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ROBERT HASEGAWA

Gérard Grisey and the 'Nature' of Harmony

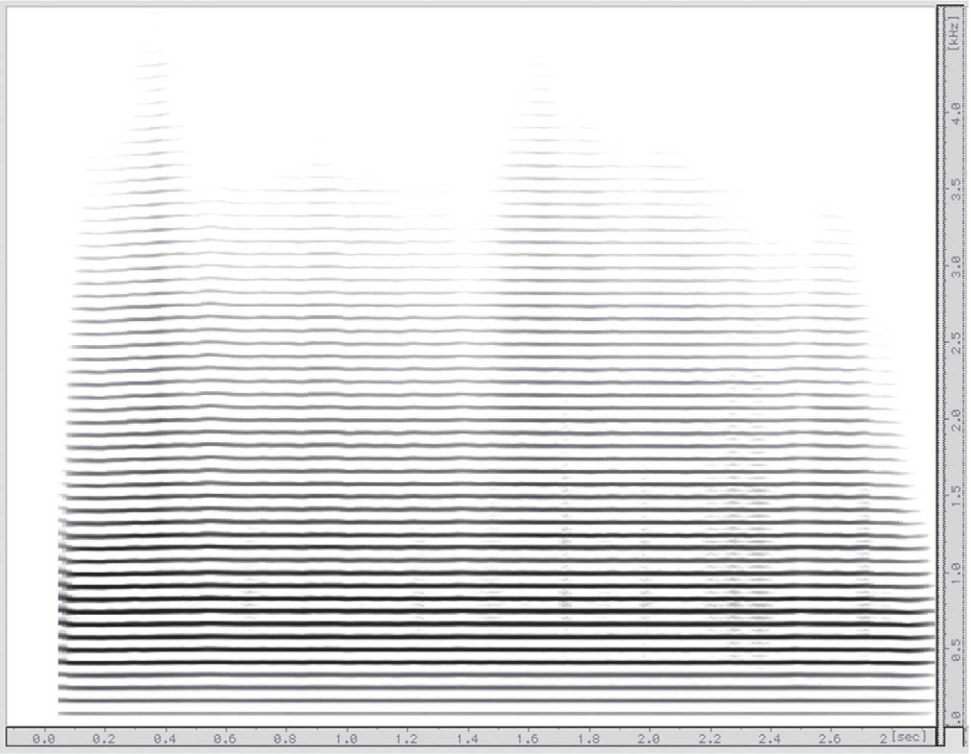
Gérard Grisey (1946–1998) was a founding member of the 'spectral' movement – a group of French composers born in the 1940s whose best-known members are Grisey, Tristan Murail, Michaël Levinas and Hugues Dufourt. Spectral music emerged in the 1970s, in part as a reaction against the abstraction of serial music. Instead of basing their music on the manipulation of rows or motives, spectral composers take inspiration from the physical properties of sound itself. Each of these composers defines 'spectral music' differently (some even rejecting the label altogether), but as a generalisation we could say that the essential characteristic of spectralism is the dissection of sounds into collections of partials or overtones as a major compositional and conceptual device. Spectral composers use the acoustical fingerprints of sounds – their spectra – as basic musical material.

In their writings, spectral composers have often emphasised the natural origins of this material, even while acknowledging the artificiality of some of the procedures used to transform and develop spectral pitch sets. In this article I explore how Grisey's music invokes the idea of nature and what this idea might mean for listeners and analysts. For Grisey, the mimicry of features of natural sounds is an essential compositional technique; such procedures are amply documented in analytical studies based on sketch material.[1] While such studies can explain how nature is harnessed in Grisey's music, they tend to overlook the equally important role played by nature in a quite different sense: the way our innate mechanisms of aural perception make sense of musical sound. For the analyst of Grisey's music, these contrasting concepts of nature – one based on the objective, physical nature of external reality, the other on the subjective, internal nature of aural perception – lead to very different ways of thinking about musical structure. There is often a significant gap between the theoretical structures produced by spectral compositional procedures and the perception of these structures by the listener; due to this gap, an account of a work based solely on a reconstruction of compositional procedure often fails to reflect a listener's experience of the work. By developing an analytical method which reflects the natural biases of our aural perception, we can arrive at an analysis more sensitive to the actual experience of listening to Grisey's music.

Instrumental Synthesis and Inharmonicity

Among the most characteristic procedures of spectral composition is instrumental synthesis: this technique mimics the electronic music technique of additive

Ex. 1a Spectral analysis of a trombone sound



synthesis, but replaces pure sine tones with the complex sounds of real instruments. An iconic example is the opening of Grisey's *Partiels* for chamber orchestra (1975), based on a *fortissimo* trombone E2.[2] The trombone sound can be analysed into a set of partials of varying frequencies and amplitudes; this can be expressed either as a numerical table or graphically as a spectrogram (Ex. 1a). In a spectrogram of a sound, the sound's evolution in time is represented on the x axis from left to right, and frequency is shown on the y axis, with low frequencies at the bottom and high ones at the top. The intensity of vibrational energy at any frequency is indicated by shades of grey from light (weak) to dark (strong). Ex. 1b reproduces the opening page of the score. We first hear the trombone itself, accompanied by *sforzandi* in the double bass an octave below; as the trombone fades out, instruments from the ensemble enter gradually from low to high, playing pitches which match selected partials of the analysed trombone sound. For example, the third partial (played by the clarinet) is a perfect twelfth above the trombone's fundamental, with a frequency three times that of the fundamental; the cello's G♯ approximates the trombone's fifth partial, and so on. Grisey uses the strength of each partial in the trombone analysis to assign dynamics to the instruments participating in the synthesis, and also to shape the

Ex. 1b Instrumental synthesis at the opening of Grisey, *Partiels* (1975)

order of entries. In most brass sounds, the upper partials emerge slightly later than the lower ones, a phenomenon which Grisey imitates (on a greatly expanded time scale) with the staggered entries in his synthesised replica of the trombone. The goal of instrumental synthesis is not a precise reproduction of the trombone sound – which would in any case be impossible given the complex spectra of acoustic instruments – but rather a hybrid sonority permitting us to hear both the individual instruments and their fusion into a unified timbre.

The physical properties of sound are brought into focus by these techniques of analysis and re-synthesis; this is an appeal to nature in the objective sense of the term. For music theorists, Grisey's technique will have strong echoes of Rameau's *corps sonore*. The essential difference, however, is that Grisey is dealing with real sounds, not with an idealised source of overtones. Recall that Rameau's *corps sonore*, as formulated in the *Génération harmonique*, conveniently stopped vibrating after the sixth partial to avoid the 'out-of-tune' natural seventh.[3] In contrast, Grisey carries into his music the complexities of real sounds, including their often distorted and imperfect spectra.

Though we tend to think of the frequencies of a sound's partials as corresponding precisely to the harmonic series (x, $2x$, $3x$ ...), some of the most common musical sounds have *inharmonic* spectra. A piano string, for example, produces a stretched spectrum: that is, the first overtone is not exactly twice the frequency of the fundamental (a perfect octave), but slightly higher. (Only an idealised string with no mass or resistance would produce a pure harmonic spectrum.) The stretching continues into the higher partials. We might not realise it (although our piano tuners do), but by the fourth octave the partials of a low piano note are approximately a third of a whole tone (65 cents) higher than their equivalents in a pure harmonic series. Other spectra, such as those of certain brass instruments, are compressed: each partial is lower than its harmonic counterpart.

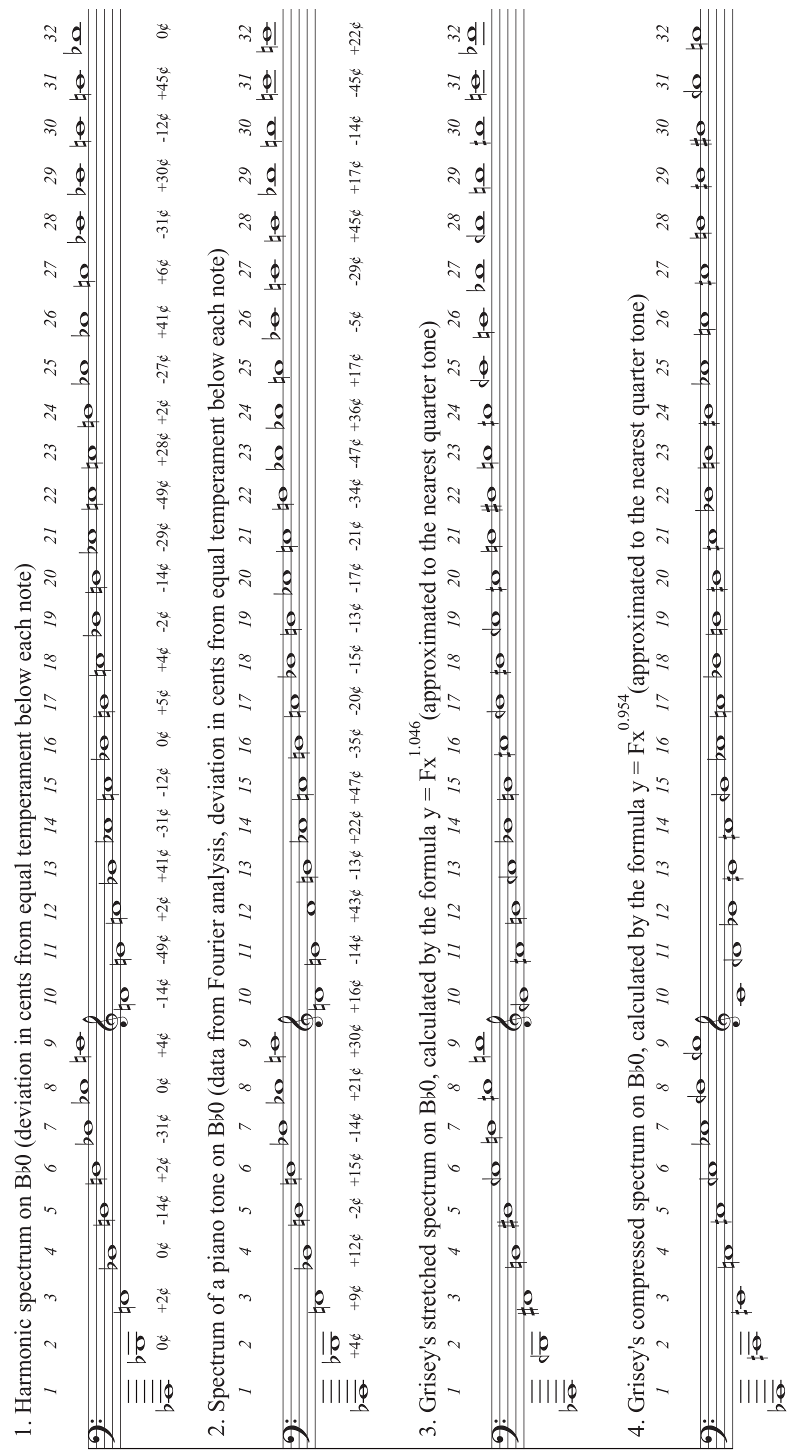
Inharmonic Spectra in *Vortex Temporum*

Grisey exploits these real-world departures from ideal harmonicity in the design of his 1996 chamber ensemble piece *Vortex Temporum*, for flute, clarinet, string trio and retuned piano (four pitches are lowered by a quarter tone). His compositional procedures are extensively documented in sketch-study monographs by Jean-Luc Hervé and Jérôme Baillet, and sketches in the Paul Sacher Foundation confirm their findings. The section which follows retraces some of Grisey's techniques to illustrate how he brings inharmonic spectra into his music; after exploring these compositional derivations, we shall examine how the harmonies might actually be perceived.

Throughout *Vortex Temporum*, Grisey uses only three types of spectra – harmonic, stretched and compressed – which are transposed to start on different fundamentals. The first stave of Ex. 2 shows the pitches of a harmonic spectrum on B♭0; each partial is represented by the nearest equal-temperament pitch, with the deviation in cents (rounded to the nearest cent) indicated below the note. For example, the seventh partial of the spectrum is A♭3, flattened by approximately 31 cents. The spectrum of a piano tone on the same fundamental, computed by Fourier analysis, is shown on the second stave of Ex. 2. In the case of low partials, the stretching of the spectrum is barely perceptible; the second partial is just 4 cents higher than its equivalent in the harmonic spectrum. The higher the partial, the more pronounced and obvious the stretching becomes, to the point that the twelfth partial is 41 cents (almost a quarter tone) above its harmonic equivalent.

Grisey is not content with the relatively slight stretching of the natural piano spectrum. He constructs a more exaggeratedly stretched version for use in *Vortex Temporum* (see the third stave of Ex. 2, which shows Grisey's stretched spectrum in his preferred quarter-tone approximation). Although the natural twelfth partial of the piano tone is 41 cents sharp relative to its harmonic partial, in Grisey's stretched spectrum it is 198 cents sharp – almost an equal-tempered whole tone above the equivalent harmonic partial. To calculate this exaggeratedly stretched spectrum, Grisey uses the equation $f_n = f_0(n^{1.046})$; that is, the frequency

Ex. 2 Comparison of a harmonic spectrum, the spectrum of a low piano pitch and Grisey's stretched and compressed spectra from *Vortex Temporum*



of partial number n equals the fundamental frequency f_0 multiplied by the partial number raised to the power of the constant 1.046.[4] This constant produces stretching of approximately a quarter tone per octave. Grisey constructs a compressed spectrum with the equation $f_n = f_0(n^{0.954})$, which produces comparable distortions in the opposite direction: the spectrum is compressed by a quarter tone per octave (see the fourth stave of Ex. 2). Throughout *Vortex Temporum*, the degrees of distortion of the stretched and compressed spectra are fixed. The spectra typically are heard only in 'filtered' form: only selected partials are played, and the rest (often including the fundamental itself) are omitted.

Grisey's distorted spectra are based on the stretching and compression found in some natural sounds but exaggerate these features to an unnatural degree. Why does Grisey exaggerate the stretching so drastically? In part, it may be to make the spectrum's inharmonicity apparent even when the partials are rounded off in a quarter-tone grid: with a smaller degree of stretching, the approximation to quarter tones could erase the difference between stretched and harmonic spectra. Also, the exaggerated distortion produces a sonic result reminiscent of the broken octaves characteristic of much atonal and serial music. (Despite spectralists' professed antipathy to serialism, the characteristic sound of serial music continued to exert a strong influence on spectral composers.) Most important, however, we must consider Grisey's self-described interest in borderline cases and thresholds – in this case, the perceptual threshold, where, as the degree of stretching increases, a spectrum is no longer heard as a fused timbre but instead breaks up into a collection of independent pitches.[5]

This is one way in which nature enters Grisey's music: as the reproduction through instrumental synthesis of the acoustical spectra of real-world sounds, with their characteristic distortions maintained or even exaggerated. Straightforward as this evocation of nature might seem in an early work such as *Partiels*, when we listen to later works such as *Vortex Temporum* it is often impossible to hear Grisey's harmonies as versions of the natural spectra from which they were derived. After the harmonies have been subjected to extensive compositional manipulation – exaggerated stretching or compression, approximation to a quarter-tone grid and omission of many partials – their natural acoustical source is no longer recognisable. What, then, does talking about Grisey's compositional techniques really tell us about how we hear his music? When the 'natural' derivation of his material collapses and we hear the distorted spectra as complex chords rather than fused timbres, the appeal to nature in the objective, external sense fails, and the working of our internal nature – the nature of our auditory perception – becomes more relevant to our musical understanding.[6]

Towards a Theory of Tone Representation

Although Grisey's compositional techniques often strain the audible connection between real-world physical models and their scored adaptations, the basic tenets of spectral harmony do reflect some of the intuitive ways in which listeners make sense of pitch combinations. Modern psychological research confirms the important role that harmonic spectra (with partial frequencies in the series x, $2x$, $3x$ …) play in our parsing and organisation of aural information. Psychoacousticians suggest that we have developed a mental template of the relationships between partials of a complex harmonic tone from our frequent encounters with such sounds, and that this template is used to make sense of incoming auditory data. Such templates are crucial in auditory scene analysis, which is the mental separation of jumbled aural input into sounds from distinct sources. For instance, when we hear two violins playing different notes at the same time, we separate the two sound sources from one another by subconsciously matching their partials to different templates. When we find a template which matches the partials which we hear, we perceive the fundamental pitch of the sound. As the acoustician William Hartmann explains, 'Modern theories of pitch perception- … are foremost pattern matching theories. They assume that the brain has stored a template for the spectrum of a harmonic tone, and that it attempts to fit the template to the neurally resolved harmonics of a tone'.[7]

One of the essential concepts of spectralism is the transfer of theories about the auditory organisation of heard partials to musical contexts, where the basic building block is not a simple, pure-wave partial, but rather an instrumental tone (with its own complex spectrum consisting of many partials). Many music theories can be understood in terms of this analogy: for example, Rameau's acoustical justification of the major triad is based on its match with partials 1–6 of an idealised vibrating body, the *corps sonore*. The Pythagorean tradition of defining musical intervals by ratios (between either vibrational frequencies or string lengths) can also be seen as an example of the analogy between overtones and complex pitches: the whole-number ratios which define just intervals are also found between the individual partials of a harmonic tone. The tendency of the ear to group partials which can be understood as overtones of the same fundamental suggests that we have a built-in bias towards such just intervals: the composer and theorist James Tenney has called the overtone series and the just intervals it contains the only perceptual givens in our understanding of pitch relationships.[8] Just intervals are the historical basis of Western music theory: octaves, fifths, fourths, thirds and sixths are all based on simple just intervals whose frequency ratios can be expressed as two, three, five and multiples thereof. A number of theorists have argued that the just intervals are referential sonorities, in the sense that we understand them as the ideal versions of intervals, even when the intervals we actually hear are out of tune. As Tenney puts it:

> I propose as a general hypothesis in this regard that the auditory system would tend to interpret any given interval as thus 'representing' – or being a variant of – *the simplest interval within the tolerance range* around the interval actually heard (where 'simplest interval' means the interval defined by a frequency ratio requiring the smallest integers). The simpler *just* ratios thus become 'referential' for the auditory system … .

> Another hypothesis might be added here, which seems to follow from the first one, and may help to clarify it; within the tolerance range, a mistuned interval will still carry *the same harmonic sense* as the accurately-tuned interval does, although its timbral quality will be different – less 'clear', or 'transparent', for example, or more 'harsh', 'tense', or 'unstable', etc. (Tenney 2001, p. 110; emphasis in original)

Our tolerance for mistuned just intervals is evident in the historical development of temperaments: the essential harmonic meaning of the just interval remains, even when it is heard only in an approximate, tempered version.

If, following the spectralists, we apply our knowledge of the perception of partials to the analysis of chords made up of many complex tones, we can make some musical observations which are impossible in theories not based in psychoacoustics. When we match a heard interval to a referential just interval, we produce two essential pieces of data: the ratio relating the two pitches and an implied root or fundamental. Given the pitches E4 and G4, for example, we identify both a just interval between the two (5:6) and the implied fundamental, C2. The number assigned to a pitch imparts a harmonic meaning – in this example, the '5' means that we hear the E as the fifth partial of C, not as an independent fundamental. The process of matching a given collection of pitches to a just-intonation interpretation is similar to Hugo Riemann's concept of *Tonvorstellung*, or tone representation. Riemann proposes that the harmonic meaning of a pitch is determined by how we 'imagine' it as one of the factors of a major or minor triad: 'According to whether a note is imagined as 1, 3, or 5 of a major chord or as I, III, or V of a minor chord, it is something essentially different and has an entirely different expressive value, character and content' (Riemann 1992, p. 86).

Riemann's triadic model of tone representation allowed only the ratios of Renaissance just intonation, based on two, three and five – but we can expand the theory of tone representation to allow more complex interval ratios with higher prime factors. This brings us into the harmonic world of 'extended just intonation', developed by the American experimental composers Harry Partch, Lou Harrison and Ben Johnston. Extended just intonation includes many microtonal intervals which fall 'between the keys' of twelve-note equal temperament, such as the flat minor seventh (4:7, or 969 cents) or the undecimal tritone (8:11, or 551 cents). If we accept that approximations of these extended just intervals still convey the same harmonic meaning as the true ratios, many 'atonal' sonorities of music of the twentieth century can be understood as equal-temperament approximations of pitch collections in extended just intonation.[9]

In translating a collection of heard pitches to a referential just-intonation set, we are guided by what Riemann calls the '*Principle of the Greatest Possible Economy for the Musical Imagination*' (Riemann 1992, p. 88). We choose the simplest just-intonation pitch set which matches the heard pitches while minimising the level of mistuning between the heard pitches and their just-intonation counterparts. The tone representation of a given pitch set can be expressed in a simple notation: to describe the pitches D, E and G as the ninth, tenth and twelfth partials of a C fundamental, we can write C(9:10:12). Depending on the context, we may wish to provide a specific register for the root (for example, C1) or indicate a microtonal deviation from equal temperament (which can be expressed in cents from the nearest tempered pitch, for example $C_{+20¢}$). Because many factors combine to determine the simplest tone representation, it is difficult (and not necessarily desirable) to completely formalise the theory; what I propose instead is a simple model based on preference rules, which gives intuitively satisfying results.[10] The flexibility of this model is not a weakness, but rather one of its greatest strengths, for the way we understand pitches and their relations needs to be context sensitive to allow for the interaction of other musical parameters with our harmonic perception. The preference rules outlined here suggest the most likely ways to interpret any given harmony while allowing the analyst to weigh the impact of contextual factors.

> **Preference Rule 1:** Prefer interpretations in which the referential just intervals correspond as closely as possible to the actual intonation of the music – that is, tone representations which require the least retuning from the heard intervals to the referential just intervals.

The first preference rule is based on the commonsense principle that our tone representation of a heard pitch set – the just-intonation proportion which lends each pitch a harmonic meaning in relation to a root – should match the heard set as closely as possible. Although it is simple to determine the closest just-interval representation for a dyad by referring to a chart of just-interval sizes, larger groups of pitches can be more difficult to match to a just-intonation interpretation. With the mathematical tools outlined by Clifton Callender,[11] it is possible to quantify how much retuning is required to map a given pitch-class set onto a target just-intonation pitch-class set by calculating the Cartesian distance between the two sets. Using basic calculus, we can find the transposition of the just-intonation set which minimises this distance – that is, the transposition which results in the least total retuning. In this study, I've used a computer program to find the just-intonation sets which best match any given input set; the number of just-intonation sets is theoretically infinite, but I've limited my tone representations to sets which do not invoke integers above 33. (The complex intervals created by higher integers are difficult to comprehend in most musical contexts.) The application of this preference rule can provide a list of many possible tone representations of a heard set, each associated with a specific fundamental and a measurement of the amount of retuning between the set and its representation.

> **Preference Rule 2:** Use the simplest possible interpretation of a pitch collection: the tone representation with the simplest just intervals between its members. (Simple intervals have low integers in their frequency ratios when reduced to lowest terms.) The presence of the fundamental (or one of its octave transpositions) tends to considerably strengthen the plausibility of a tone representation.

After we have determined several just-intonation sets which closely fit the input set, we can choose among them by applying the second preference rule, selecting the simplest possible tone representation. There are several ways to quantify the relative simplicity of a given tone representation of a pitch collection. One is to choose the representation with lower partial numbers: given two tone representations of the set C5:D5:E5:F♯5 – as F0(24:27:30:34), or as D2(7:8:9:10) – we can easily recognise the greater simplicity of the second representation by its lower partial numbers. In comparing tone representations for the same set, this is equivalent to choosing the tone representation with a higher virtual pitch: D2 is higher than F0. (The use of virtual pitch as a guide to the relative consonance of a pitch set is common among spectral composers.[12]) As a general rule, this criterion is useful, but it ignores the question of factorability: in our comparison of sets, we should also seek the representation with the simplest just intervals between its members. This fits with our intuition that the tone representation with partial classes 8:10:12:17 should be simpler than 7:9:11:17 despite the higher virtual pitch of the second list.

Clarence Barlow has proposed a measure of 'harmonicity', determined not only by the absolute size of the numbers in an interval's ratio when reduced to simplest terms, but also the divisibility of those numbers – in other words, their prime limit.[13] For example, although the intervals 25:27 and 23:29 are quite similar in the size of their constituent integers, 25:27 is easier to comprehend because it can be broken down into simpler intervallic steps. Both 25 and 27 are products of simpler primes, 5 and 3, while 23 and 29 are prime and cannot be simplified. For sets larger than dyads, Barlow sums the harmonicities of all the intervals between set members.

Another metric for simplicity based on factorability is harmonic distance, as explicated by James Tenney. Tenney's theory is based on a theory of 'harmonic space', a multidimensional extension of the Riemannian *Tonnetz*, with each axis representing a different prime factor. The distance between any two points on the lattice is calculated by the sum of all the steps in between the points; however, steps along the low prime-number axes are considered shorter than those along the axes of the higher primes. The axes are weighted by their logarithms base 2: thus, a step on the 2 axis is a harmonic distance of 1, a step on the 3 axis is a harmonic distance of $\log_2 3$, or 1.58, and so on. Steps along each axis can be summed for composite intervals: thus the perfect fifth, 2:3, can be seen as a combination of one step on the 3 axis and one on the 2 axis, a distance of 2.58. Like Barlow, Tenney calculates the simplicity of larger pitch sets by summing the intervals between each member:

> [Y]ou could go through a piece and say, 'Alright, we've heard in the beginning of the piece two pitches. You take the simplest ratio representation of that interval – tempered. Now we hear the third pitch. What specific, rational intonation for that approximate pitch will give us the simplest configuration in harmonic space, the most compact configuration in harmonic space? Let's call it that'.[14]

Barlow's and Tenney's metrics have slightly different biases with respect to the means by which they weigh interval simplicity but tend nevertheless to give roughly similar results. In general, Barlow's method gives a greater weight to interval simplicity: the presence of an interval made up only of multiples of three and two contributes significantly (perhaps too significantly) to his overall harmonicity score. These simple ratios also contribute to shorter harmonic distances in Tenney's calculations of harmonic distance; but the curve drops less sharply in his case, meaning that the inclusion of higher primes has a less drastic effect on the overall simplicity. Tenney's metric is more liberal about including higher prime numbers. A choice between the two metrics might be determined by the repertoire being examined. By considering the factorability of interval, both Barlow's and Tenney's metrics yield more intuitive results than a measurement of simplicity by virtual pitch alone.

> **Preference Rule 3:** Use the smallest possible number of fundamentals; invoke multiple fundamentals only if they yield a significantly simpler interpretation than is possible with a single fundamental.

If no just-intonation set fits the input set reasonably well, we can turn to preference rule 3 and describe the input set as the combination of just-intonation sets on two or more fundamentals; this division of problematic pitch sets into simpler entities has precursors in Rameau's 'dual generator' derivation of the minor triad in the *Démonstration du principe de l'harmonie* and Hermann Erpf's idea of *Mehrklänge*.[15] This preference rule reflects how perceptual templates are used in auditory scene analysis to sort partials into smaller, overtone-based sets. As the psychoacoustician Albert Bregman notes, we seem to apply 'a scene-analysis mechanism that is trying to group the partials into families of harmonics that are each based on a common fundamental. If the right relations hold between an ensemble of partials, they will be grouped into a single higher-order organization' (Bregman 1990, p. 507).

A tone representation analysis must continually balance the conflicting demands of the three preference rules while also taking into account other contextual aspects of the musical surface. The flexibility of the preference rules allows musically sensitive readings which can be tested aurally. In choosing one tone representation over another, we are not dealing with abstractions; these choices have something concrete to say about our musical understanding of each pitch in the collection and its relationship to all of the others. When we perceive a diminished fifth as representing the ratio 8:11 instead of 5:7, it has different tonal implications and, as Riemann notes, an 'entirely different expressive value, character and content' (Riemann 1992, p. 86). A change in the understood root changes the meaning of each of the chord members: a pitch that is relatively stable in one reading can become exotic and harmonically distant in another. Even if we do not entirely agree on the precise tone representation for a given pitch set, the terminology introduced here offers a way of discussing what we hear – asserting one tone representation over another is a meaningful, and, above all, a *musical* activity. We can continually test our analyses by playing potential roots under a harmony or by experimentally adding pitches to see how they strengthen or weaken our hypotheses.

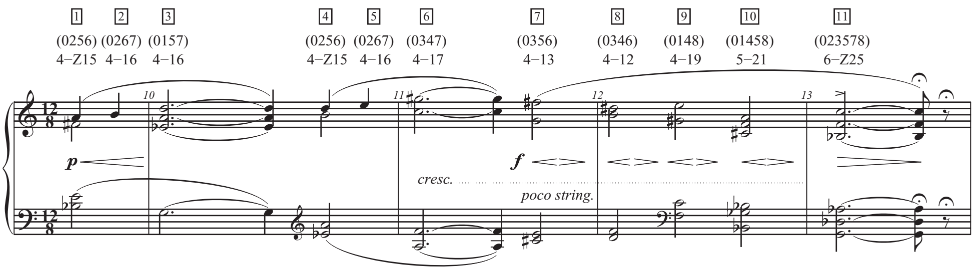
An Example of Tone Representation: Schoenberg, Op. 11 No. 2

Tone representation offers a useful alternative to other analytical methods currently used for works from the atonal repertoire. Unlike pitch-class set analysis, which focuses on motivic relationships between chords, tone representation allows us to closely examine the tensions *within* a single harmony in a way which is sensitive to vertical spacing and to the delicate balance of different tonal implications. This sensitivity is particularly valuable for the music of the twentieth century, in which striking individual sonorities are such an important feature. Rather than attempting to illustrate an organic coherence through the repetition of identical harmonic motives, we can discuss changing colour and degrees of harmonic 'rootedness'. We do not need to compare these chords to one another to get at their internal tensions and qualities, since we can refer to a consistent interpretative strategy based on the overtone series instead. This approach allows us to discuss post–common practice harmony from a phenomenological rather than an organicist standpoint. We can observe the application of tone representation in the analysis of a well-known and often-discussed passage by Schoenberg.

Ex. 3a reproduces the Chorale from Schoenberg's Piano Piece, Op. 11 No. 2. Because the tetrachords of the Chorale fall into different set classes, this passage poses a challenge to standard pitch-class set analysis. David Lewin has discussed this passage at length, using Klumpenhouwer networks to answer the question: '[I]s there some way in which we can sense the harmonic field of the phrase as unified, rather than diverse?' (Lewin 1994, p. 79). He sets out an agenda for analysis: to relate the tetrachords of different pc-set classes into a unified overall view which includes the five- and six-note sets that appear at the end of the phrase.[16]

Unlike pitch-class set analysis, which tends to emphasise motivic relationships *between* sonorities, tone representation makes it possible to discuss the competing root implications and inner harmonic tensions *within* a single chord.[17] Ex. 3b lists several plausible tone representations of each chord of the Chorale, with the most convincing representation appearing in boldface type. (Occasionally two representations seem equally convincing; in such cases, both are printed in boldface.) In this table, I have listed only the best matches – based on closeness of fit and simplicity of intervals – from the list of possibilities produced by computer calculation. A typical situation can be seen in my analysis of the first chord, B♭–E–F♯–A. The tone representation which entails the least retuning is $A_{-3¢}$(17:24:27:32); according to this representation, B♭ is heard as the seventeenth partial of a notional low A fundamental (lowered by 3 cents from equal temperament), E is heard as the 24th partial, and so on. While the intonational fit is very precise – with a distance of only 5.41 between the heard chord and its just-intonation tone representation – the intervallic relationships between the

Ex. 3a Schoenberg, Op. 11 No. 2, Chorale, set classes labelled



Ex. 3b Table of plausible tone representations for each chord in Ex. 4a (with the most convincing tone representations shown in boldface)

1	B♭ E F♯ A	*distance*
A −3¢	(17:24:27:32)	5.41
F♯ +12¢	**(10:14:16:19)**	**28.40**
C +38¢	(7:10:11:13)	40.21
D −8¢	(13:18:20:24)	45.92
E −21¢	(11:16:18:21)	49.94
B♭ +5¢	(8:11:13:15)	73.50
2	B♭ E F♯ B	
A −4¢	(17:24:27:36)	3.36
B +10¢	(15:21:24:32)	28.64
F♯ +19¢	**(10:14:16:21)**	**29.23**
C +26¢	(7:10:11:15)	34.57
D −9¢	(13:18:20:27)	45.38
E +11¢	(11:16:18:24)	50.74
B♭ +1¢	(8:11:13:17)	73.34
3	G E♭ A D	
C −2¢	(12:19:27:36)	7.15
G −12¢	**(8:13:18:24)**	**38.70**
E♭ +19¢	**(5:8:11:15)**	**41.99**
4	E♭ A B D	*distance*
D −3¢	(17:24:27:32)	5.41
B +12¢	**(10:14:16:19)**	**28.40**
F +38¢	(7:10:11:13)	40.21
G −8¢	(13:18:20:24)	45.92
A −21¢	(11:16:18:21)	49.94
E♭ +5¢	(8:11:13:15)	73.50
5	E♭ A B E	
D −4¢	(17:24:27:36)	3.36
E +10¢	(15:21:24:32)	28.64
B +19¢	**(10:14:16:21)**	**29.23**
F +26¢	(7:10:11:15)	34.57
G −9¢	(13:18:20:27)	45.38
A +11¢	(11:16:18:24)	50.74
E♭ +1¢	(8:11:13:17)	73.34
6	A F C G♯	
F +4¢	**(5:8:12:19)**	**13.99**
A −7¢	(8:13:19:30)	46.38
7	C♯ E G F♯	*distance*
E −2¢	(27:32:38:72)	7.54
D +13¢	(15:18:21:40)	27.10
F♯ +6¢	**(12:14:17:32)**	**33.72**
A +9¢	**(10:12:14:27)**	**33.75**
A +26¢	(5:6:7:13)	52.66
8	D F B D♯	
D −2¢	**(16:19:27:34)**	**7.98**
E♭ +9¢	(15:18:25:32)	28.11
G +18¢	**(12:14:20:25)**	**30.05**
B♭ +9¢	(10:12:17:21)	31.53
9	F C G♯ E	
F +3¢	**(8:12:19:30)**	**12.11**
C♯ +6¢	(10:15:24:38)	14.90
B♭ +19¢	(6:9:14:22)	51.54
10	B♭ G♭ B♭ C♯ F A	
G♭ +5¢	**(5:8:10:12:15:19)**	**16.16**
B♭ −6¢	(8:13:16:19:24:30)	40.50
11	G D♭ A♭ B♭ F C	
A +14¢	(7:10:15:17:25:38)	34.04
G +18¢	**(8:11:17:19:28:42)**	**53.21**
F −3¢	(9:13:19:21:32:48)	54.81
D♭ +22¢	(11:16:24:26:40:60)	63.14
E♭ −3¢	(5:7:11:12:18:27)	67.17

pitches are complex and obscure. For example, we're asked to hear the interval from B♭ to F♯ as the exotic interval 17:27, though we would intuitively prefer a simpler interpretation such as 5:8, a just minor sixth. We can find a simpler interpretation of the whole tetrachord by accepting a slightly greater mistuning between the heard set and its just-intonation representation. The tone representation $F\sharp_{+12¢}$(10:14:16:19) provides the most convincing compromise between intonational accuracy and simplicity of interval ratio, and the inclusion of the fourth octave of the fundamental (16) further strengthens its appeal.

An extended discussion of this excerpt is impractical here, but a few general observations will illustrate how the theory of tone representation might contribute to an analytical reading. When we look at the most likely roots for each chord in the passage, we see the frequent repetition of just a few pitch classes (allowing for some variability of tuning): F, F♯/G♭ and G. These three pitches account for nine of the eleven chords of the Chorale. G is the root of chord 3, at the end of the first gesture, as well as of chord 8 and the cadential chord 11, although the chords differ in cardinality and set class. An upwards progression by semitone from one 'fundamental bass' pitch class to the next recurs frequently – first as F♯ to G from chords 2 to 3, then as F to F♯ to G in chords 6, 7 and 8. This fundamental bass progression is repeated in chords 9–11 as F to G♭ to G, even though the pitch content of the chords is different. The fundamental bass progression cuts across the phrase structure in an interesting way, inviting the listener to group chords 6, 7 and 8 across the notated phrase boundary between chords 6 and 7. This is one way we could make sense of the crescendo beginning below chord 6: the increase in intensity accompanies the beginning of the ascent in the fundamental bass.

In a different hearing of the passage, we can hear the boundaries between the phrases as revoicings of the harmony over a repeated fundamental bass; thus, chords 3 and 4 can be heard as rooted on E♭, while chords 6 and 7 share a root of A. Note that this reading interprets the roots of these chords differently than the previous analysis – the divergent interpretations reflect two possible ways of hearing the structure of the passage, which is rich and complex enough to support a range of competing analyses.[18]

By invoking tone representation, we are no longer treating this music as atonal, but rather as exhibiting a kind of extended tonality. As we've seen, the ratio model of interval focuses our attention on very different aspects of pitch structure than those illuminated by the distance-based models of pitch-class set analysis. I do not deny the utility of this and other such atonal theories for this repertoire, but they are designed to describe different kinds of relationships to those I'm interested in exploring here. In a sense, no music is truly atonal; there is music for which atonal relationships are the basis of convincing analytical interpretations, but this does not rule out the possibility of other tonal or quasi-tonal readings. If we do not insist on forcing musical works into the framework of just one theory at a time, the two methods could be usefully combined – atonal theory's emphasis on motivic transformation could be complemented by tone representation's attention to vertical spacing, sonic colour and implied roots.

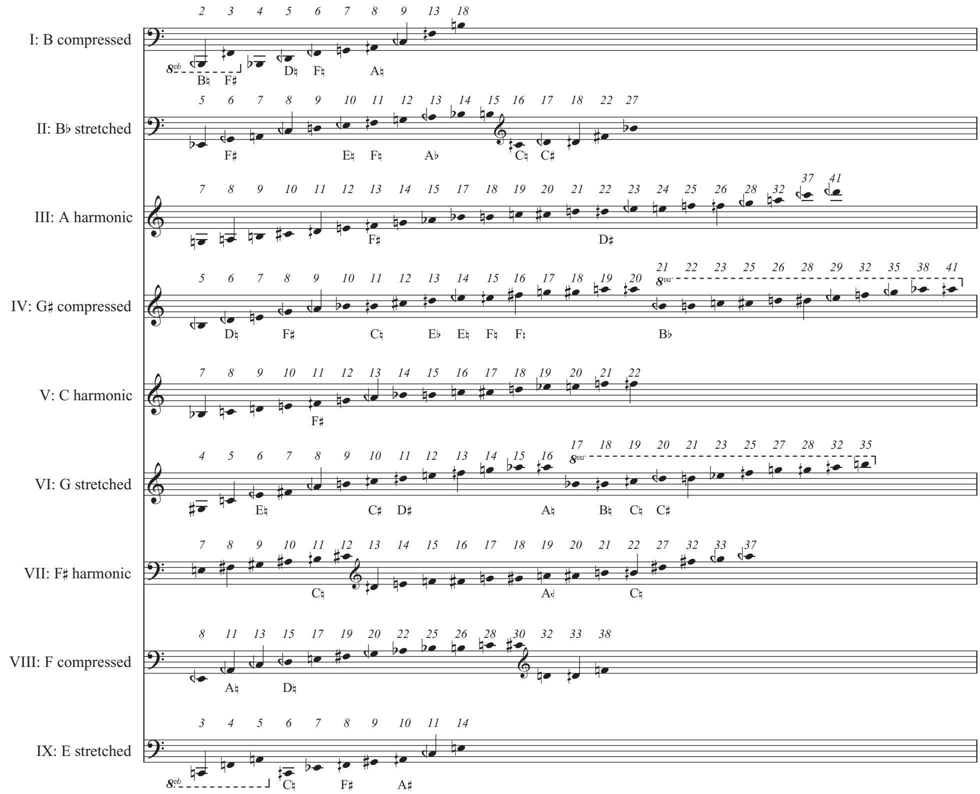
Tone Representation in *Vortex Temporum II*

As noted above, the techniques and plans which Grisey used to construct *Vortex Temporum* have been described in detail in studies based on the composer's sketches for the work. The description of a compositional process, however, is not necessarily a good description of a piece's aural and musical effect. Even though many spectral techniques take acoustic and psychoacoustic facts as their starting point, there is often no clear, unambiguous relationship between such compositional techniques and their audible musical results. Instead of analysing the music by reconstructing Grisey's derivation of the harmonies, we can use the theory of tone representation to approach the music from our own harmonic intuitions.[19] This is a turn from one sense of the natural to the other: from an external idea of the natural, based on how Grisey's harmonies draw on natural models, to an internal one, based on how we intuitively – that is, naturally – make sense of complex sonorities. We can describe Grisey's harmonies with reference not to their source, but rather to our own aural experiences. Examining the work through the lens of tone representation can offer new insights into its harmonic relationships as actually heard: tone representation can function as a 'listening grammar' for complex microtonal sonorities.[20]

We will concentrate here on the harmonic analysis of several excerpts from the second movement of *Vortex Temporum*. Ex. 4 is an outline of Grisey's deployment of spectra throughout the movement.[21] Each section is based on a selection of notes from a single spectrum, either harmonic, stretched or compressed; in the figure, the partial number of each pitch in its respective spectrum appears above each note. Over the nine sections of the movement, the pitch class of the nominal fundamental descends chromatically from B to E, with the exception of the central spectrum on C – although, owing to the changing spectrum types, this does not create a clearly audible sense of downward transposition. The texture remains consistent throughout the movement. The piano plays on every beat, gradually cycling downwards through the available pitches; stems indicate the pitches repeated by the piano on every beat. The descending pitches of the piano imitate the well-known aural illusion of the endlessly descending Shepard tone – the descent seems continuous because as the entire complex of partials drifts downwards, new high partials gradually fade in from silence and the lowest partials drop out.[22] Because the piano cannot play microtones (with the exception of its four retuned strings), it often rounds off partials to the nearest available semitone; these approximations are shown as letter names below the pitch that they replace.

Ex. 5a illustrates how the stretched spectrum on B♭ in Ex. 2 is presented in section II of the movement (rehearsal numbers 4–7). All the pitches of the spectrum are rounded off to the nearest quarter tone (or, for the piano, the nearest semitone). The pianist cycles continuously downwards through the boxed notes on the bottom stave, rearticulating the stemmed notes on every beat. The other instruments of the ensemble – flute, clarinet, violin, viola and cello – play sustained

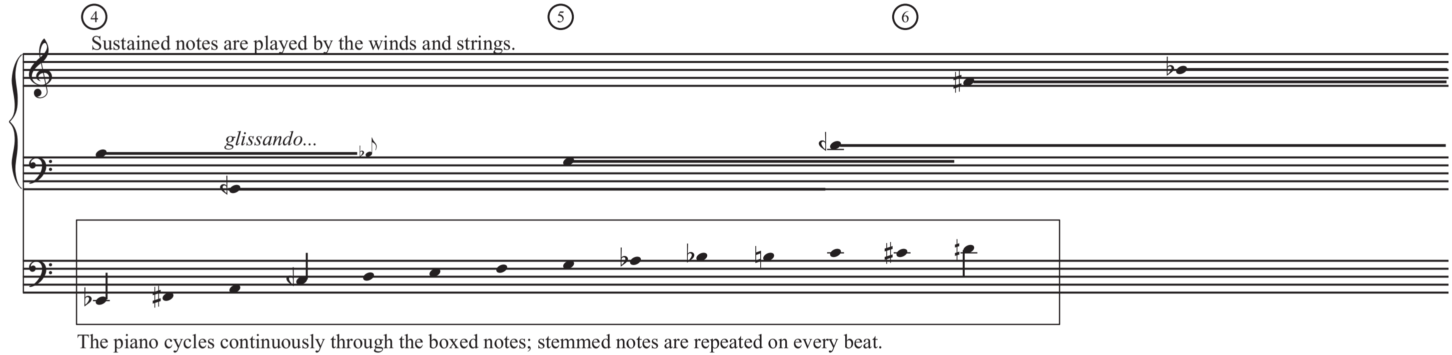
Ex. 4 Deployment of spectra in *Vortex Temporum*, ii



pitches, shown in the upper two staves of Ex. 5a with bars indicating their duration.

Since no one fundamental offers a convincing tone representation for all of the pitches in the excerpt, Ex. 5b identifies four plausible tone representations, each describing different subsets of the complete harmony. Our choice of one tone representation over another depends on the musical context and changes over the course of the passage. Often, not all pitches are equally important to our decision – we give more weight to repeated and held notes. The sonority rooted on B seems especially convincing at the beginning of the excerpt, when the B is present as a held note in the flute and violin. However, the B representation cannot account for some salient pitches in the texture: the held G$^{1}/_{4}$♭ and the repeated C$^{1}/_{4}$♭ and D$^{1}/_{4}$♯. As the B fades out, our attention turns to the tone representations which give these salient pitches more weight, and we experience the sonority as a combination of harmonies with roots on E♭ and C$^{1}/_{4}$♭ (the low repeated notes in the piano). At the end of the excerpt, the upper-register held pitches G, D$^{1}/_{4}$♭, F♯ and B♭ strongly imply the tone representation D$^{1}/_{4}$♭ (11:16:21:26); the piano's B♭, B and D$^{1}/_{4}$♯ also fit into this interpretation, as partials 13, 14 and 17.

Ex. 5a Harmonic transcription of *Vortex Temporum*, ii, section II (rehearsal numbers 4–7)



Ex. 5b Several plausible tone representations for the excerpt reproduced in Ex. 5a

The complexity and multivalence of this analysis reflects the aural richness of the harmony. I would argue that the competing pull of different tone representations is one of the things which keep our attention engaged throughout this minute-long, largely static passage. When we view the chord through the lens of tone representation, its derivation from an exaggeratedly stretched spectrum is irrelevant – we focus instead on the complex ways in which the harmony plays on our aural intuitions. The choice between the two types of nature I've discussed here, one external and one internal, illustrates a broader decision between two models of analysis for Grisey's music. One is essentially formalist, based on sketch study and the re-creation of the composer's material and ideas, while the other is essentially phenomenological and pragmatic – the analyst's subjective experience of the piece is taken as the essential explicandum. The ambiguity of the pragmatic approach is not a weakness, but rather a strength: by allowing such ambiguity, we recognise the richness of musical listening and avoid flattening our experience, forcing it into a simplistic formal mould.

Tone representation is a valuable tool of this pragmatic approach to analysis: an approach based on taking aural experience seriously, instead of formalistic abstractions or speculations on the composer's intent. By focusing our attention on sonic quality and rootedness, tone representation suggests new readings of music in a variety of styles, from Schoenberg's atonal music to Grisey's spectral works. The theory makes it possible to put into words some of the most elusive aspects of our experience of complex harmonies – and by emphasising listening instead of mathematical or formal abstraction, it offers a promising alternative to existing analytical techniques.

NOTES

1. Baillet (2000) is the most complete sketch-based study of Grisey's work; see also Hervé (2001), a monograph on Grisey's *Vortex Temporum*.

2. This discussion of *Partiels* is indebted to Fineberg (2000), pp. 115–18; see also Rose (1996), pp. 8–11. It would be an oversimplification to associate the spectralists solely with the technique of instrumental synthesis, but particularly in the early days of the movement this was an essential and frequently used technique. Later developments in the spectralists' technique added a variety of effects and transformations, including many (such as frequency modulation) based on the tools of the electronic music studio.

3. See Christensen (1993), pp. 133–68.

4. See Baillet (2000), p. 217. Grisey's equation results in a curve shaped differently from the natural stretching of the piano spectrum, which is described by the equation $fn = nf_0(1 + Bn^2)^{1/2}$ in Fletcher, Blackham and Stratton (1962), p. 756.

5. Grisey (1984) includes the composer's discussion of the concept of the 'liminal'. See also Stahnke (1999).

6. The composer Roger Reynolds (1993, pp. 282–3) has questioned the relation between such spectral models and their musical realisation, stating that it is 'clearly absurd' that instrumental synthesis 'could possibly result in an orchestrated product that bears anything other than an incoherent and metaphoric relationship to the supposed model'. Reynolds is at pains to emphasise that his characterisation of the relationship between spectral structures and their acoustical models as incoherent and metaphoric is not an aesthetic judgment so much as a theoretical one; the music may well succeed artistically despite the incoherence of the compositional technique. Reynolds's observations raise an important question: if the models underlying the music do not have a perceptible relationship to the musical surface, then can an analysis based on a reconstruction of compositional procedure tell us anything about how a work of music is heard and understood? If the compositional model is not clearly reflected in the musical surface, an analysis which proceeds instead from a perceptual standpoint is likely to tell us more about the experience of hearing a work.

7. See Hartmann (1998), p. 135. The distorted spectra Grisey uses in *Vortex Temporum* lack the unique organisational potential of harmonic spectra. One of the unique qualities of sounds with harmonic (or near-harmonic) spectra is that they are easily resolved into separate streams when presented at the same time. But, as Albert Bregman notes (1990, p. 238), 'when two stretched series of partials are sounded at the same time, you do not hear only two distinct sounds as you do when listening to two harmonic sounds'. The composite of two inharmonic spectra is not easily resolved into two distinct sources and often results in a vague or ambiguous sense of pitch, or sometimes the chimerical perception of more than two illusory sound sources.

8. See Tenney and Dennehy (2008), p. 87.

9. The use of the overtone series to explain complex harmonies was a frequent trope in twentieth-century theoretical writing. Arnold Schoenberg, for example, suggested that the future of musical evolution would rest on 'the growing ability of the analyzing ear to familiarize itself with the remote overtones' (1978, p. 21). Similar ideas are found in the work of authors from Paul Hindemith to Henry Cowell.

10. Preference rules make their first appearance in music theory in Lerdahl and Jackendoff (1983). The rules proposed here appear in a somewhat different form in Hasegawa (2006).

11. See Callender (2004), pp. 26–31. The Cartesian distance between sets is the square root of the sum of the squares of the differences between each pitch and its mapping (measured here in cents). Following Callender, this result is multiplied by a scaling factor of $\sqrt{n}/\sqrt{n-1}$ (where n is the number of pitches in the set). This brings the distance into conformity with our intuitions about pitch distance, so that, for example, the minimum distance between sets $\{0, 4, 7, 10\}$ and $\{0, 4, 7, 11\}$ is equal to 1 and not $\sqrt{3}/2$; see Callender (2004), p. 29.

12. Fineberg (2000), pp. 124–8. Spectral composers have adopted Ernst Terhardt's virtual pitch algorithm, designed to predict the most likely assignment of overall

pitch to a collection of partials; see Terhardt (1979). Terhardt's algorithm seeks matches (or near matches) between the 'subharmonics' of a given set of frequencies; a match of subharmonics means that both frequencies can be heard as overtones of a fundamental pitch at the frequency of the match. Like the theory of pitch representation advanced here, Terhardt's algorithm for finding virtual pitch frequently locates several possibilities for the virtual pitch of a given set of components. Terhardt invokes criteria similar to my three preference rules to choose between competing interpretations (Terhardt 1979, p. 169).

13. See Barlow (1987), pp. 44–55.

14. See Belet (1987), p. 462. Tenney's theory that we prefer simple explanations is closely related to gestalt psychology's principle of *Prägnanz* (conciseness).

15. See Rameau (1750) and, for example, Erpf (1969).

16. See Lewin (1994), p. 86.

17. Väisälä (2002) explores overtone-based harmonies in works by Webern, Berg, Scriabin and Debussy. Väisälä draws extensively on Richard Parncutt's research into psychoacoustics and harmony (Parncutt 1988 and 1989). Another application of the overtone series to the analysis of 'atonal' harmonies is Deliège (2005).

18. The analysis offered here might seem to imply that Schoenberg's music is 'out of tune' and needs to be 'corrected' to just intonation. This is not my intent, and Schoenberg made his preference for equal temperament very clear. Rather, I'd argue that equal temperament allows the careful balancing of ambiguities between several tone representations, an ambiguity which seems integral to the aesthetic of early atonality. A similar conclusion is drawn by Gary Don in his research on overtone series chords in the music of Debussy: he concludes that Debussy 'was content to incorporate the overtone series into his music through the lens of equal temperament, thus *suggesting* a particular sonority, without requiring a literal (i.e., just intonation) realization of those sonorities' (Don 2001, p. 69).

19. Stahnke (1999) and (2000) take a similar approach to the analysis of chords from the first part of *Vortex Temporum*.

20. The term 'listening grammar' was coined in Lerdahl (1988). Lerdahl makes a distinction between listening grammars (which a listener uses to make sense of a musical work) and compositional grammars (which a composer uses to create a work).

21. For different viewpoints on the construction of this movement, see Baillet (2000), p. 224, and Hervé (2001), pp. 56–7.

22. See Shepard (1964). An example of a continuously descending Shepard tone can be found on the website of the Acoustical Society of America: http://asa.aip.org/demo27.html (accessed 19 July 2008).

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ABSTRACT

Gérard Grisey (1946–1998) was a founder of the influential 'spectral' movement. Reacting against the abstractions of serialism, spectral composers derived their musical material from the physics of sound and the mechanisms of aural perception. The present study explores the tensions between Grisey's natural sonic models and their alterations and distortions in his music. One common spectral technique is 'instrumental synthesis' – the scoring for instrumental ensemble of the partials of a complex natural sound. Instrumental synthesis creates a musical effect which is neither atonal nor tonal in the traditional sense – rather, we can best understand this music as exhibiting an extended tonality based on the upper overtones of the harmonic series. The analysis of this extended tonality calls for new theoretical tools which can account for the complex harmonic relationships between high overtones.

I propose a modification of Hugo Riemann's theory of *Tonvorstellung* (tone representation): the idea that, given a collection of pitches, we will understand them as connected by the simplest possible just intervals. As a model of harmonic meaning based on our processes of auditory cognition, tone representation can illuminate the way we hear and understand harmony in a wide variety of works. The theory is demonstrated in a discussion of Sehoenberg's Piano Piece, Op. 11 No. 2, then applied in an analysis of Grisey's *Vortex Temporum* (1994–6). Sketches for the piece indicate Grisey's use of distorted – 'stretched' and 'compressed' – spectra in addition to the familiar harmonic series. Applying my theory of tone representation makes possible a sensitive description of the aural effect of such distorted spectra, rather than the interpretations we frequently find of these sonorities which contradict their natural origins in Grisey's sketches.