Sets, Scales, and Symmetries: The Pitch-Structural Basis of George Crumb's *Makrokosmos* I and II

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George Crumb's *Makrokosmos*, Volumes I and II, are widely regarded as major contributions to the twentieth-century piano literature and together constitute a *tour de force* of timbral exploitation of the instrument. Previous analytical studies concerned with pitch structure in these pieces consist principally of the identification of various seemingly disparate compositional materials and devices and offer little insight into any larger aspects of structure that might strengthen and energize the music.[1] Much of what has been written about the *Makrokosmos* pieces has tended instead to focus on Crumb's stylistic idiosyncracies. This in turn has encouraged an assumption that pitch structure in this work is insignificant, or at best simplistic, and that the essence of the music lies more with the extramusical references and special effects. It has often been observed, for example, that Crumb's persistent use of a limited number of pitch constructions lends to his music a high degree of clarity and consistency; but the existence of any substantive structural depth has remained in question, as evidenced in the following statement by Robert Moevs:

> Heterogeneous borrowings, superpositions, sometimes rudimentary transcriptions that enter along the way, sounds, motives, phrases, passages, procedures, entire structures fail to break this persisting unity, but rather point up the sense of constriction produced by tightly circumscribed use of primary material, an assemblage of spooky effects and symbols chosen to evoke a particular mood, and a compositional method reduced essentially to their simple concatenation. The lack of musical substance, in turn, exposes the emptiness behind the assortment of symbolic-expressionistic titles

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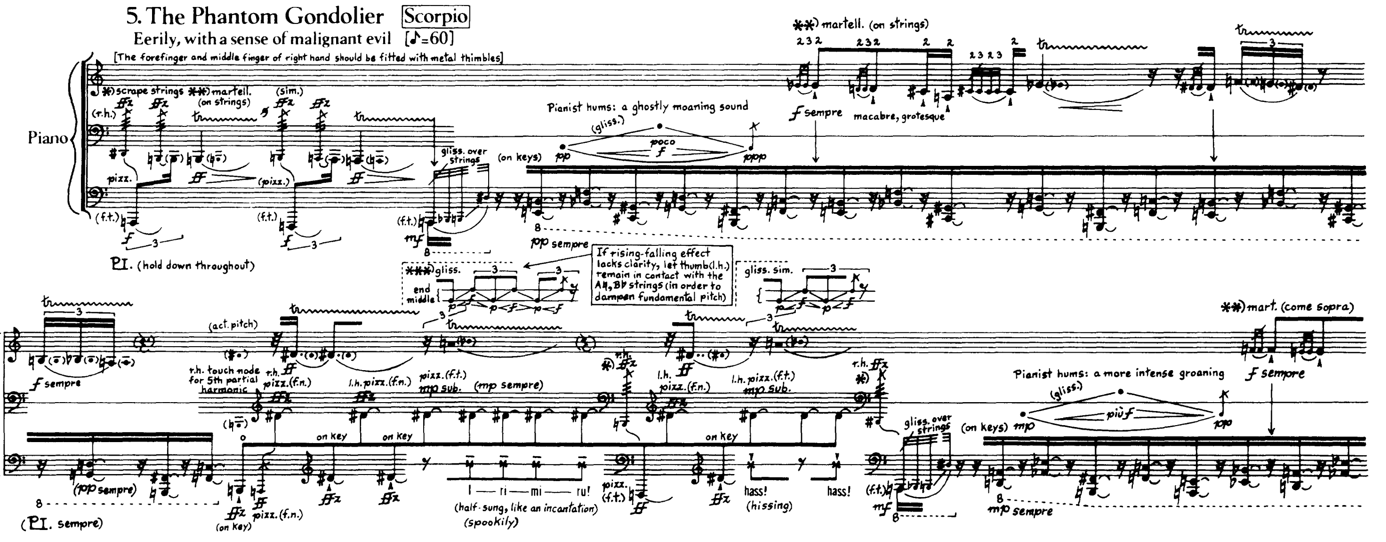
[1]Detailed analyses of pieces from *Makrokosmos* I and II are attempted in three earlier studies. Both Suzanne Harkins, in "A Study of Constructional Principles in George Crumb's *Makrokosmos*, Volume I" (M.A. thesis, American University, 1974), and Robert Vernon Shuffett, in "The Music, 1971–1975, of George Crumb: A Style Analysis" (D.M.A. thesis, Peabody Conservatory of Music, 1979), adopt descriptive-analytical approaches that fail to identify any underlying process or to set up any structural model which would give depth or perspective to their observations. Donna Gartman Schultz, in "Set Theory and its Application to Compositions by Five Twentieth-Century Composers" (Ph.D. dissertation, The University of Michigan, 1979) subjects one of the pieces ("Rain-Death Variations") from *Makrokosmos* II to a highly restrictive analysis based on the set-complex theories promulgated in Allen Forte, *The Structure of Atonal Music* (New Haven and London: Yale University Press, 1973); her inconclusive results are due largely to a rather arbitrary and myopic segmentation of the score.

Example 1. "The Phantom Gondolier," Vol. I No. 5, systems 1 and 2



and descriptions not to be taken seriously . . . that are added throughout and together create the panoply of a *cavaliere inesistente*.[2]

The purpose of the present paper is to go beyond simple identification of pitch constructions in an effort to elucidate some of the underlying processes by which the pitch-structural materials of *Makrokosmos* I and II are assimilated into reticulate organizational schemes, thereby demonstrating that these materials are in fact well integrated and rigorously treated. This study employs certain rudimentary tenets of set theory—primarily the designation of pitch-class (pc) set types—as part of an analytical method formulated to address Crumb's specific approach to pitch structure in these pieces.[3]

In the *Makrokosmos* volumes, units of pitch material are generally displayed in one of two ways: individual, self-contained *figures* which are separated temporally, timbrally, or registrally from other units; and *strains* comprised of vertical or linear formations which progress or recur in some consistent pattern over longer spans of time. The difference between the two is illustrated in Example 1. The opening gesture (preceding the first *glissando* on the bass strings) is a clearly delineated figure, as are the first melodic unit (on

[2]Robert Moevs, "Reviews of Records" (review of *Makrokosmos*, Vol. III), *Notes* 62 (1976), 302.

[3]For a complete demonstration of these structural principles, including detailed analyses of all 24 pieces in *Makrokosmos* I and II, see Richard Bass, "Pitch Structure in George Crumb's *Makrokosmos*, Volumes I and II" (Ph.D. dissertation, University of Texas, 1987).

Panoply = panóplia, armadura medieval, escudo, troféu.

the upper staff of the first system ending with the trill on E♭) and the second melodic unit, which concludes with the first triplet on the upper staff of the second system. All of this material is played on the strings, either *pizzicato* or by fingers fitted with metal thimbles. The other type of constructional unit—a strain—is represented by the succession of perfect-fifth simultaneities on the lower staff. With some internal repetition, this strain initiates a progression which continues with a transposed restatement beginning near the end of the second system.[4] Excerpts from the score reproduced in the following examples consist of figures and strains, in whole or in part, that demonstrate as economically as possible the fundamental materials and processes of pitch-structural organization throughout *Makrokosmos* I and II.

In these pieces, certain trichordal pc set types (that is, T_n/T_nI types) function as primary structural units from which larger sets and scale types are generated through symmetrically conceived arrangements of pcs.[5] One simple application of this procedure is illustrated in the opening figure of Example 1: the six-note gesture D♯–A–B/B–F–A is divisible into two three-note segments, or halves, identical in rhythm and in modes of articulation. Each expresses a [0,2,6] trichord; taken together they form a [0,2,6,8] tetrachord which is symmetrical not only in normal form but also in its particular disposition.

[4]In this piece, each statement of this strain consists of three pairs of tritone-related perfect-fifth simultaneities and contains ten pcs in all. Within statements, the transpositional levels are arranged so that the linear tritone formed by the upper pcs of the first pair of fifths (B–F in the first statement) recurs as the lowest pcs in the third pair. The pcs omitted from the first statement (A and E♭) are the ones duplicated through registral exchange in the second statement, and so on, producing a cycle of aggregate completions.

[5]Conventional set-theoretical terms and expressions employed in the present study follow those in John Rahn, *Basic Atonal Theory* (New York: Longman, 1980).

The four set types that serve as basic trichords are identified in Table 1a; these are listed in order of prevalence and exhibit certain properties which help to explain their primacy as generators of structure.[6] All, for example, contain three *different* interval classes, as indicated by their ic vectors. As a group of basic sets, they offer an ideal balance of ic content: each ic appears once in exactly two of the trichords, and any two trichords share exactly one ic. None of these trichords is transpositionally or inversionally symmetrical, but the addition of one pc to duplicate the first interval of the normal form extends each trichord to become an inversionally symmetrical tetrachord, as shown in Table 1b. Except in the infrequently used [0,1,4,5] tetrachord, these extensions produce no ics which are not present in the correspondent trichords. The two most prevalent tetrachords—[0,2,6,8] and [0,1,6,7]—are not only inversionally symmetrical but also transpositionally symmetrical at the tritone (at T_6), and both are completely saturated with the trichordal subset types from which they are derived ([0,2,6] and [0,1,6] respectively). The trichordal subset content of [0,2,5,7] is limited to two types—[0,2,5] and [0,2,7]—which are used almost interchangeably in some of the pieces.

These trichords and tetrachords are also related to certain larger collections which represent familiar scale types, including the whole-tone collection, [0,2,4,6,8,10], and the anhemitonic pentatonic collection, [0,2,5,7,9]. Both of these sets can be arranged symmetrically, and both can be generated by a series of completely interlocking trichords of the same type (Figures 1a and 1b). The use of interlocking [0,2,6]

[6]Thomas R. DeDobay, in "The Evolution of Harmonic Style in the Lorca Works of Crumb," *Journal of Music Theory* 28 (1984), 89–111, also notes Crumb's use of trichordal set types to construct larger harmonies. DeDobay's findings, however, suggest that the trichordal set types employed in these earlier works (dating from 1963 to 1971) are not as rigorously interconnected as they are in *Makrokosmos* I and II (1972–73).

Table 1. Primary structural trichords and tetrachords

(a) basic trichords

normal form	*ic vector*
[0, 2, 6]	< 0, 1, 0, 1, 0, 1 >
[0, 1, 6]	< 1, 0, 0, 0, 1, 1 >
[0, 2, 5]	< 0, 1, 1, 0, 1, 0 >
[0, 1, 4]	< 1, 0, 1, 1, 0, 0 >

(b) symmetrical tetrachords

normal form	*ic vector*
[0, 2, 6, 8]	< 0, 2, 0, 2, 0, 2 >
[0, 1, 6, 7]	< 2, 0, 0, 0, 2, 2 >
[0, 2, 5, 7]	< 0, 2, 1, 0, 3, 0 >
[0, 1, 4, 5]	< 2, 0, 1, 2, 1, 0 >

trichords to construct a whole-tone scale is illustrated in Example 2 (the actual pitches are fifth-partial harmonics; one pitch—C—is duplicated at the end of the excerpt). The conjunct symmetrical display of [0,2,5] trichords forming the pentatonic collection of Figure 1b appears in Example 3. The inversionally symmetrical tetrachords derived from these basic trichords are also represented in the scales. The whole-tone collection contains [0,2,6,8] three times, and the pentatonic collection contains [0,2,5,7] twice.

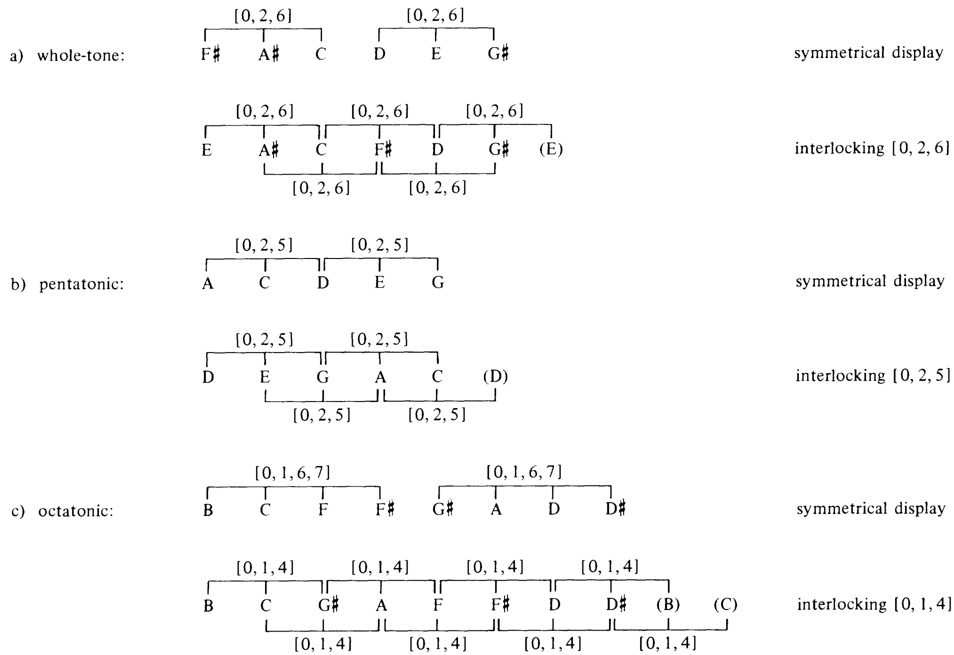
A third scale of great structural significance is the octatonic collection, [0,1,3,4,6,7,9,10]. It is also a symmetrical set, one which can be generated by a display of two [0,1,6,7] tetrachords (related in turn to the [0,1,6] trichord), or expressed as a series of completely interlocking [0,1,4] trichords (Fig. 1c). The pitches of the two [0,1,6,7] tetrachords appear in Example 4, and the interlocking [0,1,4] trichords are illustrated in Example 5. The octatonic collection is often represented by its hexachordal subset [0,1,3,6,7,9], a set type which is transpositionally symmetrical and which exhibits properties that have relevance with regard to other structural pc sets. This hexachord can be generated by the combination of two like trichords of types [0,1,4], [0,2,5], or [0,3,7], always at T_6 (Fig. 2).[7] It can also be expressed as a display of two [0,2,5,8] tetrachords, again at T_6 and with a shared tritone. The trichordal partitionings of the hexachord are illustrated in Example 6.

In addition to these generating, partitioning subsets, the hexachord contains as subsets the tetrachords [0,2,6,8] and [0,1,6,7], establishing its importance as a composite set for all the primary trichords and the two most prevalent tetrachords, as well as a source for two additional sets of secondary structural significance, [0,3,7] and [0,2,5,8]. Similarly, the octatonic collection can be partitioned into two T_6-related forms of another set, [0,3,5,8] (Ex. 7).

Figure 3 summarizes the interrelationships between the structural pc set types. The basic trichords shown at (a) are extended to produce the symmetrical tetrachords listed at (b) and also function as generators of the scale types and the [0,1,3,6,7,9] hexachord at (c). The partitioning subsets at (d) are extracted in turn from the octatonic collection or hexachord at (c). Arrows pointing from right to left denote the non-generating tetrachordal subsets of the structural hexachord. Each horizontal row constitutes a family of sets closely related through progressive derivation, but the exclusivity of each group deteriorates as the sets become larger, and all the sets are related at some point in their progressive series to the octatonic collection and the [0,1,3,6,7,9]

[7]The hexachord [0,1,3,6,7,9] may also be produced by the combination of two [0,1,3] trichords at T_6; however, this partitioning of the hexachord is not exploited in the *Makrokosmos* pieces. For a formal discussion of the property of transpositional combination, see Richard Cohn, "Inversional Symmetry and Transpositional Combination in Bartók," *Music Theory Spectrum* 10 (1988), 19–42. Also relevant is Cohn, "Some Significant Properties of Transpositionally Invariant Sets," paper presented at the Eleventh Annual Meeting of the Society for Music Theory, Baltimore, 1988.

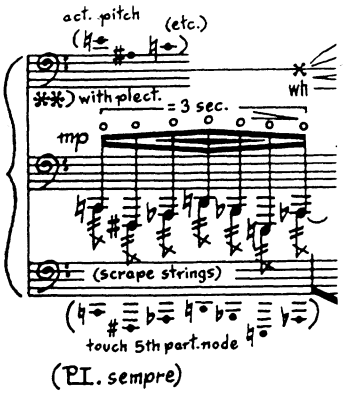
Figure 1. Segmentations of larger collections



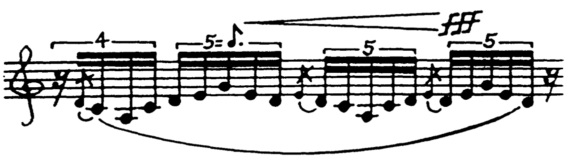
hexachord. This tightly interwoven complex of pc sets offers not only a variety of structural units but also the potential for carefully controlled interaction within the system.

The consistent use of such a small number of set types evolves a pitch-structural analogue that permits elements outside the system to be interpreted as nonessential, or embellishing, entities. For example, pc sets consisting of contiguous chromatic segments ([0,1,2], [0,1,2,3], and so forth) are prevalent as surface details but tend to function in an ornamental rather than structural capacity. These and other sets may also occur as a consequence of the interaction between structural sets or simply as subsets of the larger collections. Such is the case in Example 8, which is a display of two mutually exclusive pentatonic collections (actually a subset on the lower staff) followed by a similar arrangement of opposing whole-tone collections. The complete aggregate is expressed in this passage, and pitches which occur in close proximity to one another produce numerous small chromatic collections; but it is the opposition of similar scale types and the progression from one scale type to the other that form the pitch-structural basis of the passage. For example, the quintuplet trill figures on C5–D5 and D5–E5 on the upper

Example 2. "The Abyss of Time,"
Vol. I No. 9, beginning of system 2



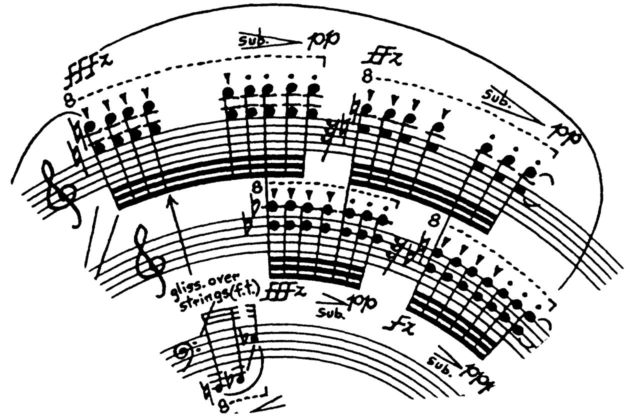
Example 3. "Morning Music," Vol. II No. 1, system 1
(excerpt, lower staff)



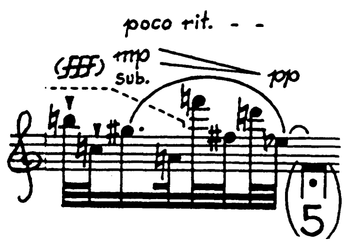
staff near the middle of the excerpt form a [0,2,4] trichord which is shared between the pentatonic and whole-tone collections in the upper part, and which represents a kind of modulation from one scale type to the next.

The pitch structure of the *Makrokosmos* pieces shows evidence of derivation from other symmetrical schemes as well. The tritone, for instance, as the interval which bisects the octave and one that is present in the two most prevalent basic trichords, [0,1,6] and [0,2,6], takes on great importance and in a number of pieces serves as a tonal axis. Other

Example 4. "Twin Suns," Vol. II No. 4, system A (excerpt)



Example 5. "Litany of the Galactic Bells," Vol. II No. 11, end of system 1



symmetrical ideas that influence pitch structure include the division of material according to the arrangement of white and black keys on the keyboard (as is the case at the beginning of Ex. 8), the use of the center of the keyboard (E4/F4) as an axis, and the notation of pitch constructions so that they have the same appearance when viewed upside down. This last device—visual symmetry—is illustrated in Example 9a. The sonority (the "mystic chord" to which the

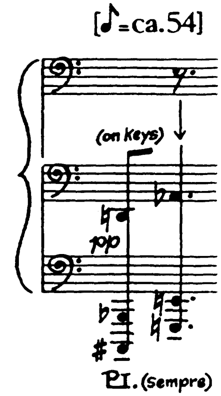
Figure 2. Partitionings of [0,1,3,6,7,9] (like subsets at T_6)

[0,1,4]: A C C♯	+	[0,1,4]: D♯ F♯ G	=	[0,1,3,6,7,9]
[0,2,5]: C♯ D♯ F♯	+	[0,2,5]: G A C	=	[0,1,3,6,7,9]
[0,3,7]: C D♯ G	+	[0,3,7]: F♯ A C	=	[0,1,3,6,7,9]
[0,2,5,8]: C♯ D♯ F♯ A	+	[0,2,5,8]: G A C D♯	=	[0,1,3,6,7,9]

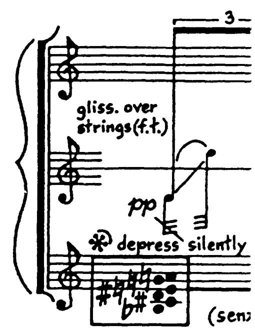
title refers) is a [0,1,6,7] tetrachord, the pitches of which fall on the same lines and spaces of the grand staff when the score is read upside down. Example 9b shows a subsequent appearance of the sonority notated to emphasize this unusual kind of retrograde-inversional symmetry.

Specific pcs and intervallic relationships often function as focal points for entire pieces and take on motivic roles in both local and long-range constructions. They may be used to connect adjacent figures and strains or to connect adjacent pieces. A specific pc may be brought into relief by its disposition as the highest or lowest pitch of a constructional unit, or as a pitch symmetrically nested at the center of a particular passage, section, or piece. The degree of structural rigor varies from one piece to another, and pitch content itself may be quite dense or remarkably sparse in the individual pieces. But the principles outlined in the foregoing discussion permeate the structure of the entire set, and there are numerous intravolume and intervolume connections that help to fuse the pieces into a coherent cycle. The analytical discussion below focuses in detail on two specific pieces as

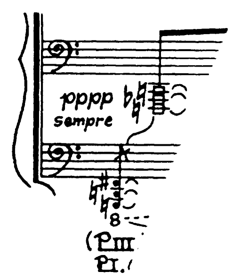
Example 6. Partitioning trichordal subsets of [0,1,3,6,7,9]
(a) "Primeval Sounds," Vol. I No. 1, beginning of system 2



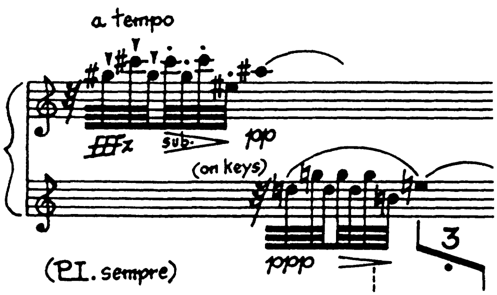
(b) "Music of Shadows," Vol. I No. 7, beginning of system 1



(c) "The Abyss of Time," Vol. I No. 9, beginning of system 1



Example 7. "Litany of the Galactic Bells," Vol. II No. 11, beginning of system 2



an illustration of the ways in which the various aspects of pitch structure are combined, and in which different organizational procedures are carried out simultaneously.[8]

"Primeval Sounds (Genesis I)," the first piece in *Makrokosmos* I, assumes a role which is largely expository in relation to the cycle as a whole. It introduces not only the stylistic character of the *Makrokosmos* volumes, but also many of the primary pitch-structural materials and processes that recur in subsequent pieces. Its focus is on the interaction between the basic trichords [0,2,6] and [0,1,4] and their expansion into larger sets, including complete whole-tone and octatonic collections. The trichord [0,2,5] and other octatonic subsets, in particular the [0,1,3,6,7,9] hexachord, are also introduced as structural entities. Symmetrical arrangements, together with the processes of textural expansion and contraction, provide the controlling organizational framework for the various pitch-structural units.

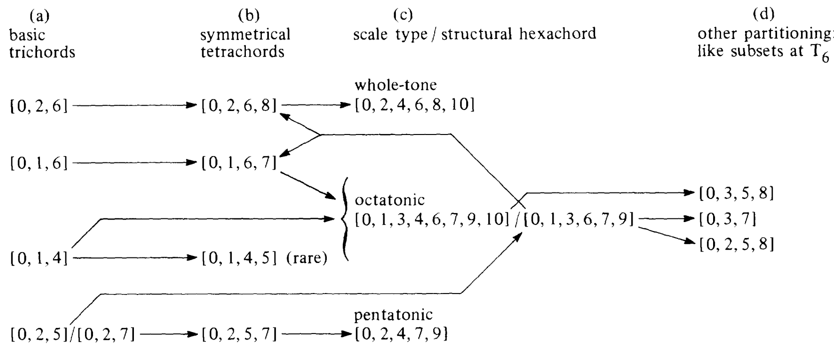
The piece is in two related sections preceded by an introductory passage (Fig. 4). The introduction consists of two similar phrases (designated *a* and *a'*), and at its conclusion a light metal chain is dropped onto the bass strings to produce metallic vibrations throughout the rest of the piece. Section I begins with a strain (*b*) comprised of three groups of seven simultaneities each. A transitional figure based on the beginning of *b* leads to figures *c* and *d*, which serve as a climax for the section. The second section opens with a strain (*b'*) very similar to that of the first section but truncated by the conversion of its third group of simultaneities into another transitional passage. The second section concludes with figures (*c'* and *d'*) similar to those at the end of section I, plus an additional figure (*e*). A figure consisting of three repeated-note gestures (*x*/*x'*) exists on a separate registral and timbral stratum and consists of the pitches A, B, and F, functioning as an "overlay" which occurs once in each section. Numerous *glissandi* and clusters are interspersed throughout the piece. The overall contour as determined by dynamic intensity, rhythmic activity, and textural density overlaps the formal divisions: the material in the first section undergoes a process of intensification which is gradually reversed at the beginning of section II and is then resumed with the third group of simultaneities in the *b'* strain.

The introductory figures *a* and *a'* consist of seven simultaneities each, all of which are of the same type: pairs of [0,3,7] trichords at T_6, comprising a succession of [0,1,3,6,7,9] hexachords (Fig. 5).[9] Viewed as minor triads in the traditional sense, these trichords are arranged in a pattern in which their harmonic positions (cycles of root position, first inversion, second inversion) yield a rising lin-

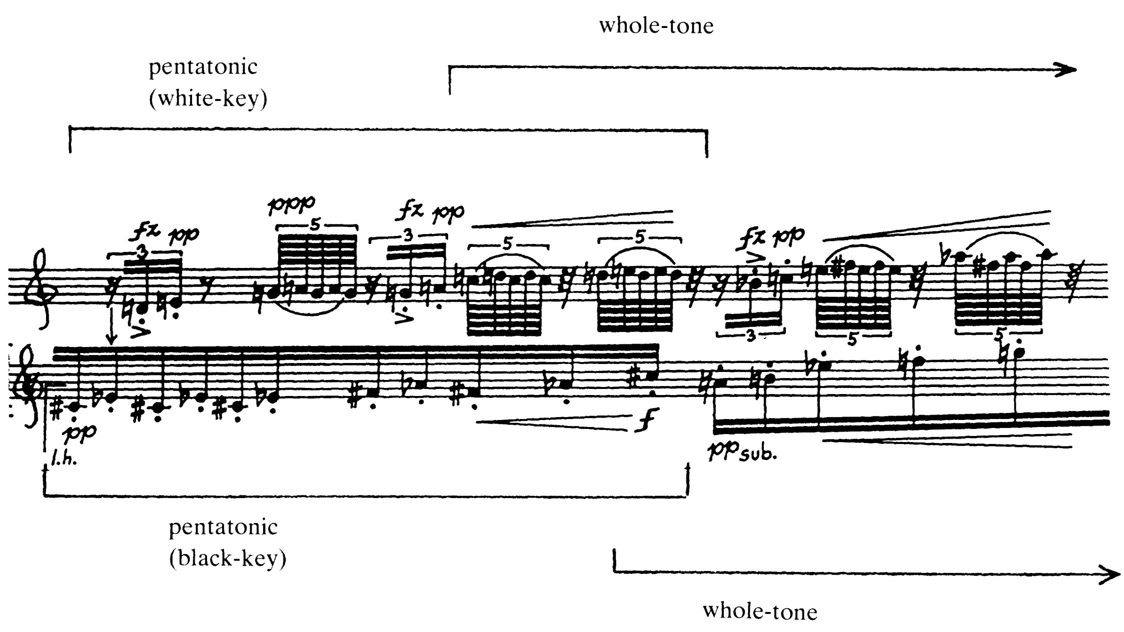
[8]It is assumed hereafter that the reader is in possession of the published scores: George Crumb, *Makrokosmos*, Volumes I and II (New York: C. F. Peters, No. 66539a [1974] and No. 66539b [1973]).

[9]A remarkable example of a long-range intravolume connection exists between the first simultaneity of this piece and that of the seventh piece in the volume, "Music of Shadows (for Aeolian Harp)"; the two are complementary hexachords. The first sonority in the latter piece, however, is constructed not as a combination of [0,3,7] trichords, but instead as two [0,2,5] trichords at T_6, the pitches of which are directly transferred from two figures at the end of the preceding piece, "Night-Spell I" (Vol. I No. 6), so that the emphasis on these pitches falls at the precise midpoint of the volume.

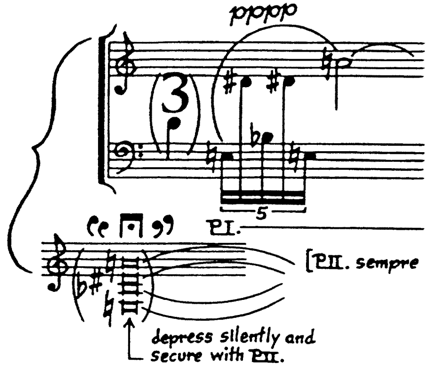
Figure 3. Summary of interrelationships between structural pc sets



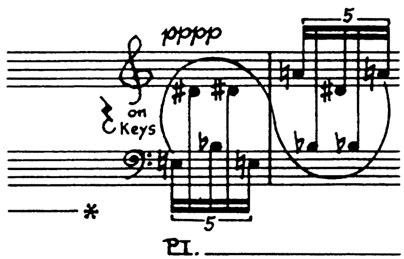
Example 8. "Rain-Death Variations," Vol. II No. 3, end of system 3



Example 9. "The Mystic Chord," Vol. II No. 2: (a) m. 1



(b) mm. 12–13



ear progression in all voices, whereas the progression of triad roots descends chromatically. Figure *a′* begins with a repetition of the preceding simultaneity and continues the progression. The result is a second registral exchange which reverses the first.

Another consequence of the symmetrical structuring of these figures is the trichordal content of the ascending lines. The line in the highest voice on each staff (right hand and left hand are abbreviated RH and LH in Fig. 5) consists of interlocking [0,2,6] and [0,2,5] trichords with a [0,3,7] occurring at the center of each figure as well as at the center of the two figures considered as a whole. The [0,3,7] trichords therefore appear in this passage not only as vertical sonorities but also in a retrograde-symmetrical arrangement within the linear structure of the highest voice. The entire linear progression expresses a complete octatonic collection (in the highest voice, the octatonic collection containing the pcs 0 and 1, designated "Oct-I" in Fig. 5).

The *b* strain consists principally of a succession of [0,1,4] simultaneities, but a second type of harmonic construction, a perfect fifth with octave duplication of the lower note $(^{8}_{5})$, appears at irregular intervals in the succession (Fig. 6). The first two [0,1,4] trichords (and certain other adjacent simultaneities) are tritone-related, an arrangement similar to that of the [0,3,7] trichords in the introduction, and one that also produces a [0,1,3,6,7,9] hexachord. The first two pairs of [0,1,4] simultaneities generate a complete octatonic collection, Oct-III (the octatonic collection which does not contain the pc 0), and the pc content of the first group of seven simultaneities lies entirely within that octatonic collection. This limitation offers one plausible explanation for the $^{8}_{5}$ sonorities: a similarly disposed [0,1,4] simultaneity with E in the highest voice would also contain C and D♯, which are not members of the Oct-III collection.

Adjacent pcs in the highest voice of the strain form numerous occurrences of the basic trichords [0,2,5] and [0,2,6] (also present in the linear structure of figures *a* and *a′*); there is more emphasis on [0,2,6] within the second and third groups, and the interlocking of [0,2,6] types is of greatest density at the center of the strain. This saturation of [0,2,6] trichords in the second group results from the use of pcs belonging to a single whole-tone collection (the whole-tone collection without pc 0, or "WT-II"): the pcs of the highest voice form a [0,2,6,8] tetrachord, and the WT-II collection is completed with the F and B of the next two simultaneities. The [0,2,6] and [0,2,5] trichords overlap on specific pitches

Figure 4. "Primeval Sounds," Vol. I No. 1: formal divisions

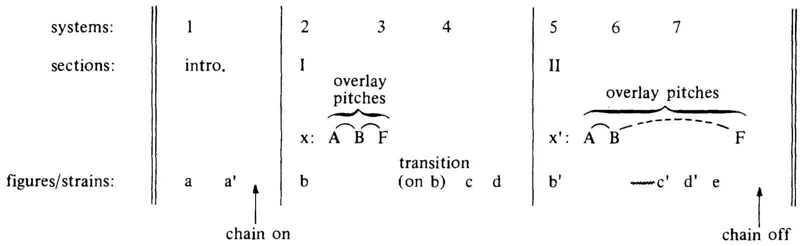
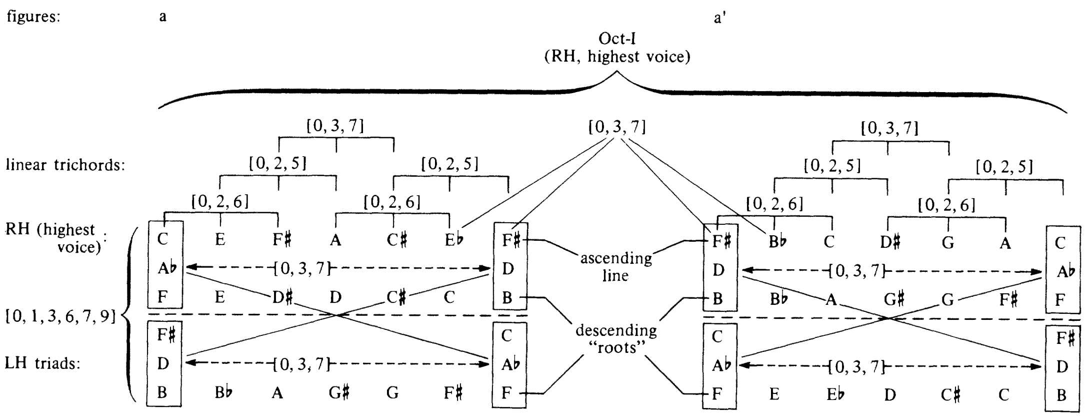
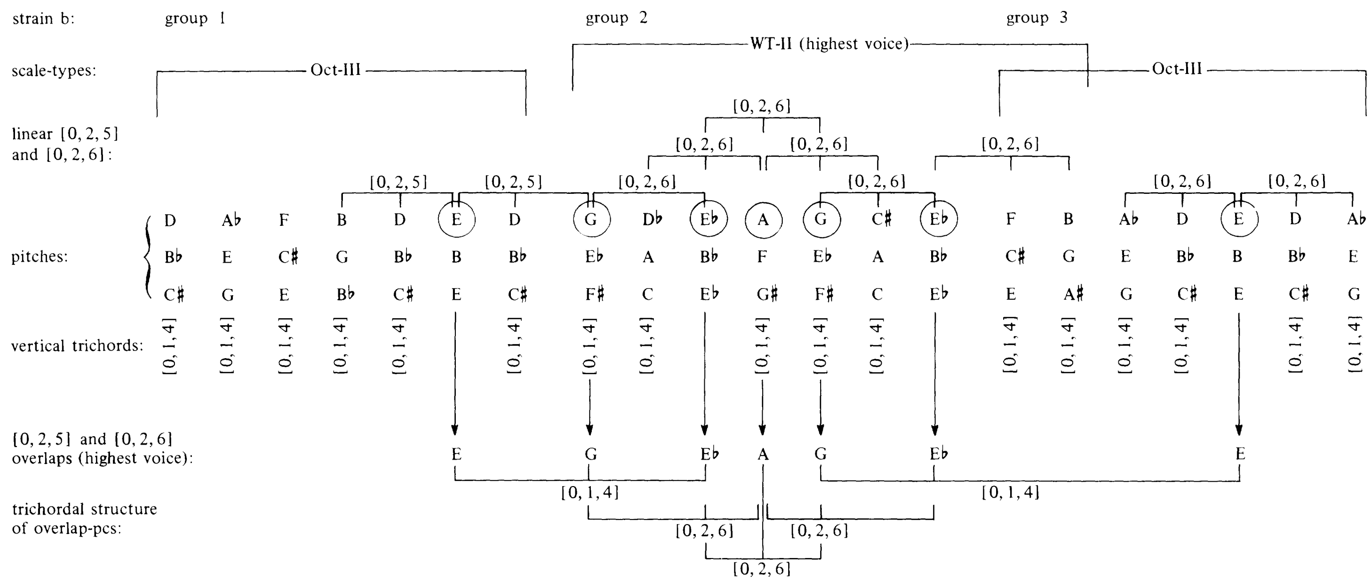


Figure 5. "Primeval Sounds," Vol. I No. 1: segmentation of figures *a* and *a'*



within the progression, and these include all the $\frac{8}{5}$ sonorities. Furthermore, the pcs of the highest voice at these points of overlap express a symmetrical arrangement of linear trichords ([0,2,6] types bordered on both sides by [0,1,4] types) centered on the note A, which is located at the midpoint of the strain (that is, at the eleventh of the 21 simultaneities). As in the introduction, the predominant vertical constructions in this strain, all instances of [0,1,4], are also represented as linear formations in the highest voice, although here they are the product of a larger structural pattern rather than of adjacent pitches in the linear progression. Similarly, the symmetrical arrangement of scale types (Oct-III/WT-II/Oct-III) corresponds to the arrangement of these linear [0,1,4] and [0,2,6] trichords.

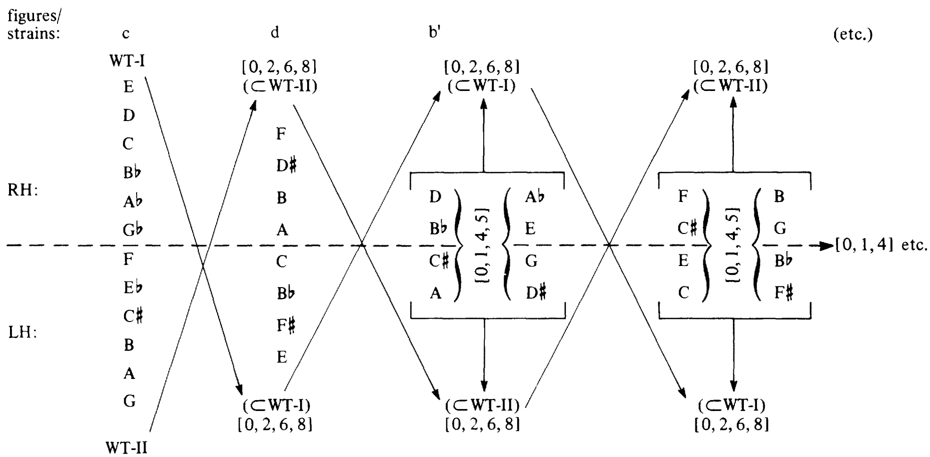
Figure 6. "Primeval Sounds," Vol. I No. 1: segmentation of strain *b*



The transition, based on material from the preceding strain, begins with a restatement of the first four simultaneities from strain *b* (divided here into single pitches plus dyad tremolos) and continues with a repetition of the four trichords at T_1. The last two trichords of the transposed statement are repeated twice, emphasizing the registral division of pcs according to opposing whole-tone subsets: the upper four pitches (D–G♭ and A♭–C) comprise a subset, [0,2,6,8], of the WT-I collection, whereas the lower two pitches (F and B) belong to WT-II.

Figure *c* represents an expansion of the opposing whole-tone idea, pitting a complete WT-I scale on the upper staff against a WT-II scale on the lower staff (Fig. 7). Figure *d* is a display of two [0,2,6,8] subsets of opposing whole-tone collections in which the relative positions of the collections in figure *c* are reversed. A second exchange occurs with the return to *b* material (strain *b′*) at the beginning of section II: here, dyadic subsets (disregarding octave duplications) combine in pairs on the middle and lower staves to form [0,1,4,5] tetrachords which represent extensions of the [0,1,4] trichords of strain *b*. The first linear dyad-pairs are divided by staves into [0,2,6,8] tetrachords in which the WT-I pcs are placed above those of WT-II once again, and the arrangement is reversed for the third time in the following linear dyad-pairs. The vertical [0,1,4,5] set types are then discontinued, and the *b′* strain continues with [0,1,4] simul-

Figure 7. "Primeval Sounds," Vol. I No. 1: opposing whole-tone elements in figures *c*, *d*, and the beginning of strain *b′*



taneities as in strain *b*. The remainder of the second section follows the plan of the first, with certain exceptions: the truncation of the *b′* strain, the addition of a figure (*e*), and the disposition of the final pitch (F) in the overlay figure (*x′*).

The extremely high register of figure *e* contrasts sharply with that of the other material in the piece. The six grace notes are an Oct-I subset partitioned by staves and by register into two [0,1,4] trichords. As a succession of ic-1 (minor-ninth) dyads, however, groupings of the upper and lower pcs of the dyads produce two [0,2,6] trichords, further emphasizing the close interaction between these basic sets. The dyad A7–B7 connects this figure to the *x′* overlay, and B7 is also the highest pitch of the piece.

The notes A, B, and F of the [0,2,6] overlay in section I are separated timbrally as muted repeated notes and positioned so that one pitch is sounded after each group of simultaneities in strain *b*. The A and B of *x′* (in section II) are articulated as harmonics embellished by grace notes resulting in localized [0,1,2] sonorities and occupy the same positions relative to the lower, principal stratum as do those of the first two overlay pitches in section I. The arrival of the third pitch (F), however, is delayed until the conclusion of the section (after figure *e*). The recurrence of A and B in figure *e* serves to reinforce the weakened connective fibers of the overlay.

The preeminence of [0,2,6] as a structural trichord is corroborated by the *x*/*x′* overlay and also evinced by the fact that this trichord works in conjunction with trichords of other types throughout much of the piece (for instance, the coexistence of linear [0,2,6] constructions and [0,1,4] simultaneities in the successions of strain *b*). A similar interaction between octatonic and whole-tone elements extends across the entire piece: octatonic collections are produced by the linear successions in figures *a* and *a'*, and are combined with whole-tone material in strain *b*. Opposing whole-tone collections and subsets become dominant in figures *c* and *d*. They are gradually recombined with octatonic constructions in strain *b'* and reintensified during the course of the second section.

Most of the figures are symmetrically constructed, and tritone relationships are present in some form within every figure as well as between similar figures (for example, *a/a'*, *c/c'*, *d/d'*). Another tritone relationship frames the entire piece: the highest pitch (on B7) occurs in the penultimate pitch-specific sonority, followed only by the enunciation of the repeated note F which completes the overlay figure, *x'*. This F forms a tritone axis with the lowest pitch (B0) of the first simultaneity in the piece, which helps to explain why the arrival of the F is postponed: its formal relocation within section II highlights this particular connection and also corroborates the importance of tritone relationships throughout the piece.

All the clusters and *glissandi* are notated to cover the range of a tritone but otherwise have no bearing on the pitch-structural organization. Excluding the A0 contained within some of these effects, the lowest pitch of the piece as a whole is B♭0 in the *b/b'* strains.[10] The axis between this pitch and the highest (B7) is the E4/F4 at the center of the keyboard, an axis which is featured also in certain other *Makrokosmos* pieces.[11]

In a probable reference to the seven days of Creation, the number seven plays an important role in the piece. Each of the phrases in the introduction, for example, consists of seven simultaneities, as does each group of the *b* strain. The concluding figure (*e*) consists of seven articulations, and each of the overlay-pitches is articulated 14 (7 + 7) times. The *glissando* on the bass strings also occurs 14 times, seven times in each section.

Numerical relationships (especially those based on prime numbers) are abundant in the *Makrokosmos* volumes but in most cases (as with "Primeval Sounds") are only superficially linked to pitch structure. "Voices from 'Corona Borealis' " (*Makrokosmos*, Vol. II No. 10) is exceptional in that numerical groupings are closely allied with the pitch-structural and formal organization.

"Voices from 'Corona Borealis' " is an example of two-voice counterpoint and as such is among the most economically composed of the *Makrokosmos* pieces. The upper line, which is whistled by the pianist, acts as a *cantus firmus*, and the notes in the contrapuntal voice are played as fifth-partial harmonics by plucking or scraping the strings. The piece also includes some percussion effects (striking the crossbeams with the knuckles) which are not pitch-specific. The principal structural features are: (1) the [0,2,6] used to generate whole-tone collections which operate in opposition to one another and in alternation to produce aggregates; (2) the [0,1,6] used to generate an octatonic subset; (3) F and D♯ (or their enharmonic equivalents), which take on a motivic role, as does the intervallic relationship (T^{p}_{-2}) between them; and (4) the number five as it affects pitch structure and the retrograde-symmetrical formal scheme. (This arch form is in turn corroborated by the extramusical reference contained

[10]The notated range of the *glissandi* (A0–D♯2) corresponds to the set of strings between the first two crossbars on many models of grand pianos. The notation in this case is also a matter of convenience for the performer.

[11]The E4/F4 axis is featured to some degree in at least six of the *Makrokosmos* pieces. In some cases, however, it is displaced to another octave, eventually becoming a structural entity independent of its original conception based on the design of the keyboard (see the reference in note 3 above). This is, to my knowledge, the first instance in which an axis of symmetry is derived from the range of the modern keyboard. Other composers, notably Bernhard Ziehn in his "Canonical Studies" (1912) and, more recently, Vincent Persichetti in his "mirror" pieces, have used axes on D and/or G♯, around which the white and black keys form a symmetrical pattern.

in the title: Corona Borealis is a small constellation in which the stars are arranged in a semicircle.)

Sectional divisions, or "phrases," are determined by restatements of the whistled line, designated "strain *x*" in Figure 8. Strain *x* is stated five times, and its duration is five measures of quintuple meter (five dotted half notes to a measure). Therefore the piece is 25 (5 × 5) measures in length. Variations in the mode of execution of this strain produce an arch-form arrangement: the first and last statements are performed without vibrato, the second and fourth statements are marked "molto vibrato (quasi Theremin)," and the third, central statement calls for a warbling effect. The contrapuntal voice is present only in the second, third, and fourth phrases (designated strains *a, b,* and *c* respectively in Fig. 8), and these also exhibit arch-form characteristics with regard to modes of articulation: in the second and fourth phrases the harmonics are played *pizzicato,* whereas in the third phrase they are performed by a rapid stroke over the string with the fingernail. The percussion effects interrupt the succession of pitches in the contrapuntal voice on five occasions. These effects are rather freely distributed within the formal layout of phrases two through five, but the third one occurs at the precise center of the form (on the third beat of m. 13), reinforcing the overall arch-form organization.

Figure 9 shows the internal structure of strain *x*, an invariant series of 16 notes, the first 12 of which express an aggregate. The first five pcs are members of the WT-II collection, and the next six express a complete WT-I collection. The twelfth note in the series, A5, completes not only the aggregate, but also the earlier WT-II collection; significantly, this A5 is the fifth note from the end of the series. Within the first two whole-tone segments, the pitches are grouped almost exclusively into [0,2,6] trichords. The last five notes in the series form a subset of Oct-I, and this segment of the strain also contains a reference to the opening intervallic gesture: the T^{p}_{-2} progression expressed by the first two pitches (F and D♯) is paralleled on a larger scale by the relationship between the last two groups of three notes—notes 14 through

Figure 8. "Voices from 'Corona Borealis,' " Vol. II No. 10: formal divisions

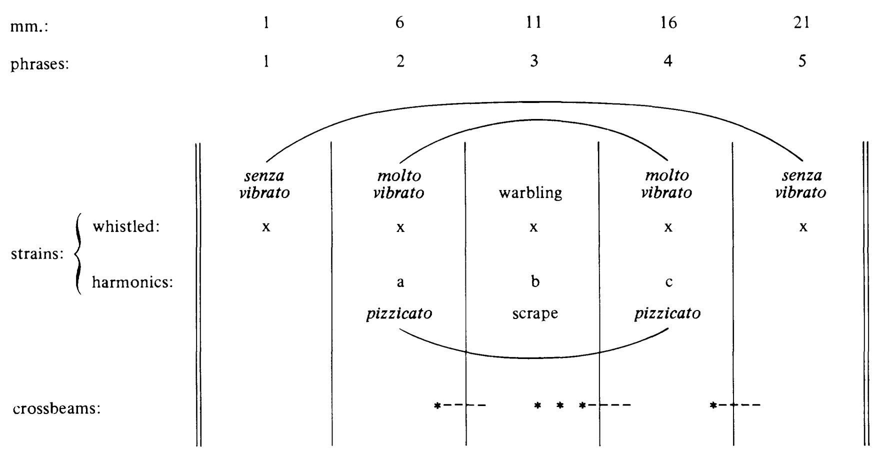
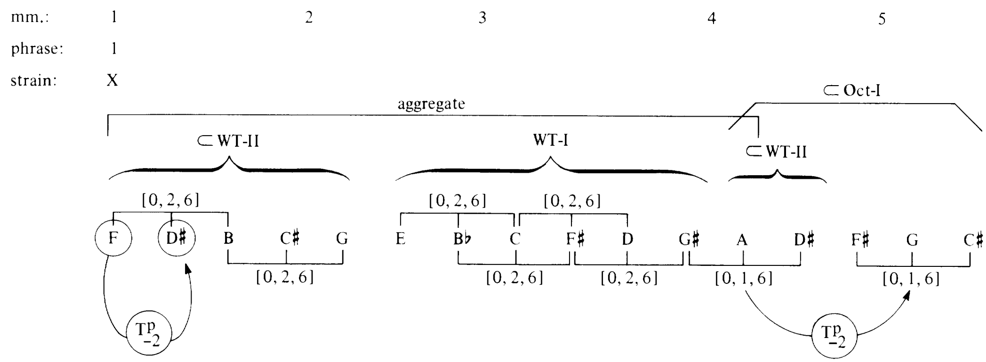


Figure 9. "Voices from 'Corona Borealis,' " Vol. II No. 10: segmentation of strain x (phrase 1, mm. 1–5)



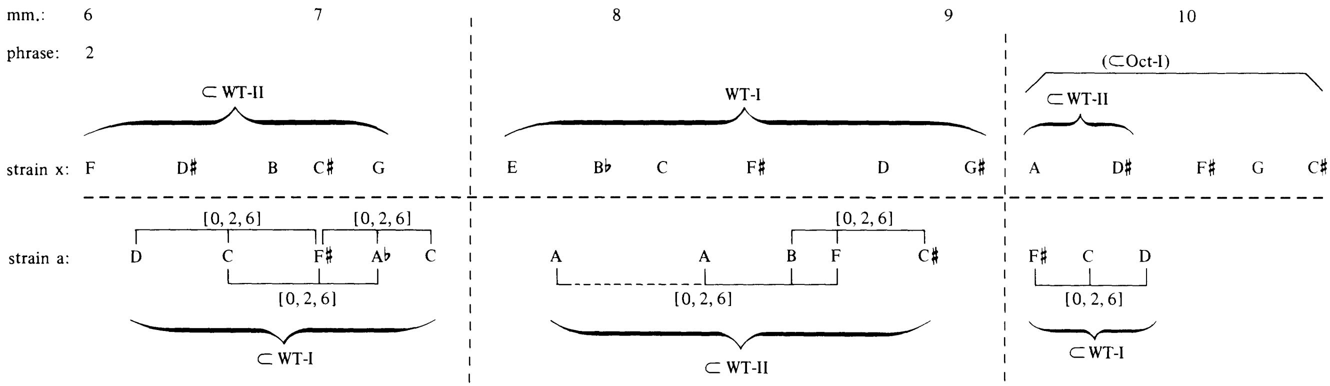
16 form a [0,1,6] trichord which is a sequential statement (at T^p_{-2}) of notes 11 through 13.

Figure 10 shows the partitioning of the second phrase (mm. 6–10), where the contrapuntal voice first joins with the *cantus firmus*. The writing in this phrase is essentially canonic—strict with regard to rhythm and melodic direction, but imprecise in intervallic successions, and the last three notes of the *cantus firmus* are not answered in the contrapuntal voice. The intervallic adjustments in the contrapuntal voice alter its linear whole-tone subset content in such a way that the entire phrase is divisible into alternating, opposing whole-tone segments involving both voices. In other words, corresponding segments of the two voices in the canon itself may or may not be invariant in their whole-tone content, but vertical whole-tone opposition is maintained throughout. The fact that whole-tone organization is supplanted by an octatonic segment at the end of strain x explains why the last three notes of the *cantus firmus* are left unanswered. Within whole-tone segments, the pcs of strain a (the contrapuntal voice) form completely interlocking [0,2,6] trichords. Also, the last three pitches are a retrograde statement of the first trichord (D–C–F♯), supporting in a localized sense the larger aspects of arch-form organization.

In the next two phrases, the structure of the contrapuntal voice is altered. Canonic writing is discontinued, and in these strains (b and c) the pitches of the contrapuntal voice are displayed in four groups of three (actually 2 + 1 groupings in strain c). There are, however, two important aspects of pitch structure which are retained throughout all the two-voice phrases: the alternating whole-tone opposition between the voices (the last three notes of strain x are consistently unaccompanied); and the interlocking [0,2,6] trichordal structure of the contrapuntal voice within whole-tone segments.

A single exception to each of these structural procedures occurs in each of the next two phrases. In the fourth phrase (Fig. 11, mm. 16–20), there is an overlap between the WT-II segments of the strains in m. 17, where G and D♯ are articulated simultaneously. But it is also at this point that the first two pitches of the piece—F and D♯—appear in suc-

Figure 10. "Voices from 'Corona Borealis,' " Vol. II No. 10: segmentation of strains x and a (phrase 2, mm. 6–10)



cession (in retrograde order) in the contrapuntal voice, so that an exception to one of the principal organizational procedures occurs concomitantly with a statement of this motive. This is the only point in this phrase where these two pcs appear in succession in the contrapuntal voice. As in the second phrase, however, the individual whole-tone segments in the contrapuntal voice are constructed entirely of interlocking [0,2,6] trichords.

In the third phrase (Fig. 12, mm. 11–15) there is no elision of similar whole-tone collections between the two voices. However, at one point (mm. 12–14) the interlocking [0,2,6] structure of the contrapuntal voice (strain b) is temporarily abandoned: the WT-II segment at the center of strain b contains two linear interlocking [0,2,6] trichords, but the last one (F–D♯–C♯) is a [0,2,4]. The interlocking [0,2,6] structure would have been continued if G had been used instead of D♯ as the penultimate note in the WT-II segment, but again the exception allows for the incorporation of the F–D♯ within the strain. In fact, these two notes are symmetrically positioned around the precise center of the form (the percussion effect at the middle of m. 13): F is the last note in the contrapuntal voice in m. 12, and D♯ is the first one in m. 14. Again, as in the fourth phrase, this is the only point in the phrase where the pitches F and D♯ appear in succession in the contrapuntal voice. In the second phrase, which contains no exceptions to these two structural patterns, F and D♯ never appear in succession in the contrapuntal voice.

The T^{p}_{-2} relationship expressed in strain x becomes an important structural element in the contrapuntal voice as well (Fig. 13). The pitches of the first [0,2,6] trichord in strain a are C, D, and F♯, and those of the last trichord in strain c (that is, the last trichord of the entire contrapuntal voice) are A♯, C, and E. This long-range relationship is duplicated within the b strain, in which the first trichord is again C–D–F♯ and the last is A♯–C–E. T^{p}_{-14} relationships (octave compounds of T^{p}_{-2}) exist between the highest pitches of strain a and the lowest pitches of the corresponding whole-tone

Figure 11. "Voices from 'Corona Borealis,' " Volume II No. 10: segmentation of strains *x* and *c* (phrase 4, mm. 16–20)

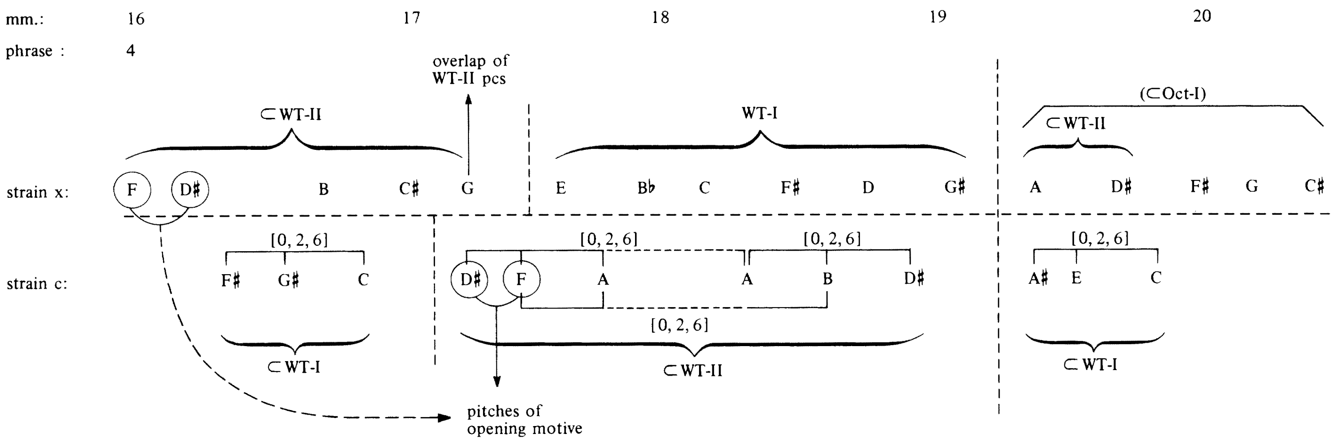


Figure 12. "Voices from 'Corona Borealis,' " Vol. II No. 10: segmentation of strains *x* and *b* (phrase 3, mm. 11–15)

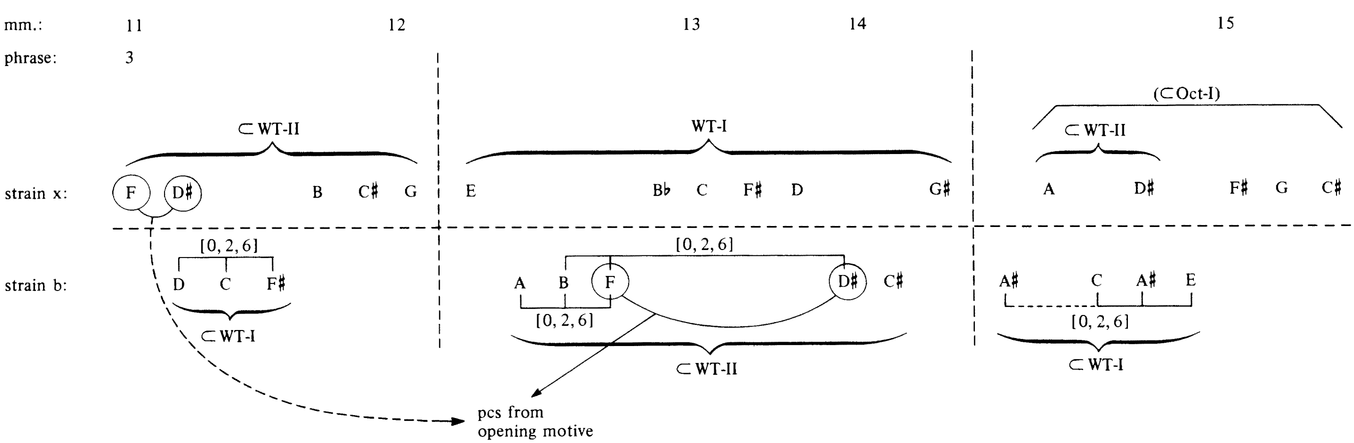
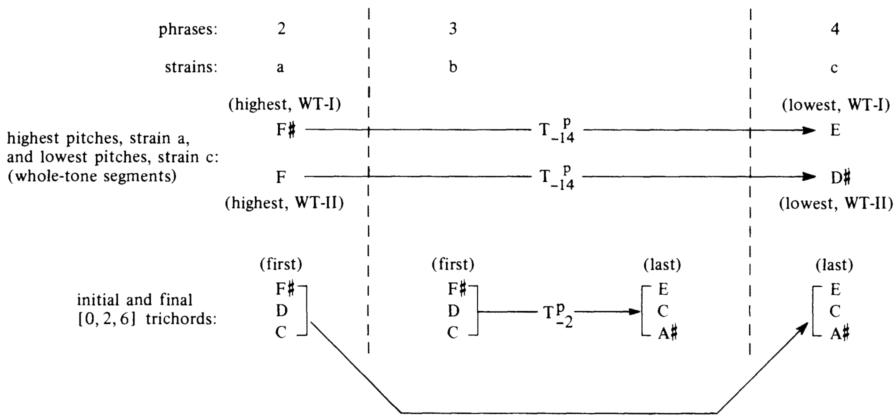


Figure 13. "Voices from 'Corona Borealis,' " Vol. II No. 10: long-range T^p_{-2} and T^p_{-14} relationships in the contrapuntal voice



portions of strain *c*. A similar connection is formed between the first and last pitches (D and C) of the contrapuntal voice as a whole.

Certain pitch-structural relationships between "Voices from 'Corona Borealis' " and the pieces adjacent to it are typical of the cyclic continuity achieved in these volumes. The last two pitch-specific gestures in the preceding piece, "Cosmic Wind," are two chromatic trichords separated by a tritone (F𝄪–G♯–A and C♯–D–E♭). These are centered around F, which is the first pitch to appear in "Voices." A connection involving the retention of important pitches exists between this piece and the next one, "Litany of the Galactic Bells": the opening gesture of "Litany" consists of opposing whole-tone clusters, and the highest two pitches of the gesture (occurring as the highest pitches of the second and third simultaneities) are F and D♯, the same pitches that serve as the primary motive in "Voices."

Motivic statements and cross-references in the first two volumes of *Makrokosmos* function not only as unifying elements in the conventional sense, but also (and perhaps more significantly) as a means of altering or transforming the repetitive, quasi-static patterns and symmetrical formations. The heavy reliance on symmetry in these pieces does not lead to structural rigidity or circularity largely because motivic ideas are incorporated in ways that promote and enhance the developmental processes: symmetrical organization serves as a flexible framework within which the primary pc sets and motives interact. The relationships resulting from this interplay provide convincing evidence that this work should not be viewed simply as an experiment in novel effects, but instead as a dynamic, organically conceived union of idiosyncratic and extramusical elements with those involving more traditional structural parameters, including that of pitch.

ABSTRACT

Pitch-structural materials in George Crumb's *Makrokosmos* I and II include four basic trichordal set types from which larger sets are generated through various symmetrical dispositions of pcs. The largest collections correspond to whole-tone, pentatonic, and octatonic scale types. These materials are assimilated into a tightly interwoven complex of pc sets which offers not only a variety of pitch-structural units but also the potential for rigorously controlled interaction within the system.

The primary materials are developed principally through symmetrical organizational schemes within which certain pc relationships function motivically in both local and long-range constructions. The resulting reticulated structures are illustrated in detailed analyses of "Primeval Sounds: Genesis I" from Volume I and "Voices from 'Corona Borealis' " from Volume II.