# Polysystemism: A Tool for Shaping Music by Relation to Acoustic Phenomena

## A Brief Introduction to Polysystemism

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**Abstract:** What is more evanescent than sound? What is closest to immaterial among the manifestations of the perceptible realm, if not music? Although this has been noted since the dawn of time, music in its historical path has fallen into the error of becoming a language. It has certainly reached peaks of inestimable beauty and depth of thought, but it has gradually moved away from its ethereal essence and I would even say magical-alchemical dimension. During my career as a composer, I have tried to trace music back to what I believe to be its most authentic origins, and I have tried to organize the sound according to the ways in which we perceive it, making Berkeley's expression my own, according to which "being is being perceived". In the search for a meaning of music as *sensation*, I have developed a compositional technique that I call polysystemism, that is, the simultaneous use of different tuning systems in order to create acoustic phenomena on which to base the aesthetics of my research and music. The present paper reports on the excursus of this almost twenty-year investigation, both through its musical works and through some practical solutions for the realization of its intentions. In the final analysis, I believe in the effect of music on human thought and soul, and to put it like Plato: if music changes, the most important institutions will also change. And so be it.

**Keywords:** Polysystemism, microtonality, non-locality, tuning systems, acoustic phenomena, psychoacoustics

The physical aspects of sounds are at the center of my musical research. I use acoustic phenomena as the means to shape timbres and musical form and as tools for the composer to organize musical material and command the forces that underlie it. In order to achieve a large palette of physical phenomena, I have explored the interactions between different types of tuning systems, because the resources a composer has for bringing out the physical qualities of sound when employing only 12-tone equal temperament (12-ET)[1] are minimal, due to the limited frequencies that one tuning system has and the consequent limited combinations possible.

The process of using different tuning systems simultaneously, which I have named "Polysystemism," presently includes eight tuning systems: 12-ET, 24-ET,[2] just intonation (JI),[3] Werckmeister I, II, and IV, meantone,[4] and Pythagorean, plus different types of commas, especially the Pythagorean, which are a direct consequence of the tuning systems themselves. A central aspect of my musical investigation is the perception of sonic and aural phenomena, and the tools by which it is possible to draw the attention of the listener to them through a formal construction that takes into account the way human beings perceive transformations through time.

In recent years, much attention has turned to sonic material in its residual traces, so that a large group of composers have written, and continue to write, a type of music close to the borders of silence and noise.[5] It is certainly an interesting field to investigate, but this approach to composition still acts within the domain of sound matter (this is also valid for spectral music in all its forms).

With Polysystemism, however, I wish to affirm that music is primarily a *sensation* and therefore strictly connected to the way our organ of hearing can perceive it (with its qualities and limits). This last consideration can be related without hesitation to the famous motto of the Irish philosopher George Berkeley (1685–1753), *Esse est percipi* (to be is to be perceived),[6] which underlines the importance of perception in the process of creating our experience of the world around us and even of ourselves. Polysystemism makes phenomena as they are perceived through the organs of hearing the foundation for the music objects employed in a composition, and also the ultimate result of their transformation through time.

1 Or any other tuning system. Here I refer symbolically to 12-ET, its being the most frequently employed.

2 It is also possible to consider 24-ET as an extension of 12-ET, the quarter tone being half a semitone.

3 Sometimes I refer to just intonation as "natural tuning." The two terms are interchangeable.

4 Whenever the term meantone appears in the text, I am always referring to quarter-comma meantone.

5 I think, for example, of Sciarrino, Lachenmann, Mark Andre, and many other composers whose music is addressed to the development of a kind of *musique concrète* realized through acoustic instruments.

6 Extended also to *Esse est percipi (aut percipere)*—to be is to be perceived (or to perceive); see *Principles #3* in George Berkeley, *A Treatise Concerning the Principles of Human Knowledge* (Dublin: Printed by Aaron Rhames, for Jeremy Pepyat, 1710).

This article aims to analyze the possibilities for the use of non-tempered sounds, demonstrating how these pitches play an important role in the realization of acoustic phenomena.

## Frequencies—the main resources for non-tempered pitches: String scordaturas, pitched glasses, harmonic series, and unusual pitches for tuning the woodwinds

Among the several means by which it is possible to create acoustic phenomena, the employment of non-tempered pitches unquestionably plays an important role. This is because non-tempered pitches create a significantly larger degree of sonic manifestations. If we consider, for example, the simple phenomenon of beats, it can be deduced—I would even say that is so obvious as to be banal—that having a greater number of frequencies increases the variety of beat rates enormously. The same happens with all the other acoustic phenomena: Polysystemism amplifies them exponentially.

The first time I made use of non-tempered pitches was in 2005 for the piece *Luminescences*,[7] and it was on this occasion that I first used the term Polysystemism. Since the beginning of this musical research I have wished to use this term to define the simultaneous use of different tuning systems within the same work. For this first attempt, I employed only two tuning systems: the 12-ET and just intonation.[8]

The main resource at my disposal for obtaining several pitches in JI and Pythagorean tuning was the employment of scordaturas in the strings (Fig. 1). Each open string became a generator of harmonic series whose frequencies belong to JI, while the relation between the fundamentals (the open strings in this case) is still set in 12-ET, so that equal temperament is also employed. The choice to use scordaturas has a double function. On the one hand, by using only open strings and natural harmonics we have a very particular timbre,[9] and, on the other, we have the certainty that the frequencies employed are very precise.[10]

7 *Luminescences*, for clarinet, violin with scordatura, viola with scordatura, cello with scordatura, and percussion. First performance: 6 August 2005, Chigiana Music Academy, Siena. Ensemble of the Chigiana Academy conducted by Mauro Bonifacio. The piece was awarded the Chigiana Academy Merit Diploma 2005.

8 Potentially it is also possible to have an interval belonging to Werckmeister II and another from Werckmeister IV. By using the fifth harmonic of each harmonic series, which is 14 cents lower, we can obtain the 7M of WII (-14 cents) and the 2M of WIV (-14 cents).

9 We must also consider that the instruments are designed to respond to an ordinary tuning, and when this is altered, consequently the physical qualities of the instrument also change, altering the timbre.

10 The pitch of the open strings and of the natural harmonics cannot be altered. In the first case, the left hand does not touch the fingerboard of the instrument, in the second the natural harmonics are emitted only in the nodal points of the strings, and the variation of frequency is only susceptible to a few cents which are negligible from the point of view of perception. In some positions of natural harmonics, in particular the octave, it is possible to alter the frequency of the sound significantly, but this entails special techniques—such as bending realized by pulling the string—and not an ordinary execution of these sounds.

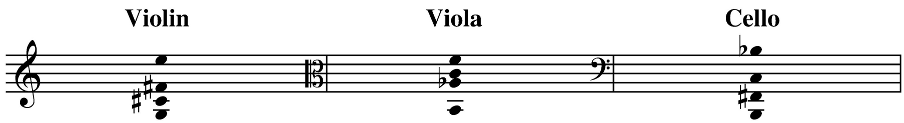


**Fig. 1.** Scordatura in *Luminescences*

In all my works that make use of scordaturas, only open strings and natural harmonics are used.

The use of stopped pitches is rare, and limited either to doubling some sounds of other instruments (in this case the pitch belongs to the intonation system of the doubled sound), or to glissando-tremolos whose sounds are calculated through the 12-ET system with reference to the open string on which they are played, which means that they preserve the tuning deviations of the open string itself. As can be seen in the following example, taken from the piece *Traces from Nowhere* (2017), the B, the D, and the D# preserve the deviation in tuning of the open string, tuned 32 cents below the ordinary. This means that in relation to the open string, these sounds are played according to the 12-ET (Fig. 2).


**Fig. 2.** *Traces from Nowhere*, cello scordatura, and bar 20

The piece that marks the transition to a more radical use of this compositional technique is *Beyond Perturbative States* (2013), a work that I consider the musically concretized "manifesto" of Polysystemism. It is with this piece that I extended the number of the tuning systems employed up to seven: 12-ET, just intonation, Pythagorean, meantone[11] and Werckmeister I, II, IV.[12]

[11] As previously mentioned, I always refer to quarter-comma meantone.

[12] Of all the tuning systems mentioned, except for the 12-ET, only a few specific intervals are used in a specific range and only between certain instruments. This creates "local" harmonic and melodic intervals that cannot be transposed precisely because they emerge from the scordaturas of the string instruments and the consequent use of only open strings and natural harmonics.

It is in this work that, for the first time in Polysystemism, the scordaturas of the strings are based on open strings no longer tuned according to equal temperament, whether in relation to each other or considering their frequencies in themselves (Fig. 3).

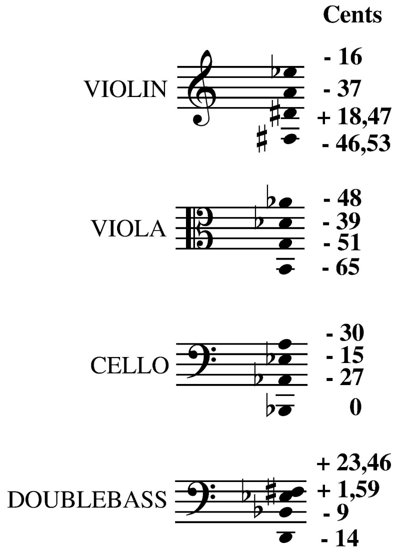


**Fig. 3.** Scordatura in *Beyond Perturbative States* (2013)

It is precisely because of this different approach to the scordaturas that the different Werckmeister temperaments (I, II, IV) and meantone can be achieved, not only by relating the frequencies produced by the strings (open strings and natural harmonics) but also by taking into account the different intervals emerging by a superimposition of those frequencies onto the ones produced by the other musical instruments involved. Before turning to a detailed analysis of the intervals that emerge from the string scordaturas, and that belong to different tuning systems, in order to understand how the piece is constructed, it is necessary to introduce the subject of *perturbative states* and their relationship to string theory.[13]

From the agitated and restless world of quantum objects, a characteristic due to the uncertainty principle,[14] string/antistring pairs, which produce opposite vibrational patterns,

[13] String theory postulates the existence of one-dimensional strings of matter whose vibrations would give life to elementary particles.

[14] The uncertainty principle, also called the Heisenberg uncertainty principle or indeterminacy principle, is a statement, articulated (1927) by the German physicist Werner Heisenberg, that the position and the velocity of an object cannot both be measured exactly, at the same time, even in theory. See "Uncertainty principle," Britannica, accessed 20 September 2020, https://www.britannica.com/science/uncertainty-principle.

can momentarily come into existence, taking energy from the universe at the moment of their creation and giving it back once they annihilate each other. These string/antistring pairs, which recombine in one loop after they annihilate, are called *virtual strings*.[15] As one loop appears at the center of the diagram representing the course of this recombination, this development is named the one-loop process (Fig. 4).

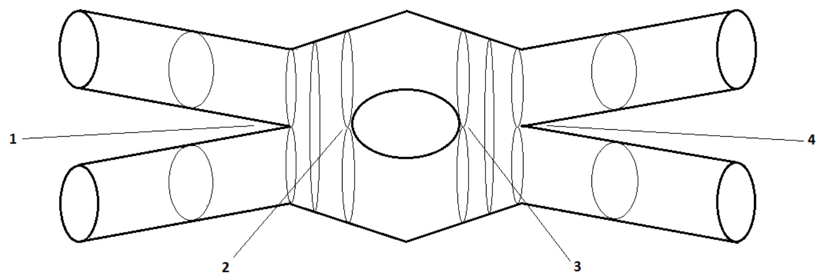


**Fig. 4.** Virtual strings. At point 1 the two virtual strings collide, creating a single loop. At point 2 the quantum fluctuations create a pair of virtual strings whose annihilation occurs at point 3, creating a single string again. At point 4 this single string releases its energy, splitting into two strings, each of which will continue its path separately.

As quantum fluctuations can divide these virtual strings again and again, the one-loop process can occur several times, making the calculations very difficult. To solve this problem, string theorists assume that a good approximation is made when the whole procedure is considered as a zero-loop process, so that the one-loop processes represent just a refinement of the zero-loop result. This is an example of a perturbative approach. We can then define the perturbative states as an approach to the one-loop process, which occurs between a couple of virtual strings. This approach approximates the difficulties caused by the complexity of calculation and assumes an approximation starting from the zero-loop process. Put simply, the perturbation is a way to get closer to the exact result and to make the calculations easier.

The BPS (Beyond Perturbative States) are instead those approaches to the one-loop process that can describe the virtual strings without employing a perturbative calculation (i.e. without making approximations). In music, the BPS correspond to the exact frequencies of the intervals.

In my piece *Beyond Perturbative States*, the perturbative version of the intervals are intervals whose frequencies are not precisely the ones that correspond to the exact

[15] For further insights, see chapter XII, "Beyond Strings: In Search of M-Theory," in Brian Greene, *The Elegant Universe* (New York: W. W. Norton, 2003).

frequencies of the tuning systems from which they are taken.[16] Intervals present in the score belong both to the domain of exact frequencies and to the “perturbative” category.

In the following figures (Figs. 5–7) we see some of the intervals belonging to different tuning systems. The lower staff (POS = positions) shows where to touch the strings, the higher staff (S.R. = suoni reali) shows the relevant resulting harmonics.

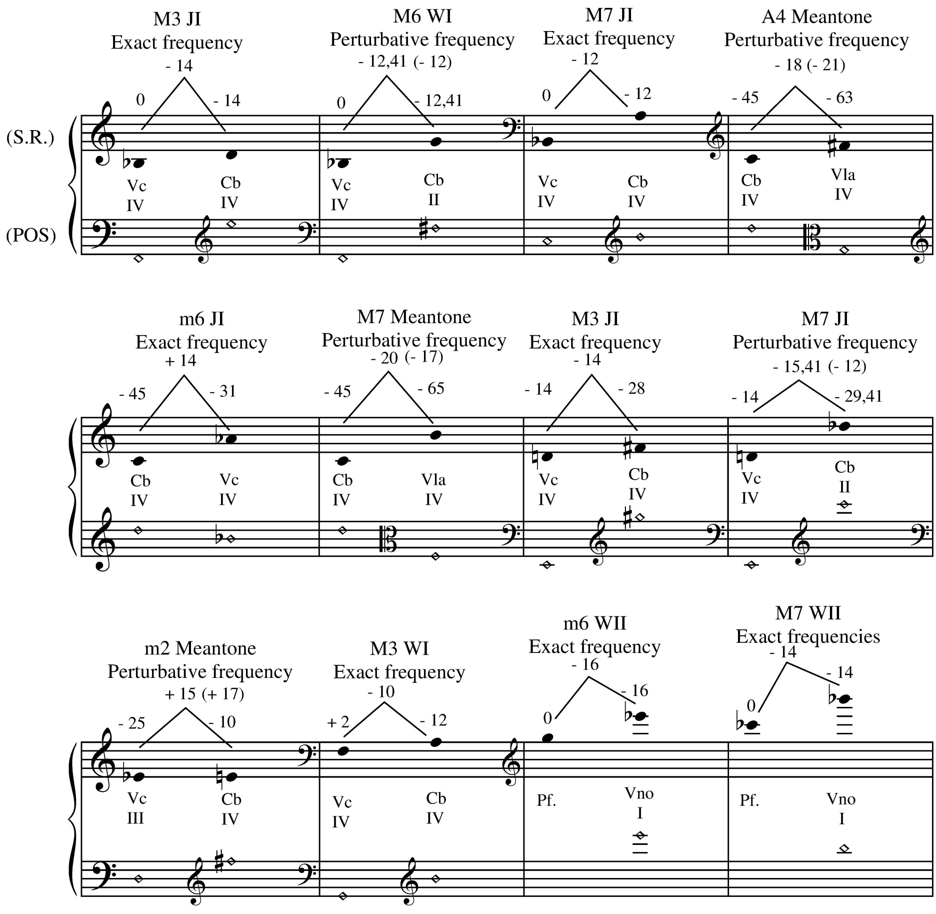


**Fig. 5.** Some intervals in *Beyond Perturbative States*

[16] The maximum difference between the theoretical exact intervals and the perturbative ones used is 4 cents, a difference practically imperceptible to the ear.

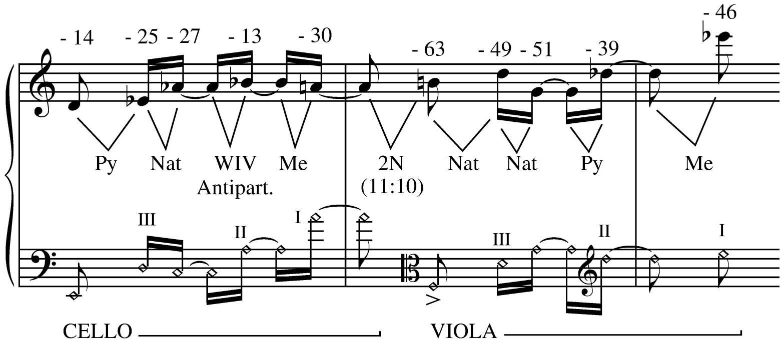


**Fig. 6.**[17] *Beyond Perturbative States*: bars 46–48

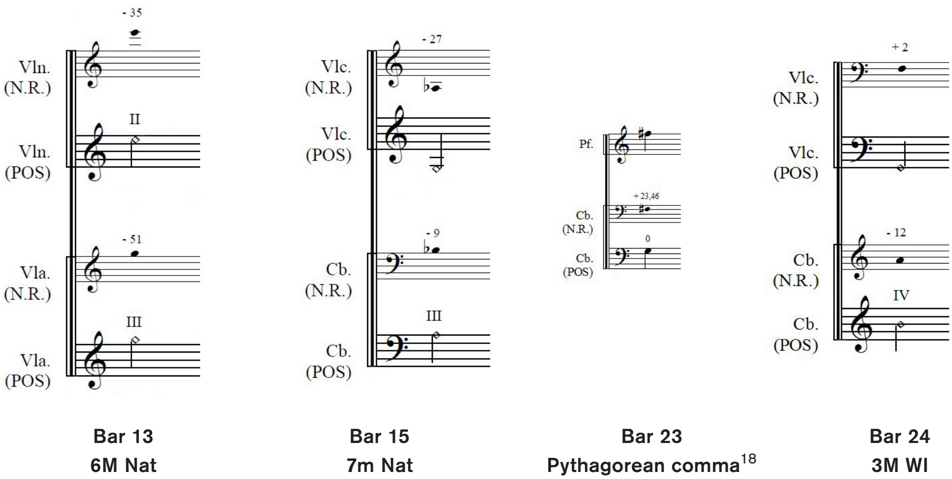


**Fig. 7.** *Beyond Perturbative States*

Additionally, in *Beyond Perturbative States* the piano is prepared, which has the role of creating sounds similar to the *kempul*,[19] the pitched gong used in the Indonesian gamelan.

[17] In regard to the neutral second (11:10), I use JI considering possible all the interval combinations that arise from the pitches belonging to the harmonic series.

[18] The Pythagorean comma is the difference between 12 perfect fifths and 7 octaves.

[19] Generally forged in bronze, the *kempul* is a metal gong, part of a Javanese iron gamelan. It is used to articulate the underlying cyclical formal structure of a piece (*gendhing*) by being played at prescribed moments of that structure.

The preparation is realized in such a way that soft rubbers are inserted at specific nodal points of the piano strings to provide not only this particular timbre but also a residual sound of the harmonics isolated by the rubber itself (Fig. 8).

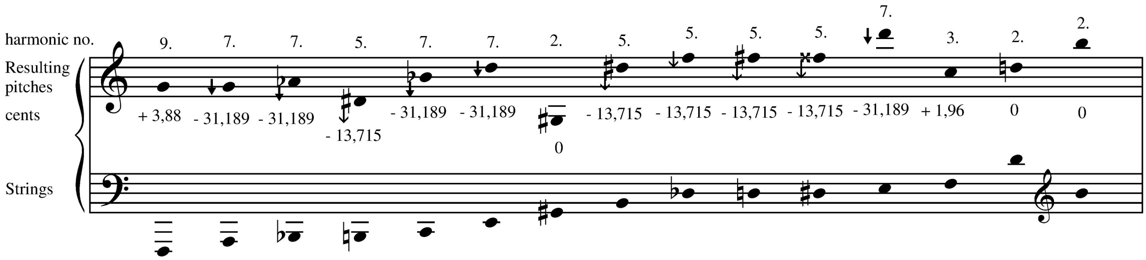


Fig. 8. Piano preparation in *Beyond Perturbative States*

The first orchestral piece to make use of Polysystemism, *Dimensioni nascoste* (Hidden Dimensions) was written in the same year (2013), and went on to receive the first prize in the orchestral category of that year's UMZF competition (Forum of New Hungarian Music), whose jury was chaired by Peter Eötvös.[20] In this work I decided to renounce scordaturas in the strings and entrust the wind and brass instruments with the task of realizing unequal frequencies, using the untempered pitches belonging to the harmonic series of these instruments, with the explicitly manifest aim for the first time of using Polysystemism as a tool for the production of physical-acoustic phenomena.

As the title of the piece suggests, the idea refers to the challenge of generating the extra dimensions assumed by string theory with sounds. Those dimensions can be created by a meticulous positioning of the physical-acoustic phenomena in specific registers within the global audible range, an achievement that is directly connected with the idea of *inner space*, to be discussed later in this paper.

Although it will be extremely difficult to validate string theory, and one day it may even turn out to have been nothing more than fantasy, nevertheless I believe that it indicates a path in music that is certainly true. The acoustic quality of a sound is given not only by its frequency, that is, by its vibrational motion, but also, and I would say above all, by the greater or lesser presence, in terms of acoustic weight, of its spectral components, plus other parameters that will not be analyzed in this paper. In the same way, string theory assumes that the vibrational motion of the strings determines the "birth" of each elementary

[20] *Dimensioni nascoste*, for large orchestra. First performance with the Hungarian title *Rejtett dimenziók*, 26 September 2013. Bartók Hall, Művészetek Palotája (Palace of Arts), National Hungarian Auditorium, Budapest. National Hungarian Radio Orchestra conducted by Gergely Vajda.

particle. In light of these considerations, I conceived an elaboration of the orchestration that thinks of the counterpoint, which is classically considered only a superimposition of lines, as a generator of timbres. Towards this goal, the concept of sonic permeability plays a very strong role in the transformations of the instruments' timbres.

By the term "sonic permeability," I mean that feature of a sound to "permeate" or "be permeated" by other sounds. In other words, this parameter expresses the degree of clash that can occur between sounds. Sonic permeability is an extension of the criterion consonance/dissonance, but, contrary to the latter, it refers only to the physical aspect of the sound, not including subjective and arguable perceptions like musical tradition or education. The different degrees of sonic permeability are strictly connected with the characteristics of the spectrum of every single sound involved in the sound agglomerate we wish to define.[21]

In works written before *Dimensioni nascoste*, the aspect of acoustic phenomena is also present but relegated to a secondary position. In the first Polysystemic works, the use of non-tempered intervals has the principal aim of transforming the timbre of musical instruments. With *Beyond Perturbative States* and *Hidden Dimensions*, the construction of physical-acoustic phenomena emerges clearly as a prominent feature and achievement of Polysystemism.

The work that invests most in this purpose is certainly *Trasparenze* (2014), commissioned by Radio Bartók for the ArTRIUM series, the group of concerts of the National Hungarian Radio Orchestra dedicated to contemporary music.[22] In this work, not only are the scordaturas in the strings reintroduced (the first Polysystemic orchestral work in which they are used—see Fig. 9) but we can also observe a profound integration between the different musical parameters and categories of sound (pitched sounds, noises, and effects) in a conception of music intended as a continuous flow.

[21] A study on the possibilities of timbres to shine through each other was conducted by composer and music theorist Koechlin in his treatise on orchestration and subsequently discussed by Frédéric Chiasson et al. in the article "Koechlin's volume: Perception of sound extensity among instrument timbres from different families," *Musicae Scientiae* 21, no. 1 (2017): 113–131. Unlike Koechlin, who takes into account the parameters of *volume* and *intensity*, meaning by volume "the extensity of an instrument sound, the space it seems to occupy in the auditory scene" and for *intensity* (*intensité*) "its perceived loudness or strength," my approach is to deduce the degree of permeability by comparing the "phonic weight" of the partial components of each sound, i.e. their greater or lesser presence in the acoustic spectrum.

[22] *Trasparenze*, for large orchestra. First performance 21 May 2014, Studio 6 of the National Hungarian Radio. National Hungarian Radio Orchestra conducted by László Tihanyi. Live broadcast by Bartók Radio.


**Fig. 9.** Scordatura in *Trasparenze* (2014)

The scordaturas that we see in the figure above are designed to allow the emergence of intervals belonging to the following intonation systems: 12-ET, JI, meantone, Pythagorean, Werckmeister I, II, IV. The following figures show some of these intervals (Fig. 10–12). As we can see, most of them have exact frequencies. Some, however, are "perturbative frequencies," approximated within 1 or 2 cents, maximum 4.

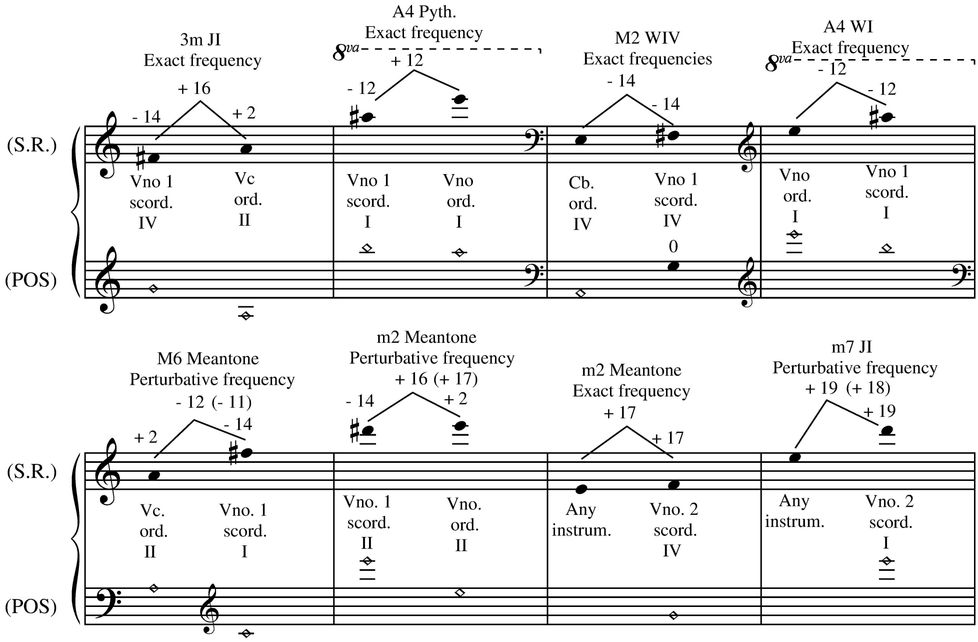
(S.R.)
(POS)
3m JI
Exact frequency
- 14
+ 16
+ 2
Vno 1
scord.
IV
Vc
ord.
II
A4 Pyth.
Exact frequency
8va
- 12
+ 12
Vno 1
scord.
I
Vno
ord.
I
M2 WIV
Exact frequencies
- 14
- 14
Cb.
ord.
IV
Vno 1
scord.
IV
0
A4 WI
Exact frequency
8va
- 12
- 12
Vno
ord.
I
Vno 1
scord.
I
M6 Meantone
Perturbative frequency
- 12 (- 11)
+ 2
- 14
Vc.
ord.
II
Vno. 1
scord.
I
m2 Meantone
Perturbative frequency
+ 16 (+ 17)
- 14
+ 2
Vno. 1
scord.
II
Vno.
ord.
II
m2 Meantone
Exact frequency
+ 17
+ 17
Any
instrum.
Vno. 2
scord.
IV
m7 JI
Perturbative frequency
+ 19 (+ 18)
+ 19
Any
instrum.
Vno. 2
scord.
I

**Fig. 10**

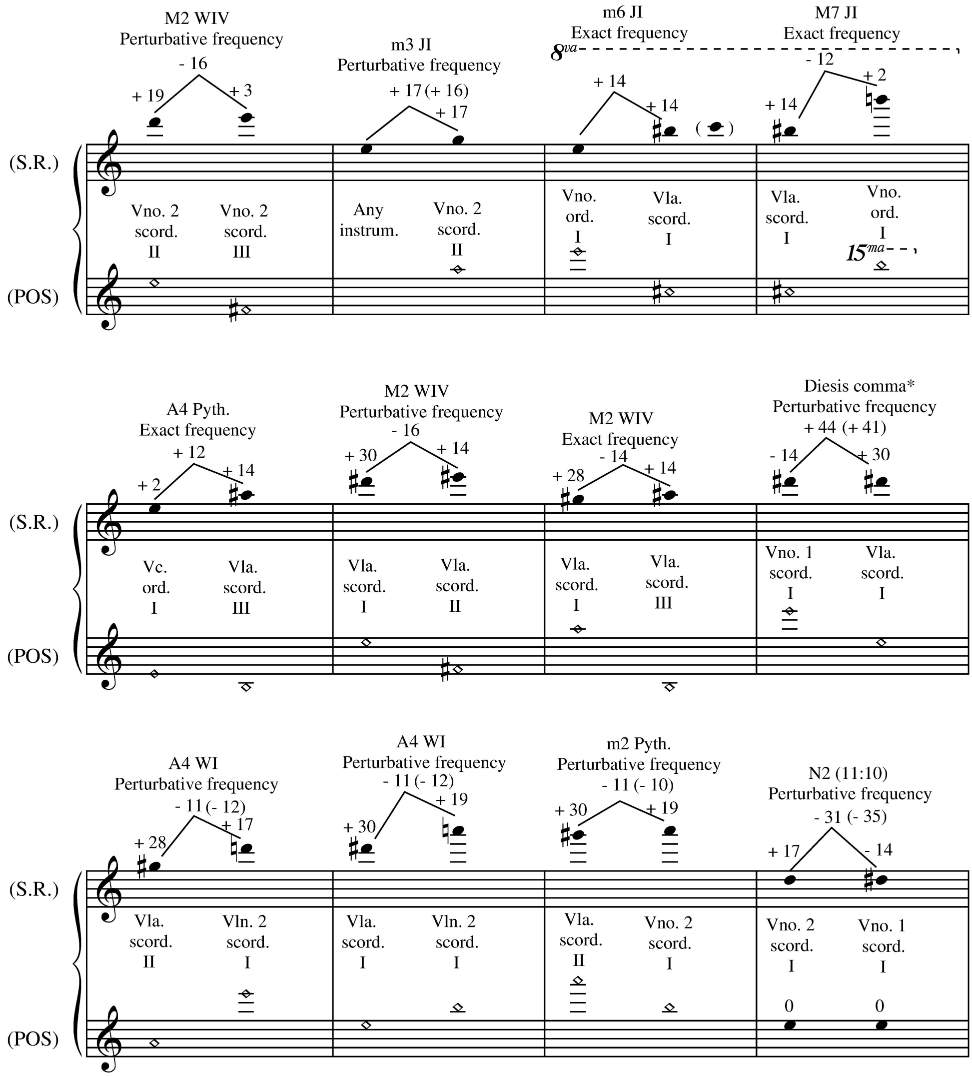
M2 WIV
Perturbative frequency
- 16
+ 19
+ 3
m3 JI
Perturbative frequency
+ 17 (+ 16)
+ 17
m6 JI
Exact frequency
8va
+ 14
+ 14
M7 JI
Exact frequency
- 12
+ 2
+ 14
(S.R.)
Vno. 2 scord. II
Vno. 2 scord. III
Any instrum.
Vno. 2 scord. II
Vno. ord. I
Vla. scord. I
Vla. scord. I
Vno. ord. I
15ma
(POS)
A4 Pyth.
Exact frequency
+ 12
+ 2
+ 14
M2 WIV
Perturbative frequency
- 16
+ 30
+ 14
M2 WIV
Exact frequency
- 14
+ 28
+ 14
Diesis comma*
Perturbative frequency
+ 44 (+ 41)
- 14
+ 30
Vc. ord. I
Vla. scord. III
Vla. scord. I
Vla. scord. II
Vla. scord. I
Vla. scord. III
Vno. 1 scord. I
Vla. scord. I
A4 WI
Perturbative frequency
- 11 (- 12)
+ 28
+ 17
A4 WI
Perturbative frequency
- 11 (- 12)
+ 30
+ 19
m2 Pyth.
Perturbative frequency
- 11 (- 10)
+ 30
+ 19
N2 (11:10)
Perturbative frequency
- 31 (- 35)
+ 17
- 14
Vla. scord. II
Vln. 2 scord. I
Vla. scord. I
Vln. 2 scord. I
Vla. scord. II
Vno. 2 scord. I
Vno. 2 scord. I
Vno. 1 scord. I
0
0

**Fig. 11**

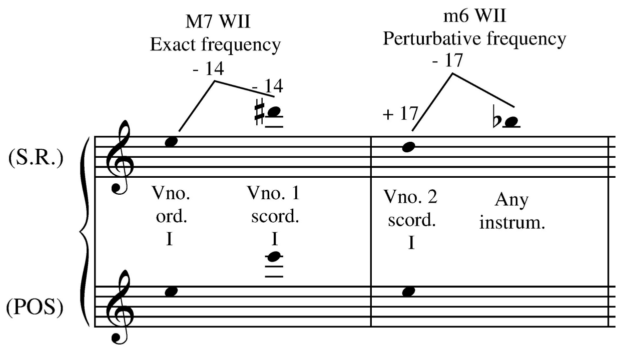


**Fig. 12**

In *Trasparenze*, the frequencies not belonging to the 12-ET are also realized through glasses played with the bow by violinists, cellists, and percussionists (Figs. 13 and 14).

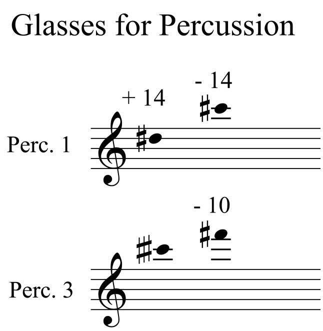


**Fig. 13.** Frequencies obtained through glasses played by the percussionists, *Trasparenze* (2014)

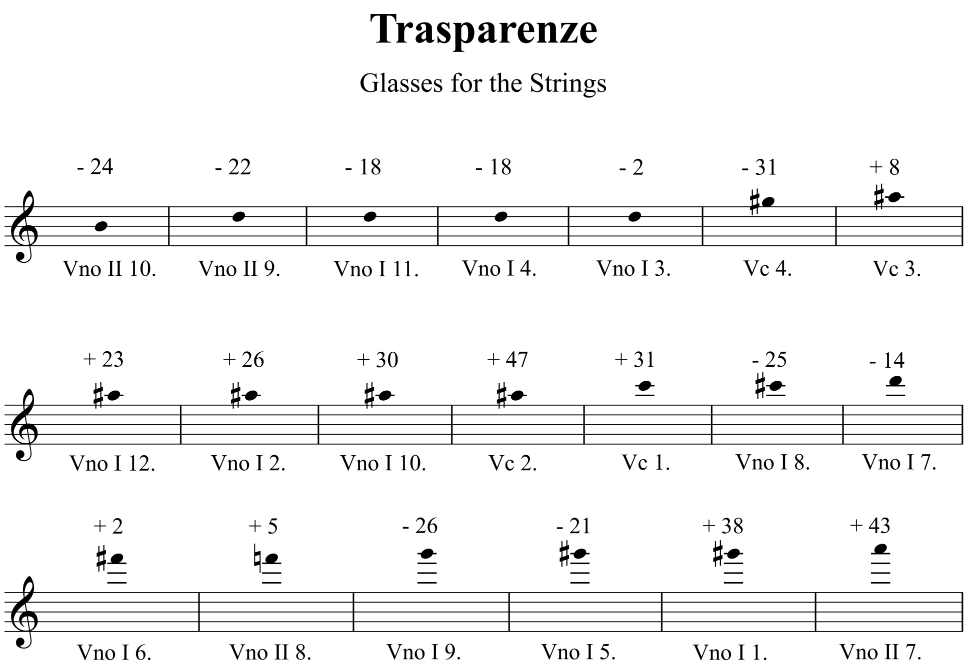


**Fig. 14.** Frequencies obtained through glasses played by the string players, *Trasparenze* (2014)

The idea of a sound flow in continuous development is the de facto main focus of sound organization in *Trasparenze*, where harmony, rhythm, melody, timbre, effects, and noises become integrated parts of an iridescent sound magma, from which some peculiarities of the components that constitute it suddenly emerge (hence the title of the piece, which suggests elements that shine through a global sound surface).

A separate experience is the *Heisenberg Suite* (2013; new version 2016), in which, although different intonation systems cannot be found explicitly, the focus on the physical dimension of the sound is a fundamental feature of the work. The main focus of the piece is the application of the Heisenberg uncertainty principle to musical parameters. The principle asserts a fundamental limit to the precision in the evaluation and measurement of specific pairs of physical quantities. If we know one of them exactly, we can have only an approximate knowledge of the other. A similar conception can emerge in pairs of musical parameters highlighted by an appropriate musical writing.

Such is the case, for example, with the speed/frequency pairing in the following writing for strings (Fig. 15).

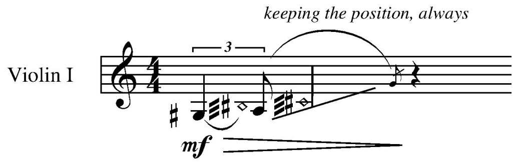


**Fig. 15.** *Heisenberg Suite*, bar 1

The tremolo G#–B# produces as a resulting pitch B# two octaves higher (artificial harmonic of major third). In this gesture, the frequencies are known. When the glissando is added to the tremolo, and if during the sliding of the fingers we keep the position of the major third (the physical distance between the two fingers), we know the speed of the gesture (given by the length of time from the beginning to the end of the gesture itself) but we lose the exactness of the frequency because of the position of the major third, which at the beginning has a resulting pitch but does not have one anymore during the glissando, because the distance between the two fingers does not correspond to any interval having a resulting pitch in terms of artificial harmonics.[23] The result is a mixture of pitched sounds (the ones resulting from the glissando realized by the base finger) and noises (emerging from the gesture of the tremolo with harmonic pressure realized with the "trembling" finger), which have a very transparent texture.

The most recent pieces written with Polysystemism are: *Ekpyrotic suicide*[24] (2019), commissioned by UMZE, the historical ensemble founded by Bartók; *Implicate Inklings*[25]– Clarinet Concerto (2019), written for Csaba Klenyán and Concerto Budapest orchestra conducted by Zoltán Rácz;[26] *Caducae resonantiae* (2020), a short piece for solo guitar commissioned by Katalin Koltai for the event "Bloomsday in Budapest"; and *Incantesimi di Merseburg*[27] (2019) for a 16-part choir of soloists commissioned by Kammerchor Stuttgart conducted by Frieder Bernius, this last piece being also the first employment of Polysystemism with voices. Most recently, *Outskirts of matter* (2020) was commissioned by the ensemble Wiener Collage, with soloists and members of the Wiener Philharmoniker.

23 This is because to maintain the same interval (the major third in the specific case) as one goes up towards higher positions, the distance between the fingers must decrease.

24 First performance at BMC (Budapest Music Center) on 31 March 2019. UMZE Ensemble conducted by László Tihanyi.

25 First performance at Grand Hall of the Liszt Academy on 4 May 2019.

26 For whose ensemble, Amadinda, Ligeti wrote his last work, *Síppal, dobbal, nádihegedüvel.*

27 The piece was premiered on 21 February 2020 at the Paul-Gerhardt-Kirche in Mannheim and the day after at the Gedächtniskirche in Stuttgart. The Merseburg charms or Merseburg incantations (die Merseburger Zaubersprüche in German) are two medieval magic spells written in Old High German. They are the only known examples of Germanic pagan beliefs preserved in the language. As far as I know, my piece is the first to put these texts to music.

*Implicate Inklings* asks performers to employ microtones in the woodwinds through alternative fingerings and through the use of certain harmonics (5th, 7th, 10th, 11th) of the harmonic series in the horns, which are naturally not tempered sounds.[28]

In searching to create such acoustic phenomena, my clarinet concerto attempts to discover the world of invisible sounds, that is, it aims to sound those notes that, although not set down in the score, still become perceptible and audible through orchestration. The title of the piece refers to the theory of the great 20th-century quantum physicist David Bohm, according to which everything we sense in the world is the manifestation of implicit, hidden things. In every detail of the work, there are latent, concealed aspects, which manifest themselves in the next parts, causing unexpected, surprising sound experiences for the listener. A brief explanation of *implicate-explicate order* in Polysystemism will be discussed later in this paper and will underline the role of latent objects in the domain of musical form.

*Incantesimi di Merseburg* is surely a difficult piece for the singers, especially if we think about the non-tempered pitches of which it makes use. To make the study and performance of it easier, I have asked an instrument builder to create special tuning forks (Figs. 16 and 17), which provide the singers with the exact frequency required.

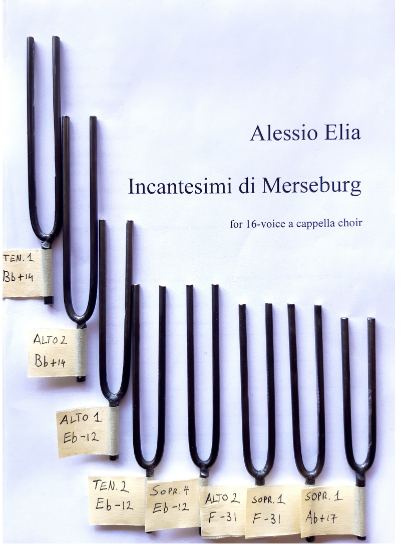


**Fig. 16.** Cover of *Incantesimi di Merseburg* with special tuning forks (2019)

[28] The deviations in tuning of these harmonics are as follows: 5th (-13,715 ≃ 14 cents); 7th (31,185 ≃ -31); 10th (-13,715 ≃ 14 cents); 11th (-48,74 ≃ -49).


**Fig. 17.** Frequencies for the special tuning forks in *Incantesimi di Merseburg* (2019)

In order not to lose the pitch, the piece is written so that the voices can listen to one another. When a voice comes out of 12-ET, it can re-enter it in two ways: by re-singing the sound it sang before (which is always in 12-ET), or by singing the sound of a nearby voice in spatial terms (also in 12-ET); see Figs. 18–19.

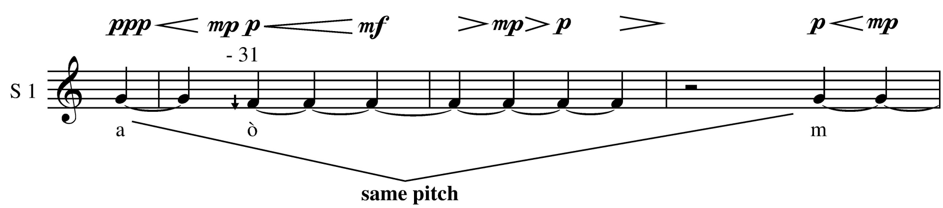


Fig. 18. *Incantesimi di Merseburg.* Soprano 1 sings G, then leaves 12-ET by singing F-31 (whose reference pitch is given by the special tuning fork), and re-enters 12-ET by singing G again.

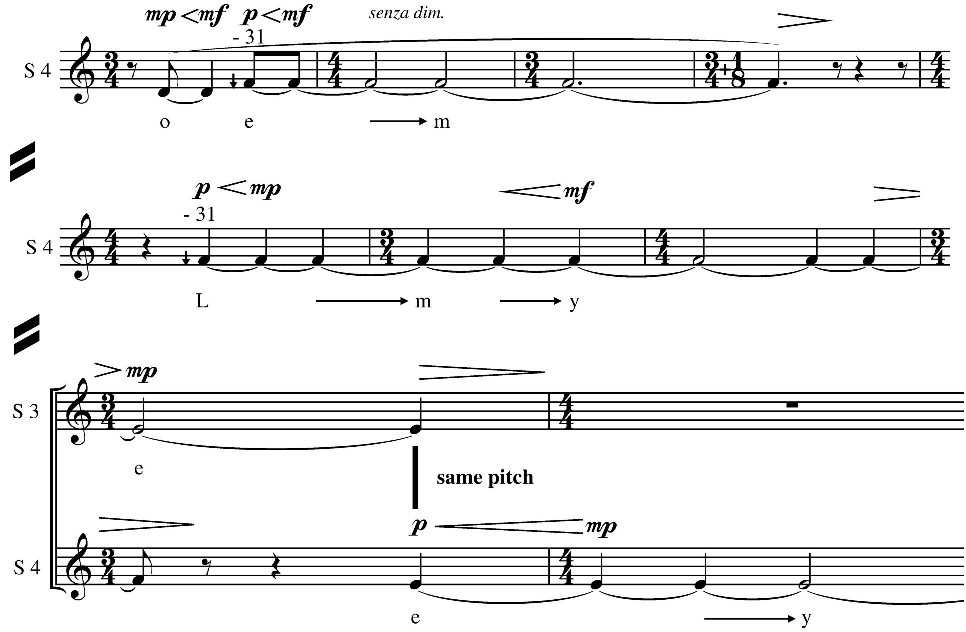


**Fig. 19.** *Incantesimi di Merseburg.* Soprano 4 sings D, then leaves 12-ET by singing F-31 (whose reference pitch is given by the special tuning fork), and re-enters 12-ET singing E, taking the sound from Soprano 3.

In this first section of this paper, we have seen some of the tools at our disposal to get untempered pitches, which are an important base for the achievement of the acoustic phenomena on which Polysystemism relies. In the following section, I will deal with the acoustic phenomena that emerge from the use of Polysystemism and the repercussions on timbre and formal structure.

### Acoustic phenomena achieved through Polysystemism

The sound objects realized through Polysystemism are the result of the perceptive faculties of our auditory system, with all its possibilities, but also—and I would say above all—with its limits. It is with the interstices of these limits that I wanted to play, and in this border area that I wanted to build my aesthetic.

Directly from the above assertions there emerges the necessity of making perception the central feature of this typology of music. I believe that music should be composed *in primis* to be heard. In this sense, I wish to underscore how in Polysystemism the process of transformation of the sonic material is implicitly comprehended by the aural mechanisms of perception through which the music is perceived. Keeping in mind Berkeley's motto *Esse est percipi*, Polysystemism makes phenomena as they are perceived through the organ of hearing the basis of the musical material employed in a composition, as well as aiming at the transformation through time of the material itself.

The table below clarifies how Polysystemism significantly shapes acoustic phenomena, being able to vary considerably the degrees of their manifestation (see Table 1).

**Table 1**

| **Acoustic phenomenon / Sound features** | **Results achieved through Polysystemism** |
|---|---|
| Beats | Increase in the variety of beat rates available. Beats produce an internal rhythm in static sounds (sustained sounds) in which speed varies in relation to the frequencies used. Therefore, by having a larger amount of frequencies as a result of using different tuning systems, it is possible to articulate the rhythm of beats in very different ways and vary the speed significantly. |
| Virtual fundamental[29] | Better audibility of the virtual fundamental, especially when the frequencies of the two or more sounds employed correspond exactly to the relevant frequencies in the harmonic series emanated by the fundamental we wish to resonate. |
| Differential tones | Increase in the number of differential tones available, because of a larger number of frequencies at our disposal. |
| Sound roughness | Creation of different types of sound roughness. As roughness basically occurs only if the frequency difference between two sounds lies in the range 31–100 Hz,[30] the 12-ET can only realize a small number of its types. It goes without saying that the more tuning systems we use, the more typologies of roughness we obtain. |
| Colours | The employment of different tuning systems affects not only the intonation of the intervals but also changes the colors of the instruments.[31] The combination of harmonic spectra not belonging to 12-ET fundamentals considerably modifies the timbre of the instruments through the interactions of their constituents.[32] |
| Sonic permeability | Having modified the timbres of the instruments, through the employment of different tuning systems, the possibilities of sounds interacting with each other is significantly increased.[33] |

29 Having two frequencies, the ear is able, in particular cases, to identify a common fundamental of which the two sounds are partials or harmonics.

30 The concept of the critical band, which will not be discussed here, should also be considered. Further insights can be found in William A. Sethares, *Tuning, Timbre, Spectrum, Scale* (London: Springer, 1999).

31 This aspect has been discussed previously. Changing the pitch of the strings through scordaturas and tuning the winds with tuning forks lower than the standard ones necessarily alters the physical characteristics of the instruments, and with them the timbre.

32 This phenomenon is clearly related to the superimposition of sounds. When two or more sounds are superimposed, their relevant spectra are also superimposed. It goes without saying that the spectra of sounds whose fundamentals are not harmonically related (because they belong to different tuning systems) create a very wide variety of beats and sound roughness.

33 Since the sound permeability between two or more sounds is given by the relationship of their spectral components, having changed the timbre of the instruments through the different tuning systems, and having consequently modified the phonic weight of these components, it follows that the sound permeability will also have undergone a modification.

**Non-locality and multidimensional inner space**

Polysystemism places each tuning system in a specific range and between specific instruments (local spaces), tying together the physical phenomenon with the specific sound qualities of the musical instruments that produce it. In this way, with each region of the sound space occupied by a particular acoustic phenomenon, we have created a sound space that is already born within the sound itself (inner space).

A listening experience as complex as the acoustic phenomena enacted, in addition to the abolition of the boundaries between the different musical parameters, creates an uninterrupted sonic flux, the transformations of which over time will be investigated in the continuation of this article (implicate/explicate order). The overall result of this sonic flux, coming from the interactions of the single elements, generates an auditory macro level that is something different to just a superimposition of the individual functions of each element. This is what I call "third level" in music composition.

The first level consists in music as it appears on the surface, the second is the function its elements have within the context into which they are placed, and the third consists in what the elements generate as a global result, not merely a superimposition of the elements but rather the nature and finality that tie them together intimately, that is, an emergent effect, greater than the sum of its parts.

An example of a third level is the opening of *Traces from Nowhere* (2017), written for the Human Machine project.[34] In this piece, the wind instruments are tuned to different diapasons, lower than usual, so that all the pitches of each instrument are lowered a determined number of cents. The oboe is tuned 11 cents lower, the clarinet 26 cents lower, and the bassoon 7 cents lower. The peculiarity of these pitch alterations in wind instruments is that the extra temperate relationships occur between the different instruments, while each instrument continues to play in 12-ET. The deviations in the tuning have been calculated to have an approximation of a maximum of two cents to the exact frequencies (Fig. 20).

[34] The project, developed by me and the conductor Andreas Luca Beraldo, provides for the integration of the Disklavier within the ensemble, with the consequent relation between the machine and the human performers. The project debuted at the LAC in Lugano on 16 February 2017, within the "Late Night Modern" concert series of the Oggimusica Festival, with the Impronta ensemble conducted by Andreas Luca Beraldo. The first performance of *Traces from Nowhere* took place in this context.

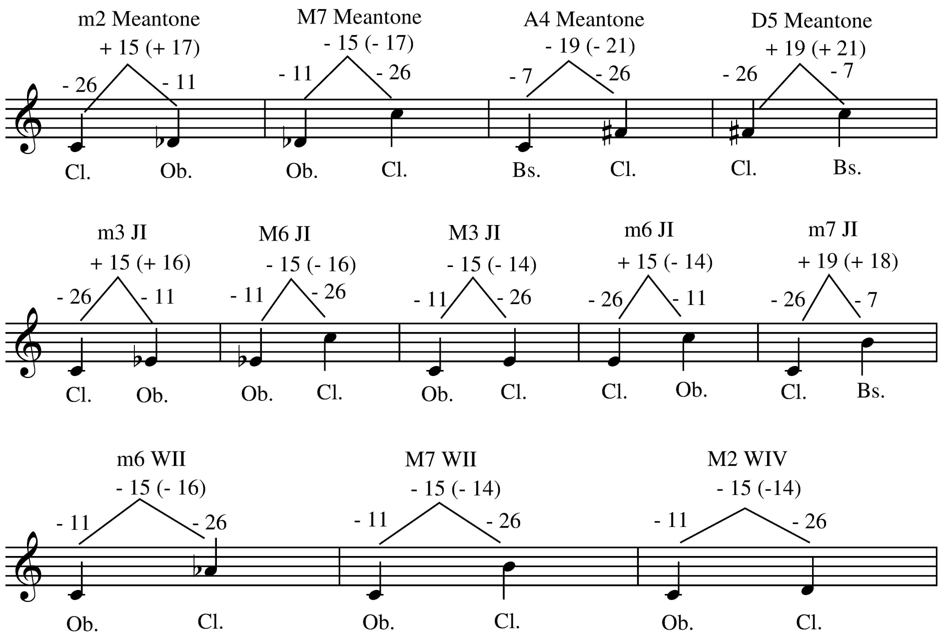


**Fig. 20.** Some intervals in the woodwinds in *Traces from Nowhere*

The use of scordaturas in the strings is preserved as a valid resource for the expansion of the frequential and timbric domain (Fig. 21).

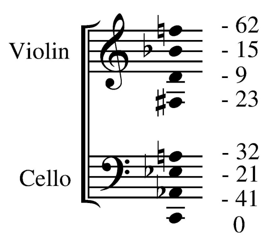


**Fig. 21.** Scordatura in *Traces from Nowhere*

The rapid pattern of pitches in the Disklavier part at the beginning of the piece is written in such a way that in holding the sustain pedal down, the emerging cloud of sounds emanates a large number of harmonic reverberations, and, at the same time, the nearness of the involved pitches also generates micro-beats that give a particular sonic halo to the passage. On the surface, this part seems just an ornamental expansion of the trill (or turn, depending on the number of pitches we take into consideration) placed at the very beginning of the piece, but actually the third level is already comprehended in the writing itself. Its presence becomes more manifest once the remaining part of the ensemble gradually enters, reinforcing the waving sound already present in the micro--beats generated by the Disklavier. Because all the instruments of the ensemble are tuned differently, the pitches they produce interfere with the pitches played by the Disklavier, with their harmonic resonances, and also between themselves.

Looking at the following example (Fig. 22), we see how E♭ played by the Bassoon and the F played by the Clarinet generate a sound roughness within themselves and beats with the pitches of the Disklavier. At bar 3, the pitches played by the strings interfere with the pitches of the Disklavier and with their harmonic projections. The same thing happens for the F# played by the Oboe, whose frequency is placed in between the frequencies of the tremolo played by the Disklavier and also interferes with the harmonic octave projection of the F in the Disklavier part.

By re-analyzing the whole passage in the light of the three levels of music composition, we observe a first level made of two layers: the trill (or turn) of the Disklavier, and the sustained sounds of the ensemble. The second level consists in the functions of these layers: the Disklavier part generates harmonic resonances and micro-beats; the ensemble reinforces these micro-beats by creating a more intense friction between the harmonic resonances of the Disklavier and the pitches played by the ensemble itself; the ensemble also adds new timbre colors to the harmonic resonances generated by the Disklavier; the ensemble has the function to provide a harmonic dimension (chord) through the superimposition of sustained sounds.

The third level is also related to the criterion of "invisible sound," which is the generation of physical phenomena (in this case complex beats and sound roughness), clearly perceptible, that are not immediately observable in the notation, a type of topic comparable with dark matter, invisible matter the existence of which is inferred from its effects on visible matter.

Finally, there is also a connection between the third level and a process I use to shape the musical form of a piece: the implicate/explicate order. This idea is related to the holographic interpretation of the universe and will be the topic of the next section of this paper.


**Fig. 22.** Opening of *Traces from Nowhere*

The concept of a music based on sonic flux implies the notion of non-locality, as everything occurring in the flux itself directly affects and modifies the global perception of the sound matter, much more so than in a type of music where the modification of one parameter does not necessarily imply the alteration of another one. The notion of non-locality describes events that occur simultaneously although separated in space, without being directly connected by an intermediate agency or mechanism.[35]

In music, the idea of non-locality can be expressed, furthermore, through the abolition of musical boundary parameters. If we think of the matter of music as a flux with sonic properties, without dividing it into the components of its parameters (harmony, melody, rhythm, layers, etc.), everything that occurs in the sonic matter will directly affect the global perception of the flux, determining an immediate effect on the sonic mass itself. If the placement of the instruments in the space of the performance (stage, concert hall, auditorium, etc.) determines the subjective perception of external space related to the position of the listener (each listener will perceive one instrument to be closer or farther in terms of the distance between themselves and the sound source), the establishment of the internal space of the sound based on multi-dimensions will point out the perception of the space within the sound material itself, which will be an objective perception of space not related to the spatial position of the listener.

The idea of a constant flow of sound in continuous variation can definitely be traced back to the works of the English composer Thomas Tallis (ca. 1505–1585)—see, for example, his piece *Spem in alium* (ca. 1570)—or even earlier, to the production of the *ars subtilior* (14th century) and the works of, in my opinion, its highest exponent, Paolo da Firenze (ca. 1355–1436). This idea of a musical composition whose parts create a surprising resultant global effect, not thought of as a mere superimposition of its constituted elements, has gone through the whole history of music, from Debussy[36] to Scelsi (his whole output), passing through Ligeti[37] and Penderecki[38] (especially in his 1960s production), and more recently through Horațiu Rădulescu and his idea of *sound plasma*[39] and the spectral school, French and otherwise.

The next step that I believe I have taken with Polysystemism is to root the result of this sonic magma in the initial choice of the material itself. In particular, I am referring to the intervals of the different tuning systems, intervals that emerge only in local contexts,

35 See, for example, Alain Aspect, Jean Dalibard, and Gérard Roger, "Experimental test of Bell's inequalities using time-varying analyzers," *Physical Review Letters* 49, no. 25, (December 1982): 1804–1807.

36 I am thinking, for example, of *La Mer.*

37 Not only his micro-polyphonic works, but also the very first orchestral works of his maturity, *Apparitions* (1958–59) and above all *Atmosphères* (1961).

38 *Threnody for the Victims of Hiroshima* (1960), *Polymorphia* (1961), *De Natura Sonoris no. 1* (1966).

39 See Roger Heaton, "Horațiu Rădulescu, Sound Plasma," *Contact* 26, no. 1 (1983): 23–24.

precisely because they are the result of scordaturas in the strings or different diapasons in the other instruments. Taking this track, these effects only come out in these instruments, with their timbres, with their pitches, and in their specific registers. This way of proceeding in the composition of a piece very deeply binds the final result to the specific structure of the instruments and to the choices made for them in terms of frequency alteration, which brings with it not only a timbre alteration but also specific acoustic phenomena that occur only between certain instruments and in specific ranges.

**Implicate/explicate order**

Composing with different tuning systems simultaneously, and connecting these systems directly with the acoustic phenomena that emanate from them, brings with it the concept of formal and architectural construction based on the concept of implicate/explicate order.

In the second half of the twentieth century, composers became very critical of linear construction. They assumed that it could no longer offer a valid approach to the development of form, as music had abandoned the hierarchical structure of relations between the different degrees of a scale (both in a melodic and harmonic sense), which had somehow ruled also the ways composers dealt with form. In my opinion, however, this consideration is based on a paradox. Even if the way we construct form is non-linear, we make sense of music and sound according to our perception, which lines up the sound events in a linear way according to their order of manifestation.

My answer to form construction lies basically in the idea of implicate/explicate order assumed by the holographic theory of the universe developed by David Bohm. Applying this idea to form, the choice of linear or non-linear construction shifts in the background, as the concept of implicate/explicate order establishes a constant relation between transformations in time and the way they are perceived through listening.

In this approach, choosing a linear or non-linear architecture is equivalent, because selecting one or the other will affect the shape of the piece (and this is clear), but will not affect how we perceive the connections between elements and the aural role of their functions, an aspect that is one of the most prominent features of a valid and well--constructed form.

The implicate/explicate order assumes that what we perceive, what we call reality, is the manifestation of something hidden at a deeper level. The implicate order is the hidden reality while the explicate order consists of its unfolded manifestations: “In the enfolded [or implicate] order, space and time are no longer the dominant factors determining the relationships of dependence or independence of different elements. Rather, an entirely different sort of basic connection of elements is possible, from which our ordinary notions of space and time, along with those of separately existent material particles, are abstracted as forms derived from the deeper order. These ordinary notions appear in what is called the ‘explicate’ or ‘unfolded’ order, which is a special and distinguished form contained within the general totality of all the implicate orders."[40] According to Bohm, rather than a collection of separate objects, it is an undivided whole as the ultimate aspect of physical reality that manifests itself in a continuous dynamic flux.

An example of implicate/explicate order in music is the very beginning of my *Dimensioni nascoste* (Fig. 23).

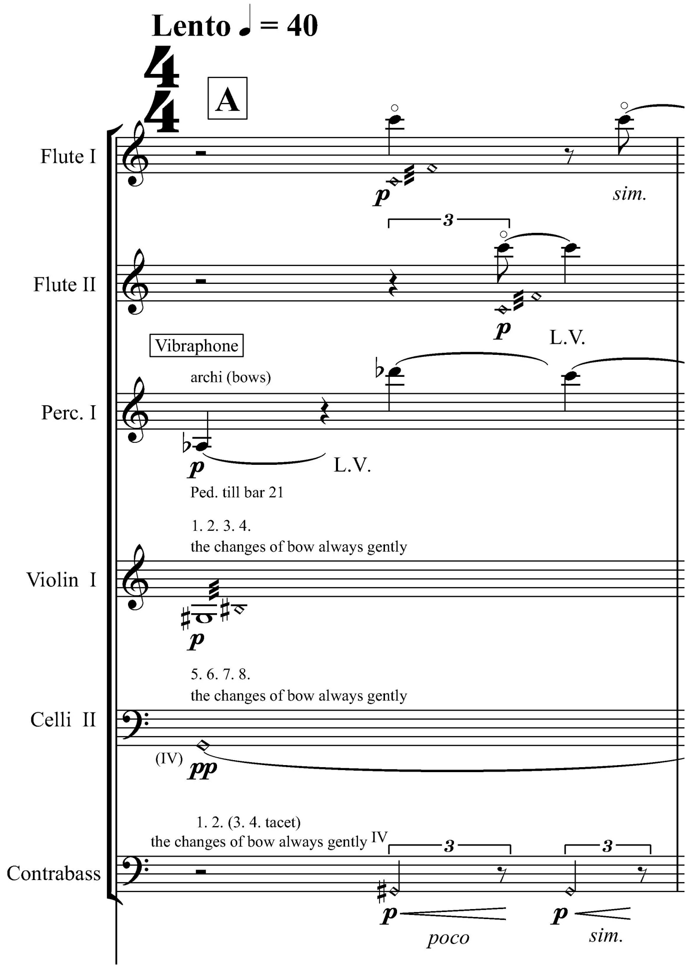


**Fig. 23.** *Dimensioni nascoste*, bar 1

[40] David Bohm, *Wholeness and the Implicate Order* (London: Routledge, 1980), xv.

The tremolo between the G# and B# (harmonic) played by Violin I produces a resulting sound of B# two octaves higher than the B# harmonic. This sound is therefore implied in the tremolo itself. In the third beat of the bar, the flutes make it more manifest, unfolded, reinforcing the resulting sound of the harmonic. The way the sound is produced by Violins I, the tremolo, is the manifestation in the explicate order of the beat occurring in the implicate order between the G# of Violin I and the G natural of the Celli, the beat being an inner and rhythmical articulation of static (sustained) sounds. Here the phenomenon of beats that produce a specific manifestation of rhythm gives birth to the way the sound is produced by Violin I, the tremolo that is in the same way a rhythmic expression of sound.[41] The beat frequency in question has a value of 11,432 oscillations per second.[42] But when the Contrabasses enter, new beat frequencies are added to this one.

Being the resulting G# of the Contrabasses the 5th harmonic of the E fundamental (open string), its frequency is ca. 14 cents lower than its equivalent in 12-ET (played here by Violins I). Its value in frequency is 206,015 Hz (41,203 × 5). This frequency interacts both with the G# played by Violin I (207,65 Hz), having a beat frequency of 1,635, and with the frequency of the G natural played by Celli II (196,218), causing a beat frequency of 9,797. When Flute I enters, playing the C as the unfolded order of the tremolo played by the Violins I (being the C [B#] the resulting sound of the artificial harmonic G#–B#), we find also the transformation of the simple beat we had at the beginning (between G# of Violins I and G natural of the Celli) into a complex beat (when the Contrabasses enter), complex because it is made by two beat rates, the one occurring between the G# of Violins I and G natural of the Celli, and the other occurring between the C of the Flute (in 12-ET) and the resulting B# of the artificial harmonic in the Violins (G#–B#), that pitch, being the 5th harmonic of G#, has a frequency 14 cents lower.

An additional consideration about implicate/explicate order is that it shows another side of immaterial objects that have the possibility to be heard once they pass from being just implied in the musical material to a manifestation of their potential.

41 Unlike Grisey's *Partiels* (1975), in which the composer tries to convert the beat rates into explicit rhythms, in my piece the relationship is in reference to the modality of sound production, in this specific case both musical gestures give it rhythmic expression.

42 The frequency of a beat is given by the difference of the frequencies calculated in Hz. Therefore: G# = 207,65 Hz // G nat. = 196,218 Hz (65,406 × 3, as the G here is the third harmonic of fundamental C – open string). Beat frequency 207,65 – 196,218 = 11,432 Hz.

## Conclusions

During my musical research, I have tried to highlight the phenomenal aspects of sound, to place the human being and the human ability to perceive at the center of the compositional art. The substantial aspect of music has thus become not so much the material but the *sensation* that this material generates in the listener. To create a large number of acoustic phenomena, and to be able to vary their gradations in a meaningful way, the simultaneous use of different tuning systems turns out to be an effective tool in the composer's hands.

I believe that by proceeding in this way it is possible to gradually go beyond the concept of language to reach a place in which forms of energy, conveyed by sound, can lay the basis for a new aesthetic and, who knows, perhaps also for a new way of understanding existence. For, as Plato said, if music changes, even the most important institutions will change accordingly.[43]

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[43] Plato, *The Republic*, Book III.