Printed and Analytical Program Notes for *Cosmos 1*

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Abstract

Contained below are two sets of program notes. The first set, §1, is what would actually be printed in the program of a concert featuring *Cosmos 1*. The second set,§2, is a detailed analysis of the work. The content of §2 is intended to be viewed at the curious leisure of a listener who chooses to follow the link provided in §1 for a detailed understanding of the compositional process.

1 Printed in the Program

Cosmos 1 is meant to be a framework for your imagination. The physical universe is alive in this piece, from the very smallest quantum mechanical processes to the largest structures in the heavens. The best way to listen to this piece is to keep your mind on whatever you think of when you think of the universe, be it galaxies, black holes, atoms, the cosmic-microwave background radiation, or the flying spaghetti monster. Allow this music to coexist with these thoughts and hopefully, by the end, your perception of the cosmos has been enhanced. For an analytical discussion of the piece and a recording, please visit my soundcloud page at www.soundcloud.com/evan11235813 or scan the QR-code.

Waveform of *Cosmos 1*

QR-code that links to www.soundcloud.com/evan11235813

2 Analytical Program Notes

Cosmos 1 is the first in a series of works that explore the use of physical processes mapped to musical variables as a means of generating material. Unlike some of my other pieces, notably *Heat Death*, *Cosmos 1* does not attempt to *only* realize these physical processes. Instead, the processes that control the temporal and harmonic distributions are designed to articulate a larger structural and sonic experience.

2.1 Temporal Distributions

The distribution of events in time has always been an issue I have seriously grappled with as a composer. Not until I found my way into this piece had I ever had an informed, interesting, or even artistically valid reason for putting things where they were in my music. This realization encouraged me to try and create a method of organization I could believe in, and the development and use of mathematical processes created such a method.

Cosmos 1 is a dense layer of interacting and non-interacting temporal distributions. The fundamental layer is a 9-second long pulse played between the bass drum and tam-tam which continues unbroken and unchanged throughout the piece. Above this layer, is the three sectional divisions of the piece, each of equal length. The lengths of these sections were constrained such that $(t_{sec} - \phi_{GR} t_{sec})$ and $3t_{sec}$ were both wholly divisible by 9, where t_{sec} is the length (in seconds) of a section and ϕ_{GR} is the Golden Ratio.[1] Due to the irrational nature of ϕ_{GR}, it is impossible to find an exact solution to the constraints, yet a close approximate solution was found to be $t_{sec} = 210.168$ seconds. This leads to a total duration of 630.504 seconds, or 10 minutes and 30 seconds. The layers above the 9-second pulse and the sectional divisions were all distributed within each section independently.

2.1.1 The First Section of *Cosmos 1*

The predominant material of the first section is a 12-voice canon of chords where each voice changes 12 equally spaced times before they all terminate at the end of the first section. The entrance of each voice is governed by the sine-accumulation equation

$$t_{entrance}(n) = t_{dur} \sin\left(\frac{\pi n}{2N}\right) \tag{2.1.1}$$

where t_{dur} is the duration (in seconds) the equation is valid for and $0 \le n \le N$ is each voice. For the first section of *Cosmos 1*, $t_{dur} = 201.168$ seconds and $N = 16$. Once each voice entered, the time at which it changed its material was governed by

$$t_{change}(k) = (t_f - t(n))k/12 + t(n) \tag{2.1.2}$$

where t_f is the time when the sine-accumulation ends, and $0 < k \le 12$ is each change. The texture these forumlæcreate is smooth, organic, and effective in their accumulation to the end of the first section.

[1]The Golden Ratio is found throughout many works of creative endeavor. It is the solution to the equation $x^2 - x - 1 = 0$ which gives $x = 1.618033989....$ Often, when using it in artistic terms, the inverse is used, $\phi_{GR} = 1/x = 0.618033989....$

The other major gesture in the first section is the violent explosions of the dominant 12-note chord. These explosions occur at the recurring Golden Ratio times which are generated using

$$t_{exp}(n) = \phi_{GR}(t_{dur} - t_{exp}(n-1)) + t_{exp}(n-1) \tag{2.1.3}$$

where, for the first section, $t_{dur} = 210.168$ seconds and $n > 0$. This function generates a recursion of events that are always at the Golden Ratio point of the remaining time before t_f, which can be seen in Table 2.1.1. The entrance of each pitch in an explosion is governed by an inverse-square

n	$t_{exp}(n)$ (sec.)	Δt_{exp} (sec.)
1	129.89	—
2	179.50	49.61
3	198.46	18.95
4	205.69	7.24
5	208.46	2.76
6	209.52	1.06
7	209.92	0.40

Table 2.1.1: The timing values of each of the explosions of the dominant 12-note chord in the first section of *Cosmos 1*. Provided as well is the difference in time between each event showing the rate of accumulation of the events toward the end of the section at $t_f = 210.168$ seconds.

relationship which is scaled by the amount of time until the next explosion. These entrances are governed by

$$t_{exp}^{entrance}(k,n) = (t_{exp}(n+1) - t_{exp}(n))(1 - \phi_{GR}) \left(\frac{k}{K}\right)^2 \tag{2.1.4}$$

where $0 \leq k \leq K$ and $K = 12$.[2]

These two musical processes, the harmonic canon and the explosions form the predominant musical material of the first section. The harmonic nature of these processes also requires discussion, and this can be found in §2.2.

2.1.2 The Second Section of *Cosmos 1*

The second section begins with the climax resulting from the accumulation of harmonic and temporal intensity of the first section. This climax lasts for 9 seconds and is followed by a cello solo of artificial harmonics on the C-string and a more pointillistic textural accompaniment. The textural accompaniment is governed by a system I have since begun to use regularly throughout many of my compositions.

In general, this system involves distributing events onto the nodes of integer divisions of sections duration. Harmonically, each event can correspond to a specific pitch that is always heard at that node. Specifically, the equations governing this process are

$$t(k,n) = t_{dur}\,(n/k) + t_0 \quad \textbf{for} \quad 0 \leq n \leq k \tag{2.1.5a}$$
$$P(k) = \mathrm{map}(k) \tag{2.1.5b}$$

[2]Here, $K = 12$ because the chord this function governs has 12 notes in it, thus 12 unique entrances. However, if it was a 4-note chord instead, K could be 4, or any other value by choice of the composer.

where t_{dur} is the duration of the section, t_0 is a time offset, n is an event, k corresponds to each 'voice' , and the map function is a conceptual mapping function that translates the index k into a pitch value.

For the second section, the specific parameters employed were $t_{dur} = 210.168$ seconds, $t_0 = 210.168$ seconds, $15 \leq k \leq 24$, and $\text{map}(k) = k - 14$ with $P(k) \Rightarrow$ C-harmonic series partial number. The duration of the events generated through this process were chosen æsthetically, and often, the sounding of an event was elaborated on musically. However, the texture this process creates, consisting in this case of 195 unique musical events in the span of 210.168 seconds was too dense and busy for my taste. To circumvent this busyness, I applied an on/off cut function to the entire structure that essentially removed half of the material in very specific ways. This cut was governed by the function and condition

$$t_{cuts}(n) = t_{dur}\sqrt{\frac{n}{N}} + t_0 \tag{2.1.6a}$$

$$\textbf{if } n \text{ is odd, } \textbf{then} \text{ cut } t_{cuts}(n) \rightarrow t_{cuts}(n+1) \tag{2.1.6b}$$

where $0 \leq n \leq N$ and, in this case, $N = 12$ and $t_0 = 210.168$ seconds. The rate at which this function cuts material increases with n, however, the length of each cut decreases with n, creating an oscillation of *on* and *off* segments. The frequency of the oscillation of the textural material increases throughout the section and reaches a maximum at the end of the second section.

Under this texture is perhaps the most complicated segment of music in *Cosmos 1*, the cello solo consisting entirely of artificial harmonics on the C-string. The rhythmic complexity of this solo is the only remnant of the highly rhythmically complex first version of *Cosmos 1*.[3] This solo consists of a melody distributed over a complex rhythmic fabric which is then played as a nearly exact rhythmic mirror, transposed down a semitone. The mirror is not exact because it was not placed in the temporal center of the solo's duration. Instead, it was placed at the Golden Ratio of the solo's duration, requiring therefore, that the material heard after the mirror, in addition to being presented rhythmically backward, be ϕ_{GM} times faster. To generate the initial rhythms, a 'path' through a network of rhythmic nodes generated using Eqs. 2.1.5 was chosen. In this situation, $t_{dur1} = 69.151$ seconds (before the mirror), $t_0 = 228.168$ seconds, $1 \leq k \leq 20$, and $\text{map}(k)$ was arbitrarily chosen as single notes of the subdominant chord, Fig. 2.2.1b. After the mirror, the path chosen for the first half was followed in a reverse direction through the same kind of rhythmic network, with $t_{dur} = 42.738$ seconds, $t_0 = 297.320$ seconds. The order of the pitches chosen before the mirror was also followed in reverse, although the pitches were selected from the tonic chord, Fig. 2.2.1a. The total duration of the cello solo was chosen such that it ends at the Golden Ratio point of the second section. Between this point and the Golden Ratio point of the difference until the end of the second section, the accompanimental texture is left to interact with freely composed imitative fragments of the cello solo.[4] The $n = 2$ Golden Ratio node of the second section, found by Eq. 2.1.3 with $t_{dur} = 210.168$ seconds and an additional $t_0 = 210.168$ seconds is also the Golden Ratio point for the entire piece.[5] I treated this moment in the piece as a moment

[3] This first version of *Cosmos 1* was first run in the September, 2013 Royal Academy of Music Symphony Orchestra workshop. The highly complex rhythms required an unnecessarily high level of concentration to generate what was predominantly an un-pulsed texture. The second version of *Cosmos 1* removed all of this rhythmic complexity except in the cello solo.

[4] For better or worse, it should be noted that this is the *only* place in all of *Cosmos 1* where there is any freely composed music.

[5] This is easy to show. Taking Eq. 2.1.3 for an arbitrary ϕ and adding t_{durA} to it for $n = 2$ gives, after some

of calm resolution, and a simple, homogeneous statement of the C-harmonic series is distributed throughout the orchestra as a single, cross-faded chord. From this chord until the end of the second section, the accompanimental texture is all that is present.

2.1.3 The Third Section of *Cosmos 1*

The third section is divided into two parts, the first being the 'afterglow' of the massive chord that begins the third section, and the second being a coda of memories. The division between the afterglow and the coda occurs at the Golden Ratio point of the third section. The afterglow consists of two very simple processes, the first being the slow accumulation of the dominant chord (Fig. 2.2.1c) in the strings and the second being a varied statement of the accompanimental material from the section section in the brass and woodwinds. The accumulation of the dominant chord in the strings is governed by Eq. 2.1.1 with $t_{dur} = 117.168$ seconds and an additional $t_0 = 432.336$ seconds, and $N = 16$. This accumulation begins 12 seconds after the third section begins by emerging as the remnant of the massive dominant chord that opens the third section, and finishes at the Golden Ratio point of the third section. Each new n corresponds to adding the next note of the dominant chord and sustaining it until the end of the accumulation.

The variation of the accompanimental texture from the second section in the afterglow uses Eq. 2.1.5 with $t_{dur} = 129.168$ seconds, $t_0 = 420.336$, and $0 \leq k \leq 12$. The mapping function simply gave the partial for ever k, such that $\text{map}(k) = k$. This texture was then cut using a Gaussian probability function

$$\rho_{cut}(n,k) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left(\frac{-(n/k - 1/2)^2}{2\sigma^2}\right) \tag{2.1.7a}$$

$$\textbf{if } \rho_{cut}(n,k) < 0.2, \textbf{ then} \text{ cut event } t(n,k) \tag{2.1.7b}$$

where $\sigma = 0.15$ was chosen on an æsthetic basis. For each event that passed the cut, the pitch generated by $P(k)$ was sustained for exactly 9 seconds. This creates a kind of slowly morphing, relatively consonant sound mass.

The coda that closes the piece consists of nine 9 second phrases that alternate between the solo cello harmonics playing through the tonic tone-row and orchestral chords that first accumulate, then dissipate, then accumulate, and finally exist in stasis. The accumulations are governed by Eq. 2.1.1 with $t_{dur} = 6$ seconds and $N = 16$, where each $t(n)$ corresponds to the next note in the chord. The dissipation process is just a mirror of this accumulation process. The stasis chord is simply 9 seconds long, and is followed by the final 9-second pulse and the end of the solo cello's tone-row.

2.1.4 Mapping Timing Values onto the Score

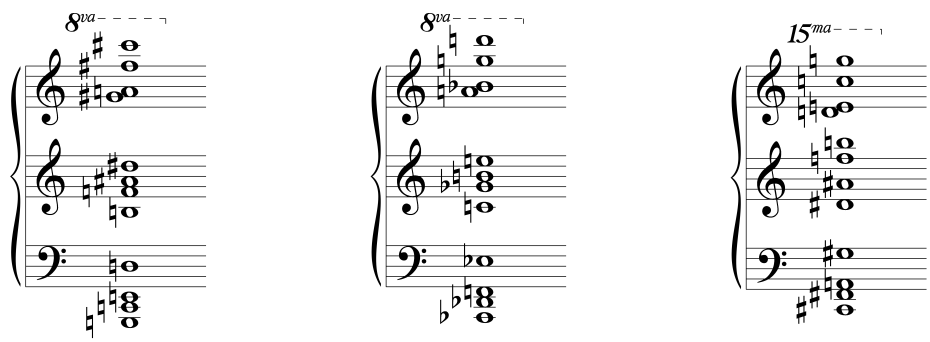
The process of turning a timing value in seconds into a rhythm requires a certain level of approximation. The first step in this mapping is to choose a tempo and time signature for the piece. *Cosmos 1* has a time signature of $\frac{3}{4}$ and a tempo of 'Cosmically Indifferent ♩ = 60' throughout. In the first version of *Cosmos 1*, the beat was divided into 5, 6, 7, and 8 equal divisions, and the timing of each event was rounded to the nearest division and this generated the rhythm. In the

manipulation, $t(2) = t_{durA}(-\phi^2 + 2\phi + 1)$. Doing the same for $n = 1$ and $t_{durB} = 3t_{durA}$ gives $t(1) = \phi t_{durB} = 3\phi t_{durA}$ and setting these two equal gives $0 = -\phi^2 - \phi + 1$ which has the solutions $(1-\sqrt{5})/2 \approx -1.618$ and $(\sqrt{5}-1)/2 \approx 0.618$, the latter of which is the Golden Ratio.

second version, only the divisions 4, 6, and $1/8^{\text{th}}$ and $7/8^{\text{th}}$s were used.[6] The rhythms generated for the cello solo in the first version, as mentioned in §2.1.2 were kept in the second version, but all other rhythms were re-calculated using these new beat divisions. All of the calculations and timing-to-rhythm mappings were made using simple algorithms in MSOffice Excel 2010.

2.2 Harmonic Distributions

The entire harmonic discourse of *Cosmos 1* is constructed out of three chords and one transposition. The most important chord, which could be referred to as the tonic chord was constructed from a spectral analysis of a cello's open C-string. An FFT was performed on a C-string sample and the partials were ranked in order of amplitude. Each new partial in the ranking formed the next note in the chord, and although this might seem like it would recreate the harmonic series, it in fact forms a much more interesting sonority. The resulting chord can be seen in Figure 2.2.1a. Of course, if there is a tonic chord, there needs to be a dominant chord. The dominant chord is simply the inversion of the tonic chord, which can be seen in Figure 2.2.1c. Similarly, there is a subdominant chord generated by transposing the tonic chord up a semitone which can be seen in Figure 2.2.1b.



(a) Tonic (b) Subdominant (c) Dominant

Figure 2.2.1: The tonic, subdominant, and dominant chords of *Cosmos 1*.

The only other sonority used is that of the C-harmonic series in root-position. This harmony first appears in the first section as the trombones, tuba, bassoons, and horns participate in the accumulation of the pitches in the harmonic series in conjunction with the 9-second pulse. Each occurrence of the next new pitch in the harmonic series added to the chord is governed by

$$P_{harm}(n) = \lfloor Cn^2 + 1 \rfloor \tag{2.2.1}$$

where C is a tuning constant and $1 < n \leq N$ is the n^{th} iteration. In the first section, where this process is deployed, $N = 24$ and $C = 11/576$ to generate the values $P_{harm}(1) = 1$ (the first partial) and $P_{harm}(24) = 12$ (the twelfth partial).[7] The use of 24 as an upper limit on n is because there are 24 9-second pulses in the first section.

[6]For instance, say the timing value indicated a beat value of 0.718. In the first version, this would correspond to an event happening on the 5^{th} part of a septuplet. In the second version, this would correspond to an event happening on the 3^{rd} 16^{th} note of the beat.

[7]The value $C = 11/576$ can be derived from requiring that $C(24)^2 + 1 = 12 \Rightarrow C = 11/24^2 = 11/576$.

As mentioned in §2.1.1, there is a 12-voice harmonic canon that evolves using Eq. 2.1.1. The harmonic content of the canon is based on the common-tone transpositions of three different 4-note chords. The three chords are made up of the 3 divisions of the tone-row generated by the C-string FFT and are shown in Fig. 2.2.2. Each of the chords in Fig. 2.2.2 was chromatically transposed

(a) Set 1 (b) Set 2 (c) Set 3

Figure 2.2.2: The three 4-note chords that are the basis of the 12-voice canon in the first section of *Cosmos 1*.

through all 12 transpositions, and the common tones were compared between each transposition and its root-position, as well as between each transposition and each of the other chords' root-positions. This created a harmonic network that could be navigated using rules about common-tones. For instance, the first and last voices of the canon ($n = 1$ and $n = 12$ of Eq. 2.1.1) have the chord progression shown in Fig. 2.2.3, and the rule governing the progression is that each new chord must have 3 common-tones with the previous. All of the voices follow this rule, except between two specific chords in the progression where only two common-tones are required. The voices are paired around the middle to have the same progressions, such that voices 1 and 12 are the same, as are 2 and 11, 3 and 10, 4 and 9, 5 and 8, and 6 and 7. In each set of progressions, the chord after the higher numbered of the pairs is only required to have two common-tones with its previous, so that, for instance, the 11^{th} chord in the progression for voices 2 and 11 has only two common-tones with the 10^{th}. This creates a harmonic texture that begins simply as an elaboration of a C-major chord and slowly evolves in complexity and dissonance until it ends as 12-voice, 12-note chord.

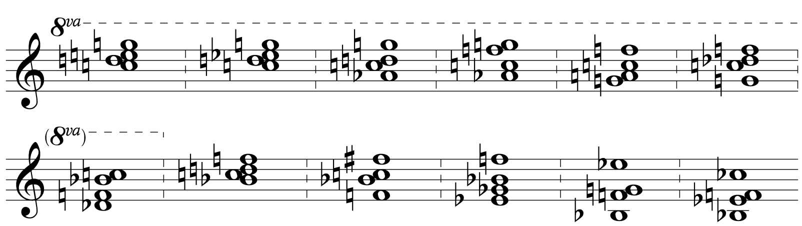


Figure 2.2.3: The harmonic progression of first and twelfth voices in the harmonic canon that opens *Cosmos 1*.

In general, the prevailing harmonic sonorities throughout the piece were chosen intuitively and in a creative response to the requirements of the form. The only major statement of subdominant chord is the melodic elaboration of this harmony in the cello solo that features centrally in the second part. The first section of the cello melody is heard in the subdominant sonority and then is repeated backward and transposed down to the tonic sonority. This is created as a way to regulate the harmonic tension and resolution of the section section, and the piece as a whole. Another example of the pseudo-tonal treatment of the harmonic material is in the third section.

Here, before the final statements of the sub-coda, the strings slowly add together to produce the dominant chord. This chord is then resolved by the melody played on the solo cello, which is the notes of the tonic chord played in order from the top of the sonority to the bottom. This creates a melodic resolution of the harmonic tension created through the entire third section. This tension is further increased by a second layer of the C-harmonic series in the brass and woodwinds juxtaposed to the string's harmony.

2.3 A Brief, Concluding Remark

As a final note, I feel it is important to emphasize how little of an understanding of everything covered in §2 is to the listening experience. The reason the program note presented in §1 fails to mention anything covered in §2 is that the *most important* experience that should be achieved by a performance of *Cosmos 1* is that it ignites the imagination of the listener in a cosmic way. I am proud of the tools I have developed to make this piece, and in the context of all of my music, I am particularly fond of the sonic results these tools generate. However, like when admiring great architecture where we do not need to know what kind of scaffolding was used to put the building together, I hope that the discourse of sounds in *Cosmos 1* speak for themselves. I have presented the tools and methods of composition here as a means of further understanding them myself, and as a way to share my rather scientific way of engaging with composition. Thank you for your interest if it has taken you this far into these notes, and I sincerely hope that *Cosmos 1* awakens within you, if only for a moment, a sense of the greatness of the cosmos.