. 991-999.

Schwarz, D., Cont, A., Schnell, N. (2005) 'From Boulez to ballads: training Ircam's score follower'. *Proceedings of the International Computer Music Conference (ICMC)*. Barcelona, Spain p.1-4.

Seidman, S. (1994) *The Postmodern Turn: New Perspectives in Social Theory.* Ed. Cambridge: Cambridge University Press.

Sethares, W. A. (2005) *Tuning, Timbre, Spectrum, Scale*. 2nd Ed. London: Springer-Verlag.

Smalley, D. (1996) 'The listening imagination: Listening in the electroacoustic era'. *Contemporary Music Review*, 13, no.2, p.77-107.

Smalley, D. (1997) 'Spectromorphology: Explaining sound-shapes'. *Organised Sound:* 2, no. 2, p.107-126.

Stockhausen, K. (1958) 'Structure and Experiential Time'. *Die Reihe, 2,* p. 64-74.

Stravinsky, I. (1971) 'Stravinsky: The Last Interview'. *The New York Review of Books* 16 (12). Internet WWW Page at URL:
http://www.nybooks.com/articles/archives/1971/jul/01/stravinsky-the-last-interview/
(Accessed 14/06/ 13)

Strawn, J. (1978) 'The Integrales of Edgard Varese Space, Mass, Element, and Form'. *Perspectives of New Music,* 17, no. 1, p. 138-160

Terhardt, E. (1974) 'Pitch, consonance and harmony'. *Journal of the Acoustical Society of America*, no.55, p.1061-1069.

Thomas, G. (1995) 'Work not in Progress'. *The Musical Times,* Vol. 136, no.1827, p.225-229.

Toop, R. (2001) 'Radulescu, Horatiu'. *Grove Music Online.* Oxford Music Online: Oxford University Press. Internet WWW Page at URL:
http://www.oxfordmusiconline.com/subscriber/article/grove/music/44998
(Accessed 19/08/ 12)

Truax, B. (1986) 'Computer Music Language Design and the Composing Process', in Emmerson, S., ed. *The Language of Electronic Music*. London: McMillan Press.

Vançon, J. C. (2005) 'Yann Robin ou le plaisir de l'imaginaire sonore'. *Interview with Jean-Claire* Vançon. Internet WWW Page at URL:
http://www.yannrobin.com/spip.php?rubrique5&lang=fr (Accessed 09/11/ 12)

Van Maas, S. (2009) *The Reinvention of Religious Music: Olivier Messiaen's Breakthrough Toward the Beyond*. New York: Fordham University Press.

Van Noorden, L. (1975) *Temporal Coherence in the Perception of Tone Sequences.* Ph.D. Eindhoven University of Technology.

Varèse, E. (1956) *Integrales*. New York: Ricordi.

Varèse, E. (1966) 'The liberation of Sound'. *Perspectives of New Music*, Vol.5, no.1, p.11-19.

Warren, J. R. (2012) *Dad. Meet Messiaen: Musical encounters and Lévinasian ethics.* Internet WWW Page at URL:
http://jeffrwarren.wordpress.com/the-ethics-of-timbre-phenomenology-spectralism-and-two-levinas/dad-meet-messaien-musical-encounters-and-levinasian-ethics/
(Accessed 26/10/ 12)

Winckel, F. (1967) *Music, Sound and Sensation.* Translated from German by T.Binkley. New York: Dover.