CHAPTER VII

SPATIAL SOUND MOVEMENT IN THE INSTRUMENTAL MUSIC OF IANNIS XENAKIS

Introduction

> For a human being it is difficult to understand space. According to relativity theory, space is linked to time through the speed of light; this theory also says that space has a curvature, but the theory does not explain the meaning of the space itself. On the other hand, from the point of view of everyday life, space is something limiting: if you are in one place you cannot be in another place at the same time.
>
> (Xenakis 1992: 1)

These words reveal the scope of Xenakis's reflection on space, embracing paradigms of modern science along with spatial features of human experience. A similar range of interests underlies Xenakis's music, from compositional implementations of mathematical concepts of space to explorations of the physical spatiality of sound.[1] This chapter presents the evolution of Xenakis's approach to spatialization as realized in his instrumental music, from *Pithoprakta* (1956) to *Alax* (1985).[2] The discussion also includes analytical examples from *Eonta* (1963), *Terretektorh* (1965-66), *Nomos Gamma* (1967-68) and *Persephassa* (1969). The study

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[1]I discuss notions of space in Xenakis's compositional theory in Chapter III, 3.3.

[2]The first draft of this chapter has been presented in a paper entitled "The technique of spatial sound movement in the instrumental music of Iannis Xenakis" (Fall Meeting of the New York State--St. Lawrence Chapter of the AMS, at the State University of New York at Albany, October 1992). A revised version of this paper is forthcoming in *Interface. Journal of New Music Research* 23 no. 3 (August 1994).

of *Terretektorh* and *Nomos Gamma* is based, in part, on compositional sketches that had not been available before.[3] In addition, the review of Xenakis's music and ideas benefits from his insights expressed in an interview of 1992.[4]

Xenakis's continuing interest in the technique of spatialization is not limited to the works discussed in this dissertation. Different aspects of spatial sound are explored in *Polytope de Montréal* for 4 identical orchestras (1967), the musical component of Xenakis's audiovisual installation at EXPO 67 in Montreal.[5] Multi-channel sound projection is required in a variety of Xenakis's electroacoustic compositions, from *Concrete PH,* an incandescent prelude to Varése's *Poème eléctronique* for the Philips Pavilion (1958), through *Bohor* with its monumental sound masses (1962), to *La Legende d'Er* (1977) with its complex patterns of sound movement in time, space, pitch and timbre.[6] Xenakis's experience with electroacoustics has not been without consequences for his role in the development of the technique of spatial sound movement in instrumental music.[7]

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[3]Xenakis graciously supplied me with copies of his compositional sketches in August 1992 (7 pages in total).

[4]I interviewed Xenakis in Paris on 25 May 1992. References to the typescript of this conversation will be labelled (Xenakis 1992). The French translation is forthcoming in *Circuit* in 1994.

[5]This work is the first in Xenakis's Polytope series, multi-media presentations which explore space (and time) by means of sound and light in movement. The earlier Polytopes (Montreal, *Persepolis* of 1971 and *Polytope de Cluny* of 1972) are discussed in a book edited by Olivier Revault d'Allonnes (1975); other works in this genre include *Polytope de Mycenae* (1978), *Le Diatope* (1978) and *Taurhiphanie* (1987).

[6]*La Legende d'Er* for seven track tape was composed for *Le Diatope*, designed for the opening of the Centre Georges Pompidou in Paris and premiered in 1978 (Matossian 1986). References to the chronology of Xenakis's compositions are based on the catalogue compiled by Lohner (1987) and the *List of Works* issued by Xenakis's publishers, Editions Salabert of Paris (1992).

[7]This experience dates back to 1956, when Xenakis began working with Le Corbusier on the Philips Pavilion for EXPO 1958 (cf. Chapter III, section 3.3). References to this work are included in *Formalized Music* (1971), in Matossian (1986) and other sources.

7.1.

Real and virtual motion of sound in *Pithoprakta* and *Eonta*

In 1955-56 Xenakis composed *Pithoprakta*, the first instance of "stochastic music," a music in which the number of individual sonic particles is so large that their behaviour is regulated by the laws of probability.[8] In this work, scored for an orchestra of 50 instruments (i.e. a string orchestra with two tenor trombones, xylophone and woodblock), all the instruments are placed on the stage according to the traditional seating plan. Nevertheless, spatially extended sonorities result from the use of a large number of divisi parts. Here, spatialization does not relate to the measurable aspects of the performance space (distances, angles, symmetries), but rather is expressed through internal, microscopic differentiation in the orchestral sonorities.

In *Pithoprakta* various categories of sound create stationary or moving clouds of sonorous material. The movement occurs in pitch and time, but may lead to a rudimentary form of spatial motion--motion confined to the expanse of the stage. The sketch for measures 239-250 of *Pithoprakta* (Ex. VII-1) displays the evolution of a stochastic sound mass in pitch space, with the divisi strings playing irregular glissandi sul ponticello from the low to the high registers. This transformation is mirrored by a shift of the sound mass from the right to the left side of the stage. However, it does so only if the traditional seating plan is preserved. In *Pithoprakta*, according to Xenakis:

> If the instruments are seated in the conventional order of the first violins followed by the second violins, violas, and cellos--all placed in a semicircle on the stage--the movement in pitch also becomes a spatial movement. But if the first violins are placed to the left and the second violins to the right, this effect is lost.
>
> (Xenakis 1992: 9)

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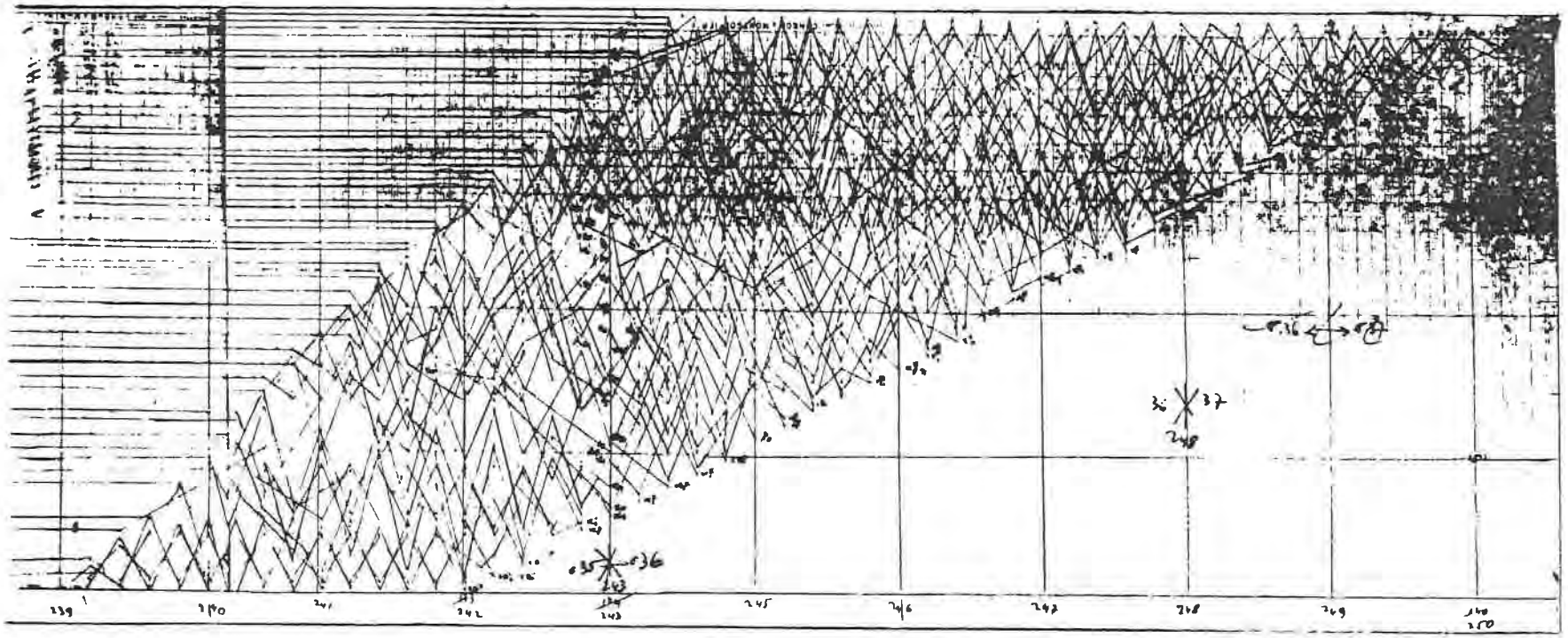
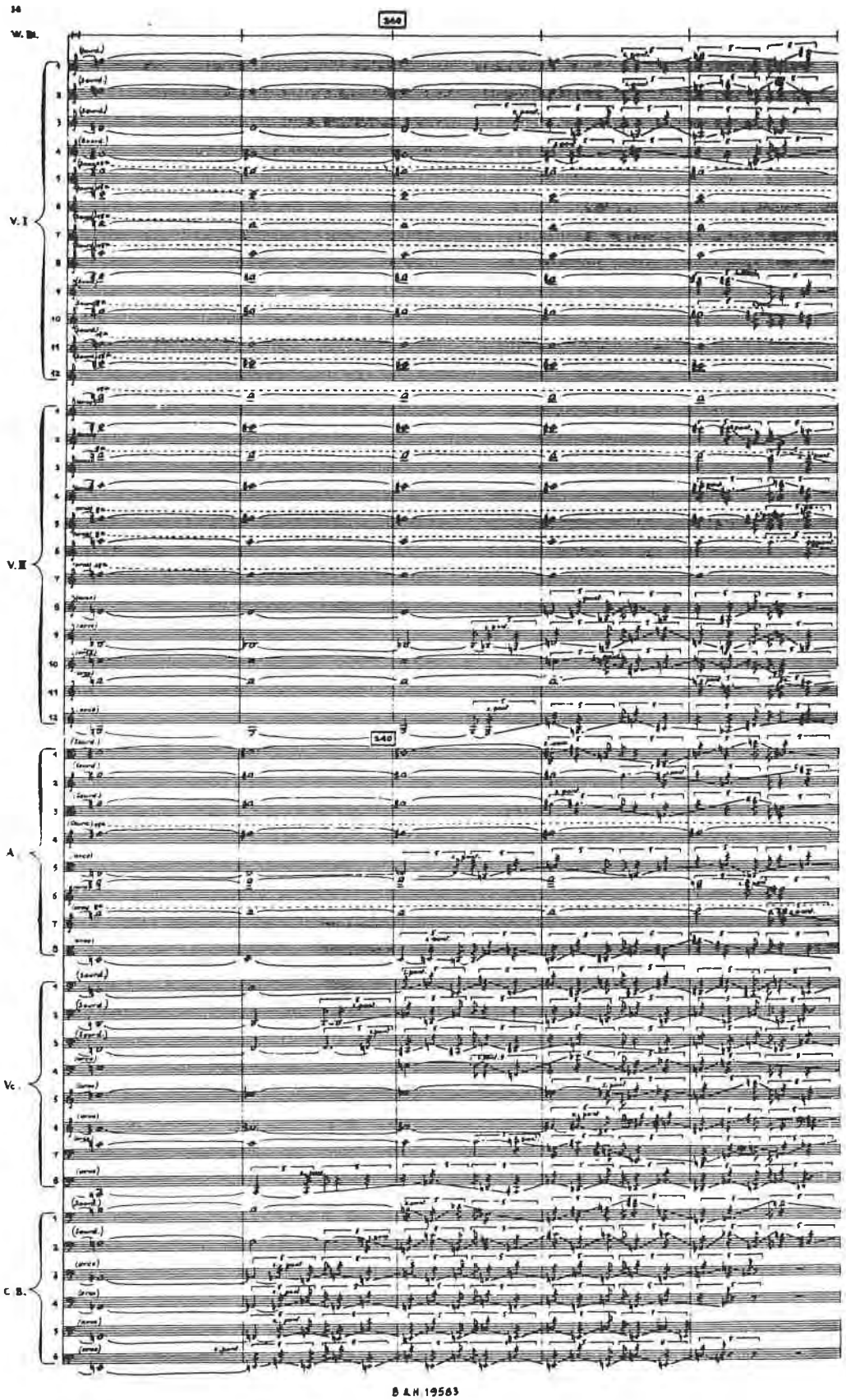
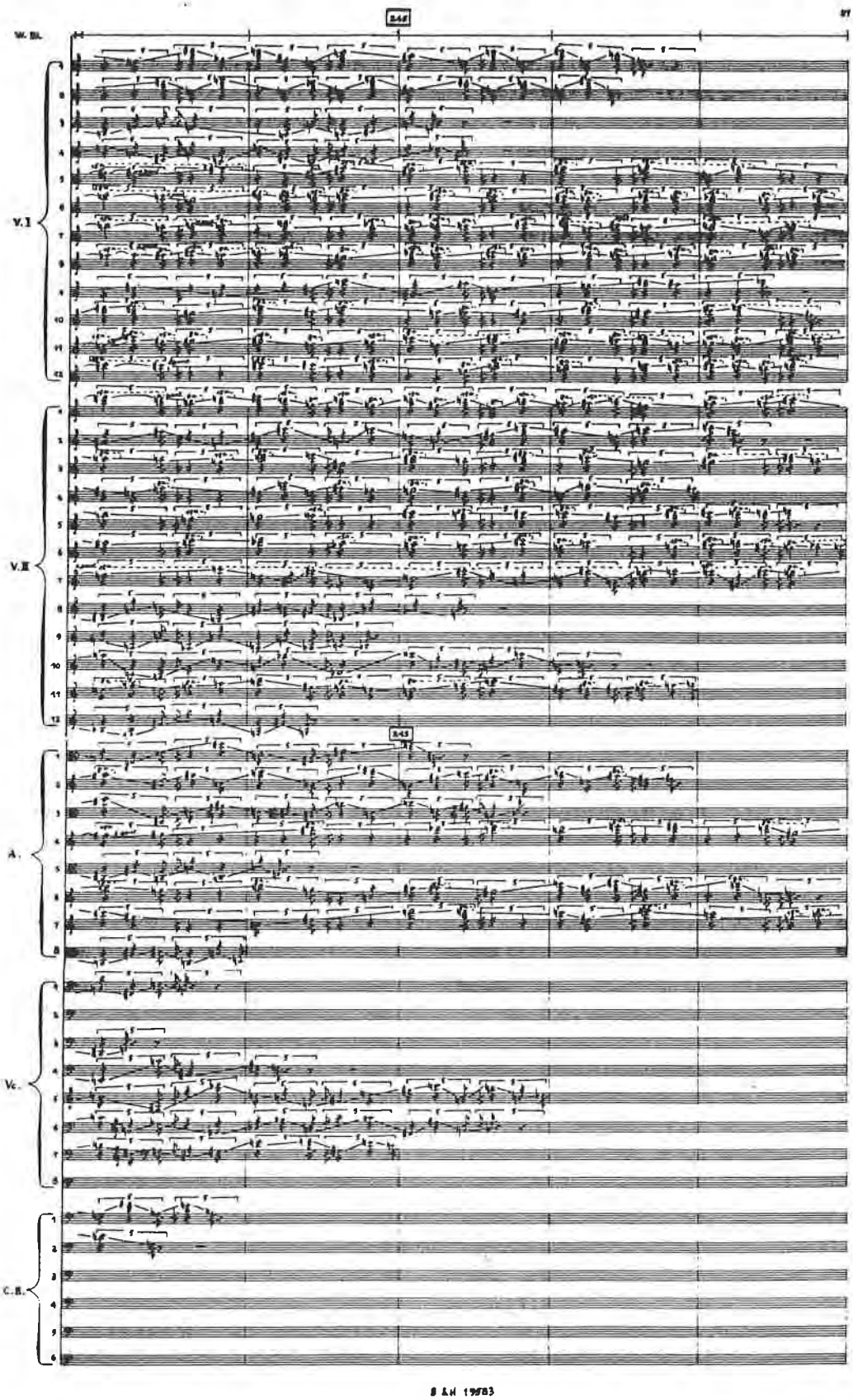
[8]Xenakis introduced the term "stochastic music" in 1956 in reference to the results of his compositional use of the laws and calculus of probability (Xenakis 1956, cf. *Formalized Music* 1971: 8).



Ex. VII-1: Xenakis's sketch for mm. 239-250 of *Pithoprakta*.



Ex. VII-2: Mm. 238-247 of *Pithoprakta* by Iannis Xenakis (1955-56).



Ex. VII-2: *Pithoprakta*, continued.

The broad movement across the pitch space filled with a mass of irregular glissandi is realized by individual instruments, not complete groups. The score shows that the movement is conceived more in terms of the evolution of pitch content than of spatial position (Ex. VII-2). The transformation is achieved by a gradual dropping out of the lower string instruments, starting with the double basses and ending with the violas, second and first violins, some of which play together at the end.

The virtual movement of sound masses is realized in *Pithoprakta* by a stationary orchestra placed on the stage, in front of the listeners. By contrast, in *Eonta* (1963-64), a work for piano, two trumpets and three trombones, the movement is a consequence of the physical motion of the instrumentalists.[9] Brass players have to change their placements on the stage six times during the course of the work (see Ex. VII-3). Moreover, on three occasions they are required to simultaneously play and move: (a) altering the timbre of their instruments by slow axial rotations in mm. 55-79, (b) walking towards the piano in mm. 82-85, (c) wandering around the "promenade" area in mm. 335-375.

That *Eonta* is an exploration of the directional qualities of sound is already apparent in the first entry of the brass instruments--the players begin with the bells pointing to the ground (mm. 40-43) and raise them to normal position during a slow crescendo (mm. 44-48). The following fragment of the music (mm. 55-79) reflects Xenakis's idea, jotted down in a notebook in 1963: "the brass concentrated with little

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[9]The spatiality of *Eonta* is just one of the many aspects of this work, which, according to the composer's note in the score, "makes use of stochastic music (based on the theory of probabilities) and of symbolic music (based on logistics)." Sections of free stochastic music, such as the piano solo in mm. 1-40, have been calculated with Xenakis's computer program developed for his '*ST*' works (*ST-4*, *ST-10*, cf. chapter V of *Formalized Music* 1971). Symbolic music, composed with pitch sets structured by means of operations from Boolean algebra (union, intersection and negation), had been introduced in *Herma* (cf. chapter VI of *Formalized Music*). *Eonta* makes use of operations on two basic sets (Ψ and Θ; e.g. $\Psi\Theta + \overline{\Psi}\overline{\Theta}$) as well as of set Σ, the universal set appearing in all stochastic sections.

internal movements, slow and fast (alteration of timbre) and chords."[10] Here, the alteration of timbre is achieved by means of changing sound direction and fluctuating dynamics. The brass players turn slowly to the right (↻) or to the left (↺) while performing a continuous chord (G#3-D4-E4-A4-G5) which varies in timbre depending on the direction and loudness of the individual sounds (Ex. VII-4). As the score calls for rotations spanning an indeterminate "obtuse angle" (between 90 and 180 degrees) it is difficult to foresee the exact positions of the instruments at a specific moment. However, the players usually move in the same direction (the second trumpet and the second trombone to the left, the rest to the right) which means that, at times, they are turned with their backs to the audience. Example VII-5 presents two hypothetical positions for the brass at the end of m. 74: (a) assuming that each motion spans 90°, (b) assuming that the angles vary between 90° and 180° and the players finish their motions by facing forward (in m. 79).[11]

The movements of the performers in *Eonta*, however interesting visually, have an acoustic purpose. Brass players vary the timbre of their instruments by pointing the bells in various directions (up, down, to the sides). Brass instruments are known to be highly directional, i.e. their timbre depends on the direction from which the sound is heard (Meyer 1978). Pointing the bells to the floor or to the side of the stage changes the timbre of the sounds heard by the audience (by a reduction of the loudness of the highest partials). Playing towards the back of the stage further transforms the brass sonority; the sounds have a darker timbre (a further reduction of the high partials) and the loudness decreases (because of the directional characteristics of the instruments and the acoustic shadow of the performers). Consequently, the instruments sound more distant (the perception of sound distance depends on dynamic

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[10]Xenakis's remark, notated after an afternoon boating in Tanglewood in the summer of 1963, is quoted in the biography by Matossian (1986: 177), presumably in her translation.

[11]Neither of these conditions are explicitly required by the composer; following this section the instrumentalists walk to the piano, so their direction at the beginning may not be important.

and timbral cues, cf. Sheeline 1982, Blauert 1983). In addition, the varied direction of instrumental sounds triggers different room responses. The pattern of reflections and its result--the reverberant sounds which influence the timbre--depend on the position and direction of the sound sources in the room.[12]

In mm. 144-168 of *Eonta* brass instruments are pointed at the ceiling so that their sounds are changed by the varied resonance of the hall (Ex. VII-6a). Simultaneously, the brass sonorities resonate in the silent chord of the piano (F-A in two octaves, 3rd pedal)--as the third and fourth partial of the pitch A3 in the piano part (pitches E5 and A5 respectively, mm. 144-147 in Ex. VII-6a).[13] To increase the resonance, the brass notes are doubled at a higher octave in another chord played by the piano.

This moment of sound 'reflection' brings to mind Xenakis's original inspiration for the piece: "Reflection in water. Water is the piano. . ." For the composer, "the piano is the centre, the others in circumference, they approach to resonate the piano" (Matossian 1986: 177). The realization of this idea may be found in mm. 86-92 and mm. 317-321 of *Eonta* where the brass players stand beside the piano and direct the bells of their instruments toward its strings. The resonance is either clearly heard in a moment of silence (general pause in mm. 92-94) or becomes a part of the overall sonority, colouring the timbre of all the instruments which continue to play without pauses (mm. 317-321, cf. Example VII-6b).[14]

The effects of resonance and timbral transformation are not the only instances

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[12]Rasch and Plomp (1982) as well as Bräm (1986) review the role of acoustic space for music perception. For a study of the dependance of timbre on resonances, see Toole and Olive (1988); for a study of room acoustics and artificial reverberation, see Schroeder (1984). A recent study of source placement and room response (Goad and Keefe 1992) indicates that differences in early reflection response contribute to timbre discrimination.

[13]A5 is also the fifth partial of F3 and the tenth partial of F2.

[14]In example VII-6b, all the pitches of the brass chord are contained in the two chords played by the piano, which amplifies the resonance.

of sound spatialization in *Eonta*. A spectacular moment of spatial sound movement is presented in the "promenade" section of the work (mm. 335-375), in which the brass players are asked to wander freely around a T-shaped area of the stage while performing soloistic passages (Ex. VII-7).[15] The changing direction of the sounds, aided by fluctuating dynamics, creates a rich and 'mobile' texture--an effect which later became a standard element of the 'contemporary-music' style adapted by many other composers. Paradoxically, Xenakis himself has come to dislike performer movement as a compositional device:

> The problem is that the movement of performers is theatrical. Besides, when the sound moves along with the speed of a walking human it is not interesting enough. If you could ask the players to run and play at the same time, that would be more interesting, but I have not seen such a thing anywhere. Sound movement is very difficult to obtain also because most performers do not like to walk, even slowly, and play at the same time.
>
> (Xenakis 1992: 10)

These words result from years of compositional experience acquired while working on a series of musical essays in spatialization (from *Eonta* to *Alax*). In the sixties, after experimenting with the performers' movements on the stage and using spatial effects to enrich the timbral aspects of the music in *Eonta*, Xenakis turned to the exploration of the space itself.

7.2.

Spirals and circles in *Terretektorh*

In *Terretektorh*[16] for large orchestra (1965-66), the 88 players are scattered

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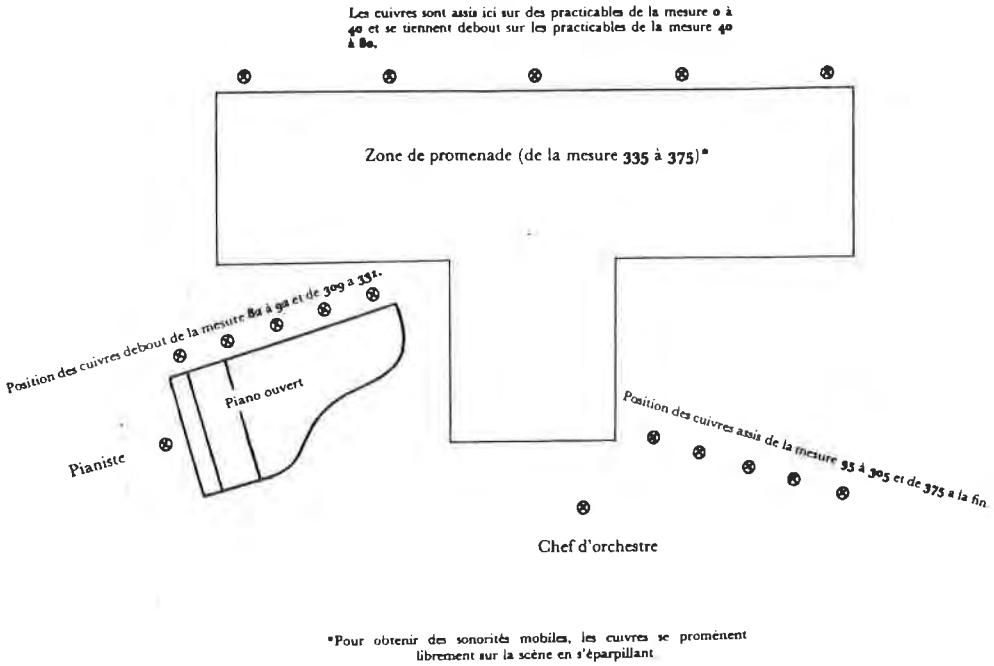
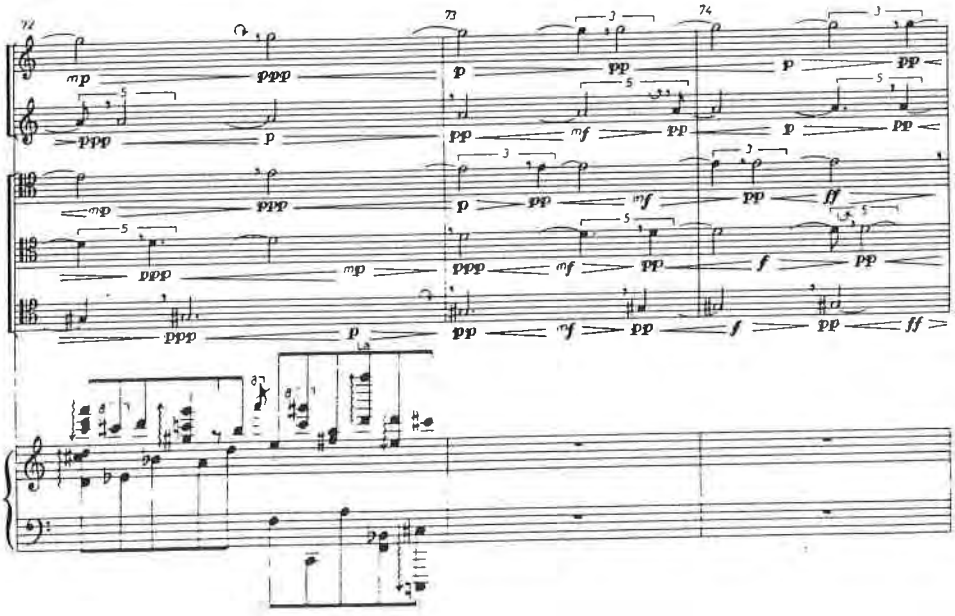
[15]Greek letters in m. 356 and 357 of Ex. VIII-7 refer to sets from which the pitches (not pitch classes) of the brass have been chosen. These sets are constructed through intersection, union and negation from two basic sets, Ψ and Θ.

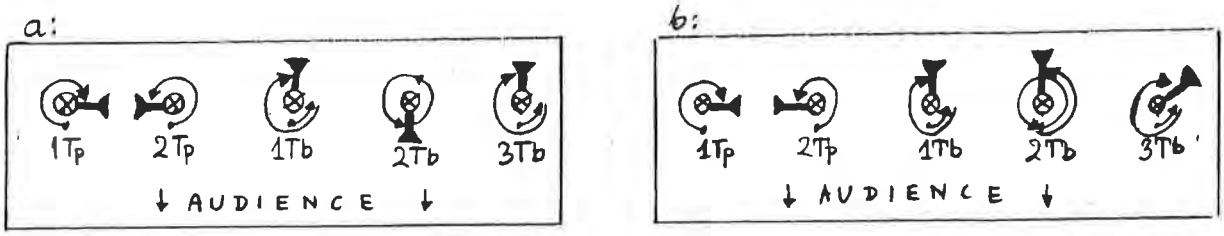
[16]Here, the most common spelling of the title is used (as in the score, the revised version of *Formalized Music* and the *Catalogue General*). Other options include: *Terrêtektorh* (Xenakis 1971: 236-237), *Terretêktorh* (Xenakis 1971: 273) and *Terretéktorh* (Matossian 1986: 271). Matossian uses also *Terretektorh* (p. 182-3) and *Terretêktorh* (p.



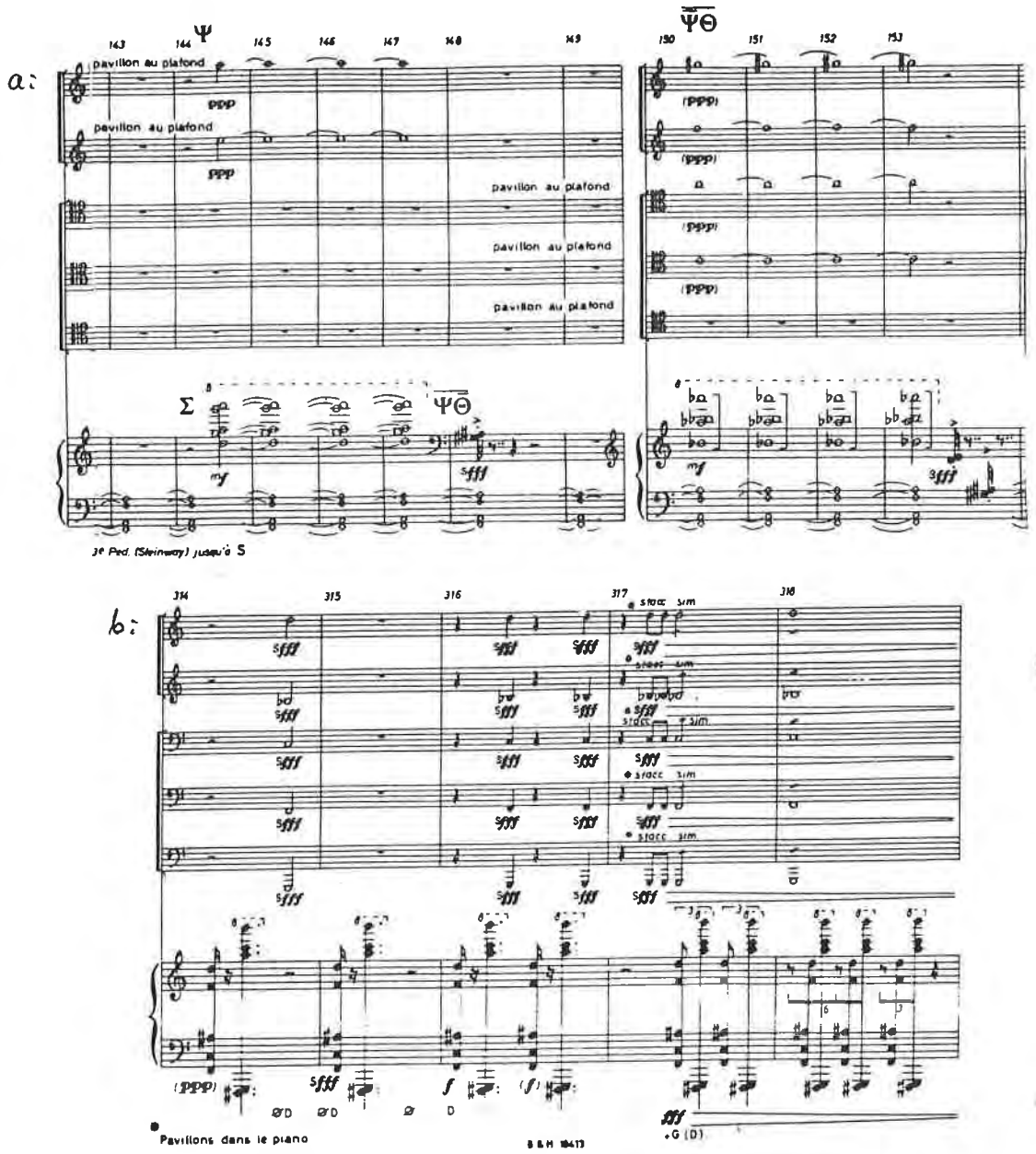
Ex. VII-3: Placement of performers in Xenakis's *Eonta* (1963-64).



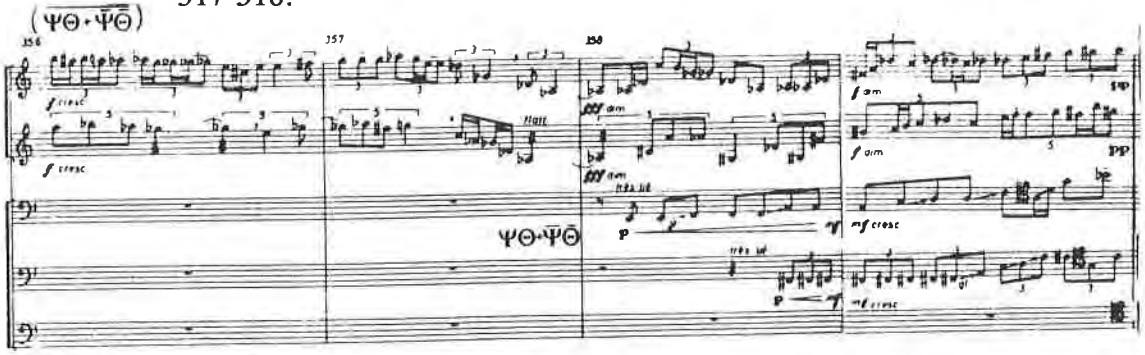
Ex. VII-4: Alteration of brass timbre by movement and dynamics in mm. 72-74 of *Eonta*.



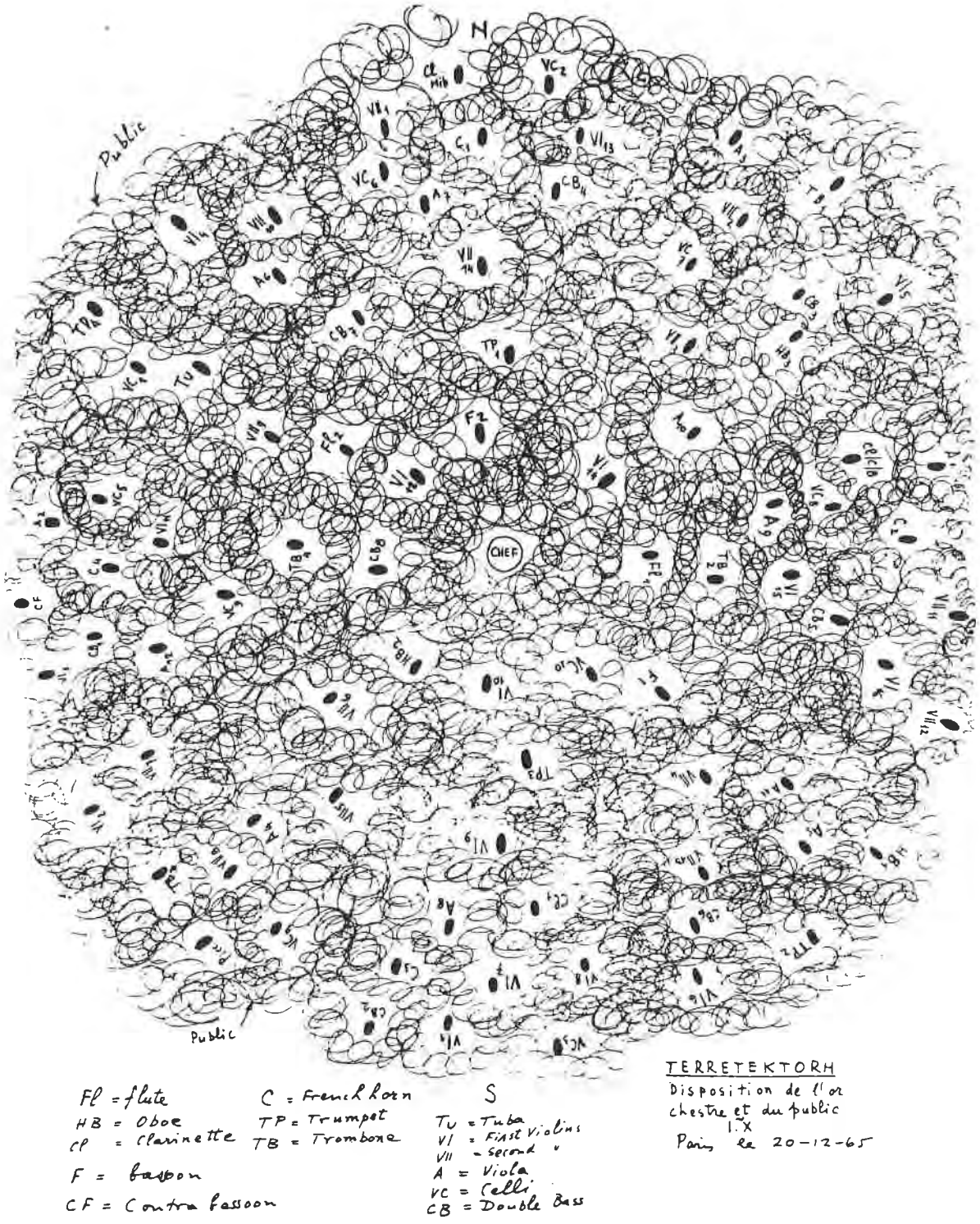
Ex. VII-5: Hypothetical positions of brass instruments in m. 74 of *Eonta;*
(a) if each motion spans 90°; (b) if II and III Trombone move by 120° to 180°.



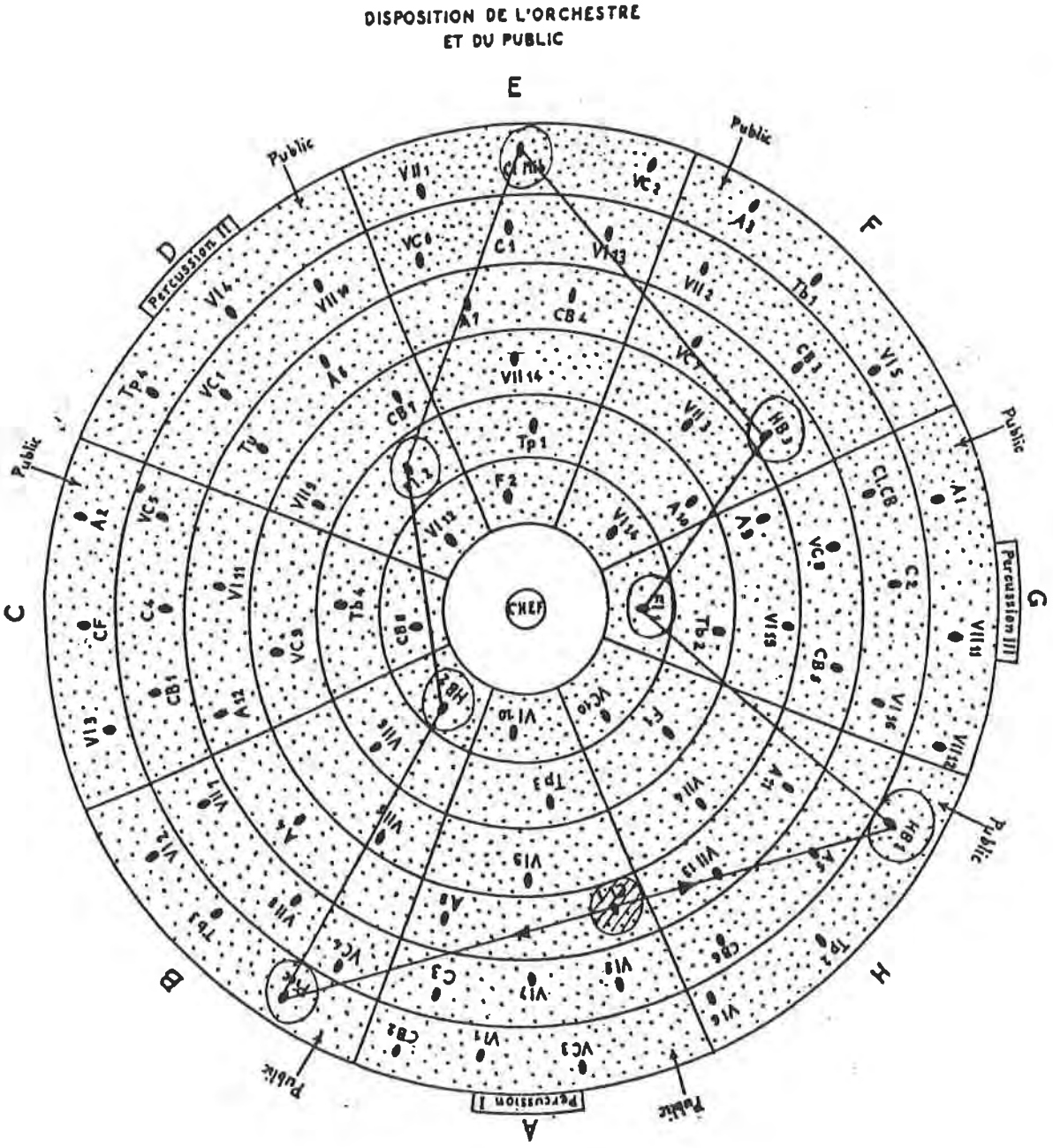
Ex. VII-6: Resonances of brass sounds in the piano in *Eonta*: (a) Brass players seated at the right, bells directed at the ceiling, piano with 3rd pedal, mm. 143-153; (b) Brass players standing next to the piano, bells in the piano, mm. 317-318.



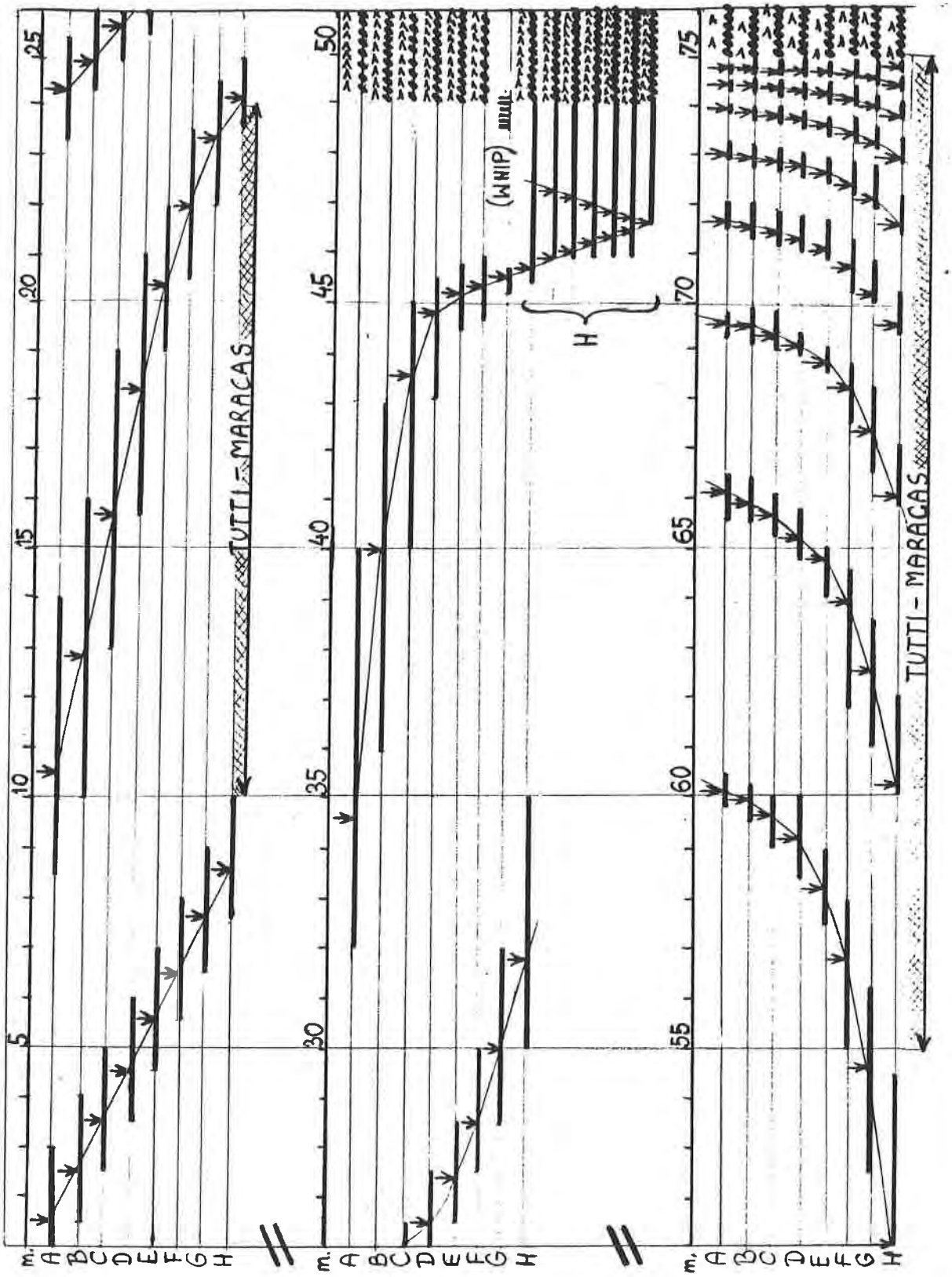
Ex. VII-7: Excerpt from the "promenade" in *Eonta* (mm. 356-359).



Ex. VII-8a: Xenakis's sketch of the seating plan for *Terretektorh* (1965).



Ex. VII-8b: Final version of the seating plan of *Terretektorh* in the score (1969), with the indication of the placement of high woodwinds participating in sound rotations in mm. 125-195 (cf. Ex. VII-11).



Ex. VII-9: Diagram of rotations of one pitch (E4) in mm. 1-75 of *Terretektorh.*

among the audience (an early sketch of the seating plan without percussionists is shown in Ex. VII-8a). The instrumentalists are divided into eight groups, A to H, filling out a circular performance space framed by three percussionists placed in a triangle (Ex. VII-8b).[17]

In this arrangement, the psychological and auditive curtain which separates the listener from the performers seated on stage is removed. The proximity of the sound creates a new aural experience strengthened by the movement of sound masses in space and enhanced by the novelty of the sounds themselves. Each musician is required to play, besides his normal instrument, four percussion instruments: wood-block, siren-whistle, maracas and whip. Here, according to the composer:

> The orchestra is in the audience and the audience in the orchestra. .. The scattering of the musicians brings in a radically new kinetic conception of music. . . The composition will thereby be entirely enriched . . . both in spatial dimension and in movement. The speeds and accelerations of the movement of the sounds will be realized, including logarithmic or Archimedean spirals in time and geometrically . . . [as well as] ordered or disordered sonorous masses, rolling one against the other like waves.
> (Xenakis 1971: 237)

At the beginning of the work, one pitch, E4, played by the strings in contiguous groups starting with group A, revolves around the circumference of the orchestra. A renotation of the score in graphic form brings out the various patterns of this movement (Ex. VII-9). As can be seen, each rotation displays a particular outline of dynamic accents (represented in the diagram by tiny, vertical arrows) superimposed on its scheme of durations (the duration of each note is depicted with a thick, black line). The instruments play overlapping sounds with similar dynamic envelopes (crescendo followed by decrescendo; these envelopes are not marked on the diagram)

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203).

[17]Example VII-8b shows also the location of high woodwinds participating in the rotations in mm. 125-195 (clarinet 1, oboe 1, flute 1, oboe 3, E-flat clarinet, flute 2, oboe 2, piccolo); cf. Ex. VII-11.

thus creating the illusion of sound movement.[18] The idea of using superimposed dynamic envelopes and temporal shifts to cause continuous changes in the apparent position of instrumental sounds was modeled on an electroacoustic technique, that is, on stereo sound projection. In stereophony, differences of intensity between identical signals from two separate channels (loudspeakers) are used to suggest changes in the location of virtual sound sources. Xenakis describes this in the following way:

> Let us say that we have a monophonic recording of one sound and we want to make this sound move from loudspeaker A to loudspeaker B when the two are separated spatially. In order to do so we need to use two potentiometers, one for each channel, opening potentiometer A then closing it while slowly increasing the level in channel B. The balance is very sensitive; the most difficult thing is to have the sound coming from the center between the loudspeakers. This is just a simple example; in reality, sound movements are usually more complex and depend on the architecture of the performance space, the position of the speakers and many other things. When you want to reproduce such a complicated phenomenon with live musicians playing one after another with amplitude changing in the same way that you change the levels in a stereo sound projection, sometimes it will work and sometimes it will not. It depends on the speed of the sound as well as on the angle of two loudspeakers or musicians, that is on the relative position of the listener. These two considerations are equally important.
>
> (Xenakis 1992: 6-7)

According to Xenakis, "in the case of circular motion one can establish a uniform progression resembling the movement of the second hand on a clock: the same amount of time--the same distance" (Xenakis 1992: 7). This is how *Terretektorh* begins. At first, the motion is circular both in space (because of the position of the instruments) and in time (because of the temporal structure of the movement with constant velocity).[19] Soon, the temporal pattern of dynamic accents changes, bringing in sound acceleration and deceleration, while the spatial form of the movement

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[18]The perception of this effect is very fragile; it depends on the position of the listener and the quality of performance, that is the placement of the groups, the exact matching of pitch, timbre, dynamics and so forth.

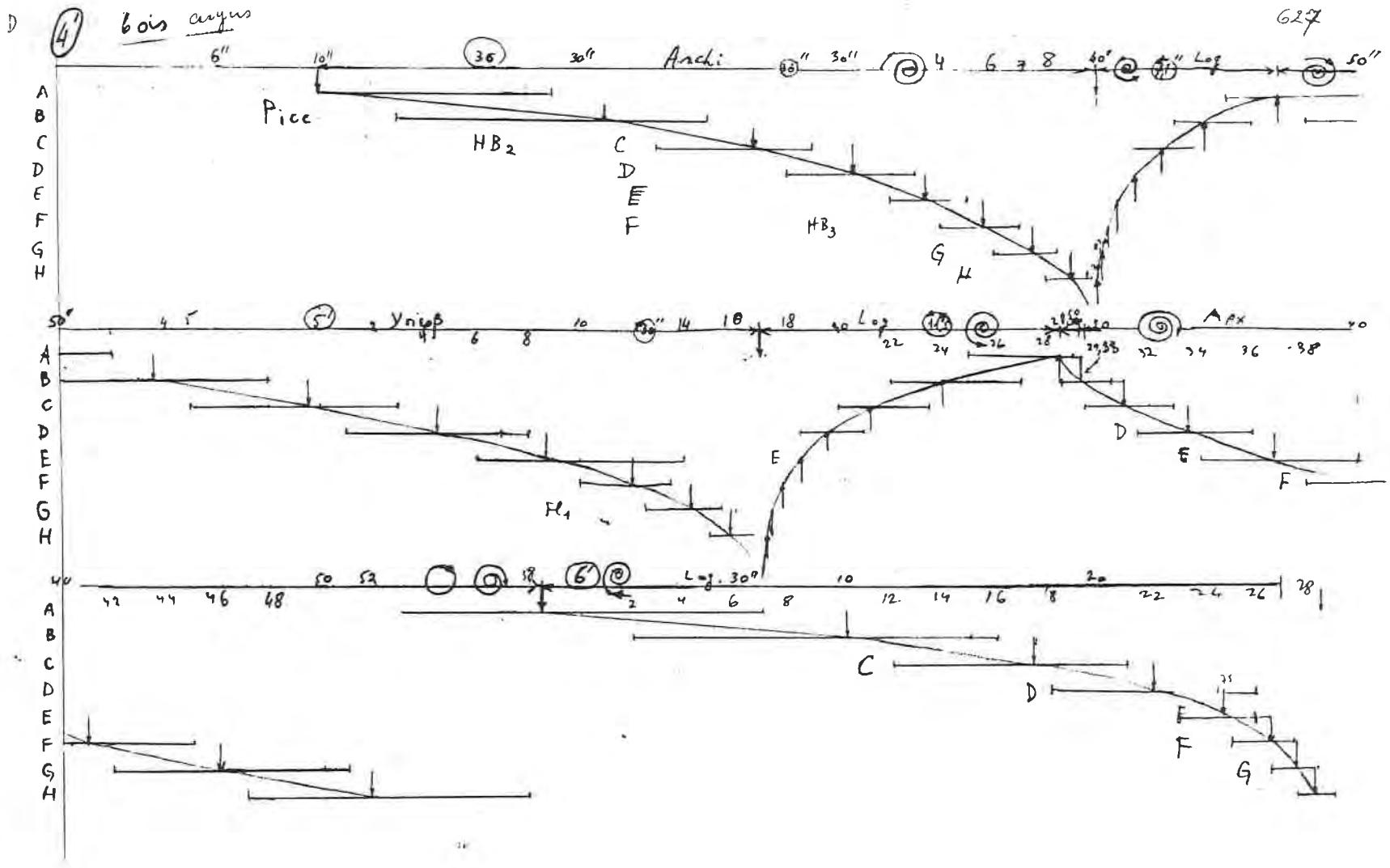
[19]In Xenakis's geometric representation of time, linear progressions (successive, equal durations) are represented by circles, while non-linear patterns (increasing or decreasing durations) are modelled with spirals.

remains circular. Following a change of direction in mm. 45-48 the movement gradually increases in velocity until the single sonic particle, E4, splits into an unstable microtonal cluster. At the moment of the change of direction, the spatial pattern of sound movement is also momentarily disturbed. Now, the motion is constrained to group H, highlighting its wedge shape from the tip outwards and back again. This disturbance, followed by an equally rapid motion of whip sounds in group G leads to a brief moment of 'turbulence' in mm. 49-50.

The increased speed of movement in mm. 51-74 is noticeable right away. What is not obvious, though, is the construction of this spatio-temporal motion. Describing *Terretektorh* in *Formalized Music*, Xenakis wrote about realizing accelerations with logarithimic and Archimedean spirals (in an excerpt quoted above). Before proceeding to search for these patterns in the opening of the work, let us turn our attention to a different fragment of *Terretektorh*, a fragment in which the identification of spirals is made possible by Xenakis's sketch (Ex. VII-10).

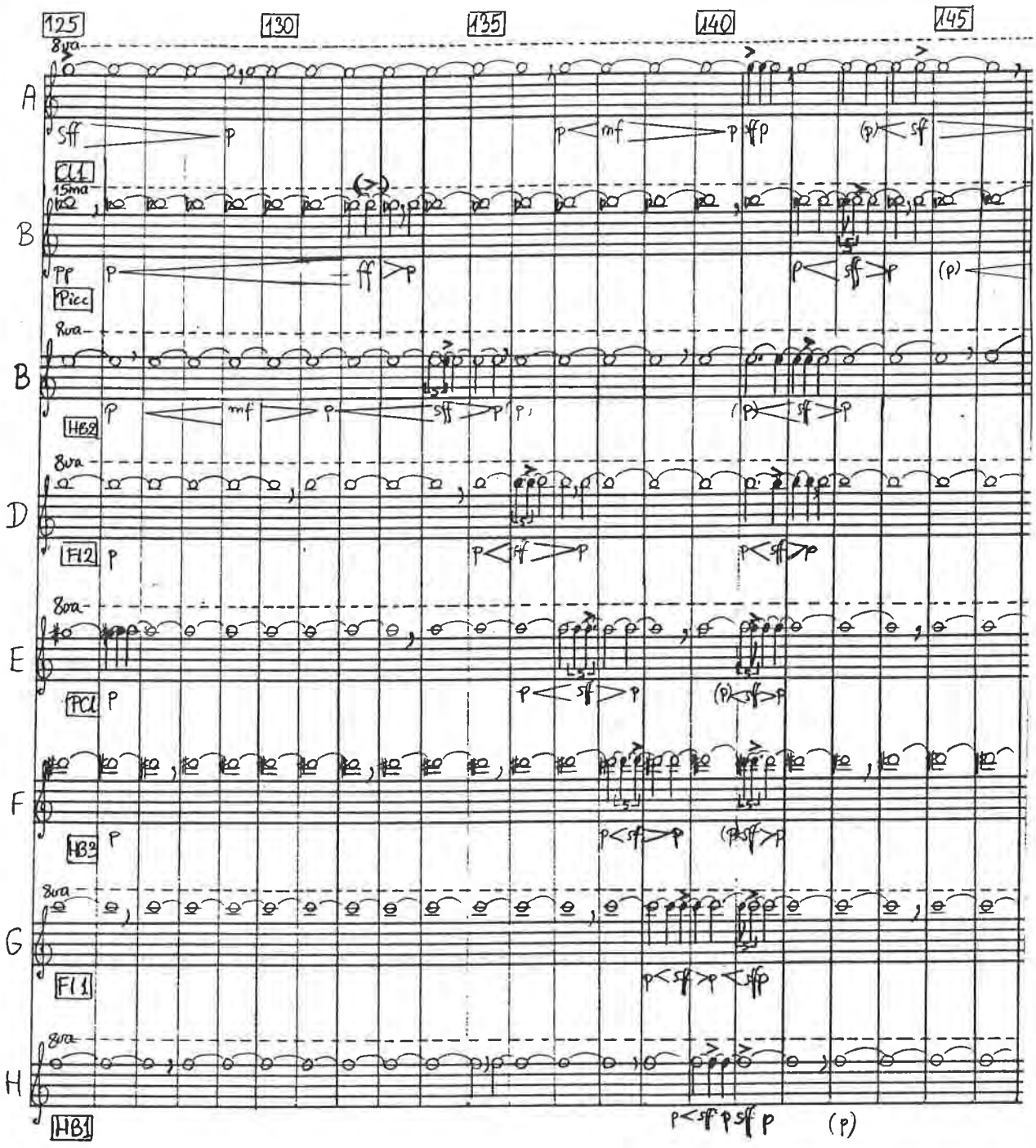
Xenakis's sketch does not contain information about all the layers of this section of the music; it reveals only the structure of the movement in the woodwind instruments. The pattern of durations and accents shown on the sketch is rendered in the score as a pattern of dynamic changes of a sustained eight-note chord in the flutes, oboes and clarinets (Ex. VII-11). Each of the instruments, placed at a different point in space (cf. Ex. VII-8b), plays one pitch continuously, ranging from D#6 to Bb7.

The spatial sound movement realized by the high woodwinds in mm. 125-195 of *Terretektorh* constitutes only one of the layers of the music. The complex, multilayered texture also includes (1) a steady rhythm on low drums from the three percussionists placed outside the circle, (2) irregular clouds of percussive sounds (that is whips, wood blocks, maracas) scattered throughout the orchestra, and (3) sporadic glissandi in the strings at various points in the space. In fact, when listening to a recording of the work, one may notice least the sustained chord in the high woodwinds. Here, the idea of spatial sound movement is raised to a new level of abstraction: continuous motion involving different elements of a chord instead of a single pitch.



Schèma des spirales Archimédienne, logarithmique, hyperbolique, dans le sens et en secondes

Ex. VII-10: Xenakis's sketch of rotations in mm. 125-195.



Ex. VII-11: The woodwind parts of mm. 125-146 of *Terretektorh*.

What is the temporal pattern of this motion? The composer's sketch contains the answer (cf. Ex. VII-10). There are 6 spirals outlined on the graph paper and identified by abbreviations of their names in Greek. The direction of the movement is also specified, together with the basics of the instrumentation (details were changed later: there are two high woodwinds in group B, and group C is missing). Among the six spirals presented in this sketch, two are Archimedean, three logarithmic and one hyperbolical. They do not look like spirals; in fact, they are not complete spirals but only segments. Spirals, described by the appropriate mathematical functions, are infinite (for the mathematical functions and diagrams of three types of spirals used by Xenakis see Ex. VII-12, after p. 290). Xenakis uses segments of spirals, represented graphically as curves (in this representation a circle, denoting motion with constant speed, would be a straight line). To obtain different patterns of velocity the composer places dynamic accents at the points of intersection of various spirals with eight straight lines assigned to the eight instrumental groups, A to H. In the score, each spiral segment is, then, represented by a temporal outline of eight successive accents suggesting an accelerating or decelerating sound motion. Thus, mathematical functions structure the patterns of spatial sound movement.

A comparison of the diagram of mm. 1-75 (Ex. VII-9), made on graph paper similar to that of Xenakis's sketch, with the sketch itself allows for the identification of the velocity patterns presented at the beginning of the work as various types of spirals. In particular, spirals No. 4 and 5 of the diagram (mm. 51-65) are very similar to spirals No. 2 and No. 4 of the sketch, that is, to logarithmic spirals. The spirals differ in their curvature and their musical realizations follow different temporal patterns: deceleration in the woodwinds (sketch), and acceleration in the strings (diagram). The underlying mathematical structure remains the same. The full list of patterns presented in mm. 1-74 of *Terretektorh* includes eleven spirals (acceleration or deceleration), one circle (rotation with constant velocity) and one instance of non-revolving motion:

mm. 1-9: circle,
mm. 8-24: Archimedean spiral, acceleration,

mm. 23-34: Archimedean spiral, deceleration,
mm. 32-45: hyperbolical spiral, acceleration,
mm. 45-47: angular, linear motion in group H,
mm. 51-60: logarithmic spiral, acceleration, new direction,
mm. 60-65: similar logarithimic spiral with steeper curvature,
mm. 65-74: six logarithmic spirals with increasing curvature (increasing acceleration of movement).

The predominantly circular (in space) and spiral (in time) movement of a single pitch in the opening of *Terretektorh*, first developed in the form of spiralling woodwind chords (mm. 125-195), finds continuation in rotations of chords and clouds of percussive sounds (maracas, sirens and wood blocks) throughout the piece (for example, two types of sonorities moving in opposite directions in mm. 313-330). Huge masses of sound inter-react and crash together to produce new sonorities; a state of equilibrium is reached only in the final chord, a sustained mass of quarter-tones which covers the whole range of the orchestra (mm. 435-447). The incessant dynamism of sound matter in *Terretektorh* is well captured by the composer's metaphoric description of this work as "an accelerator of sonorous particles, a disintegrator of sonorous masses, a synthesizer" (Bois, 1967: 35).

7.3.

Spatialization and group theory in *Nomos Gamma*

The similarity of the seating plans of *Terretektorh* and *Nomos Gamma* (1967-68), for a larger orchestra of 98 musicians scattered among the audience (Ex. VII-13), does not imply a total identity of compositional concerns in both works. In fact, *Nomos Gamma* resembles *Nomos Alpha* for cello solo (1965) in this respect, for it is also based on the principle of mathematical group structure.[20] Xenakis explains:

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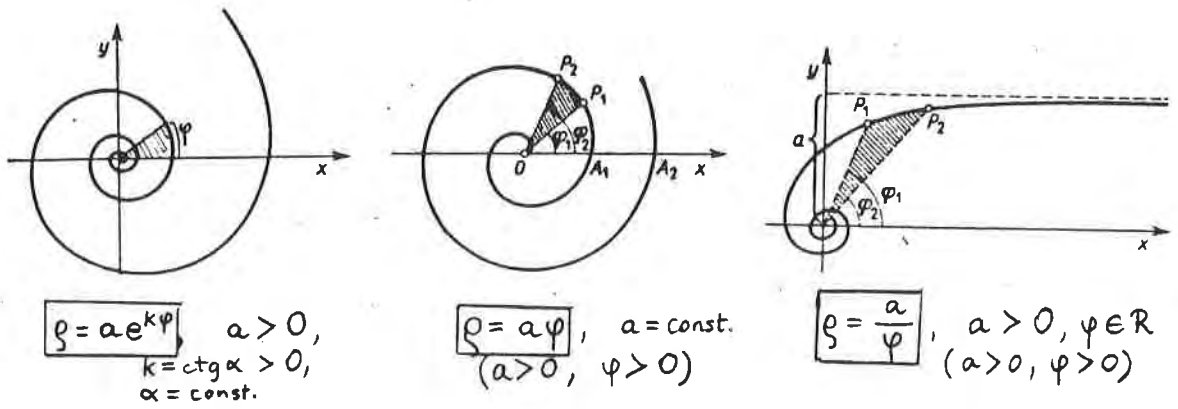
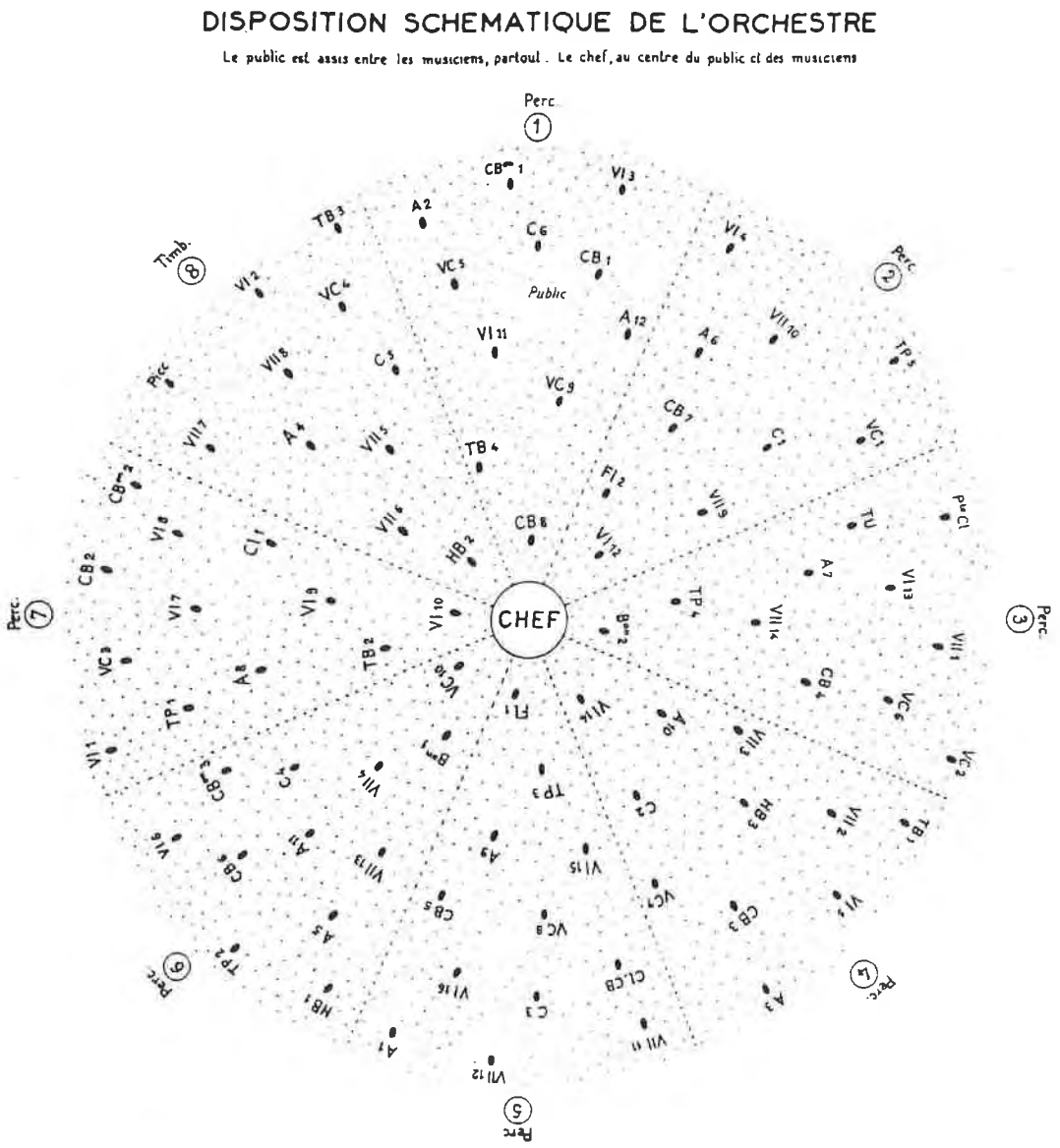
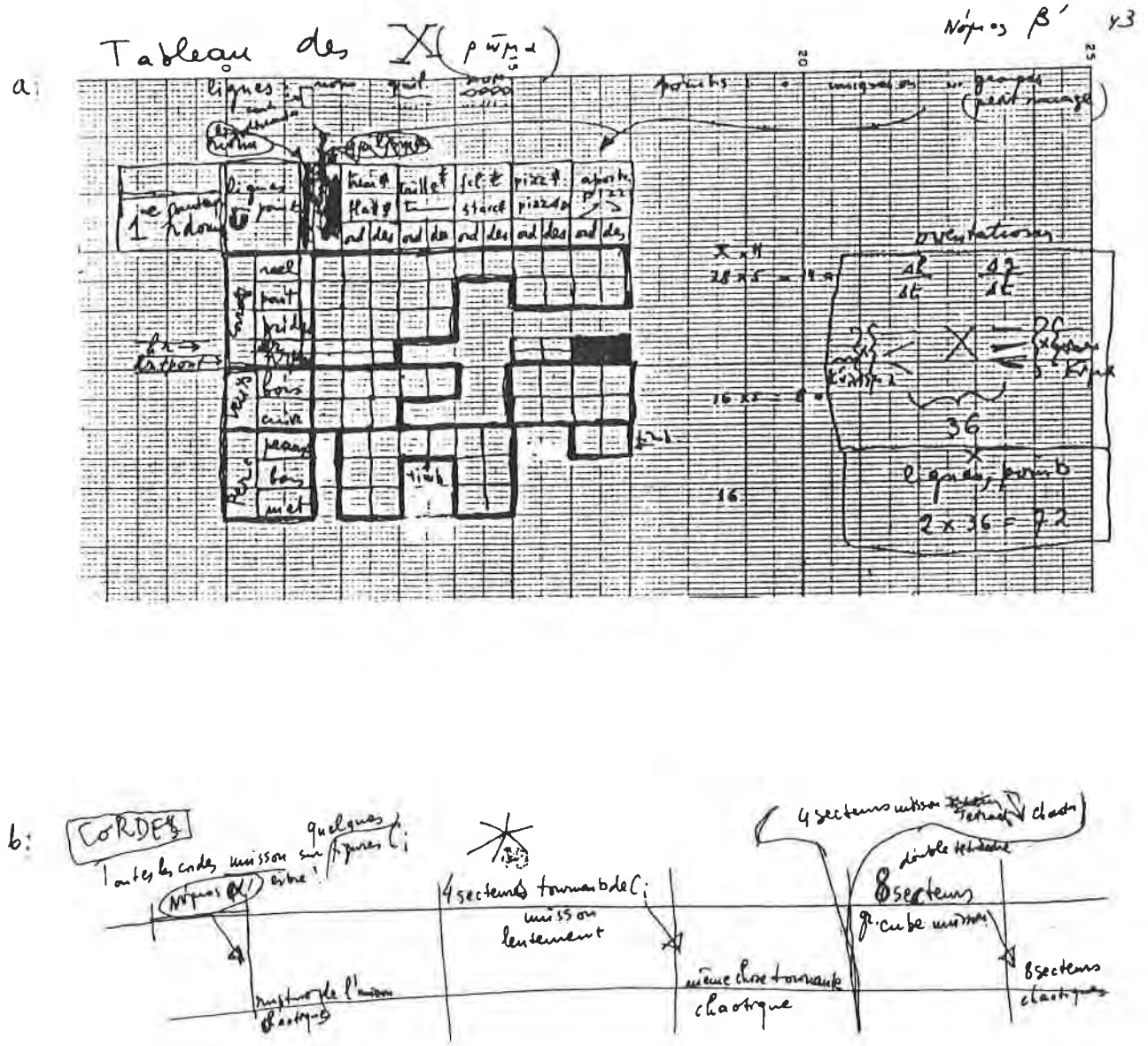
[20]Unlike *Nomos Alpha*, a favoured topic for analysts of Xenakis's music, who have been assisted by the composer's detailed discussion of the work in *Formalized Music* (e.g. Vandenbogaerde 1968, Naud 1975, DeLio 1980, Vriend 1981), *Nomos Gamma* has not



Ex. VII-12: Mathematical functions for logarithmic, Archimedean and hyperbolical spirals.



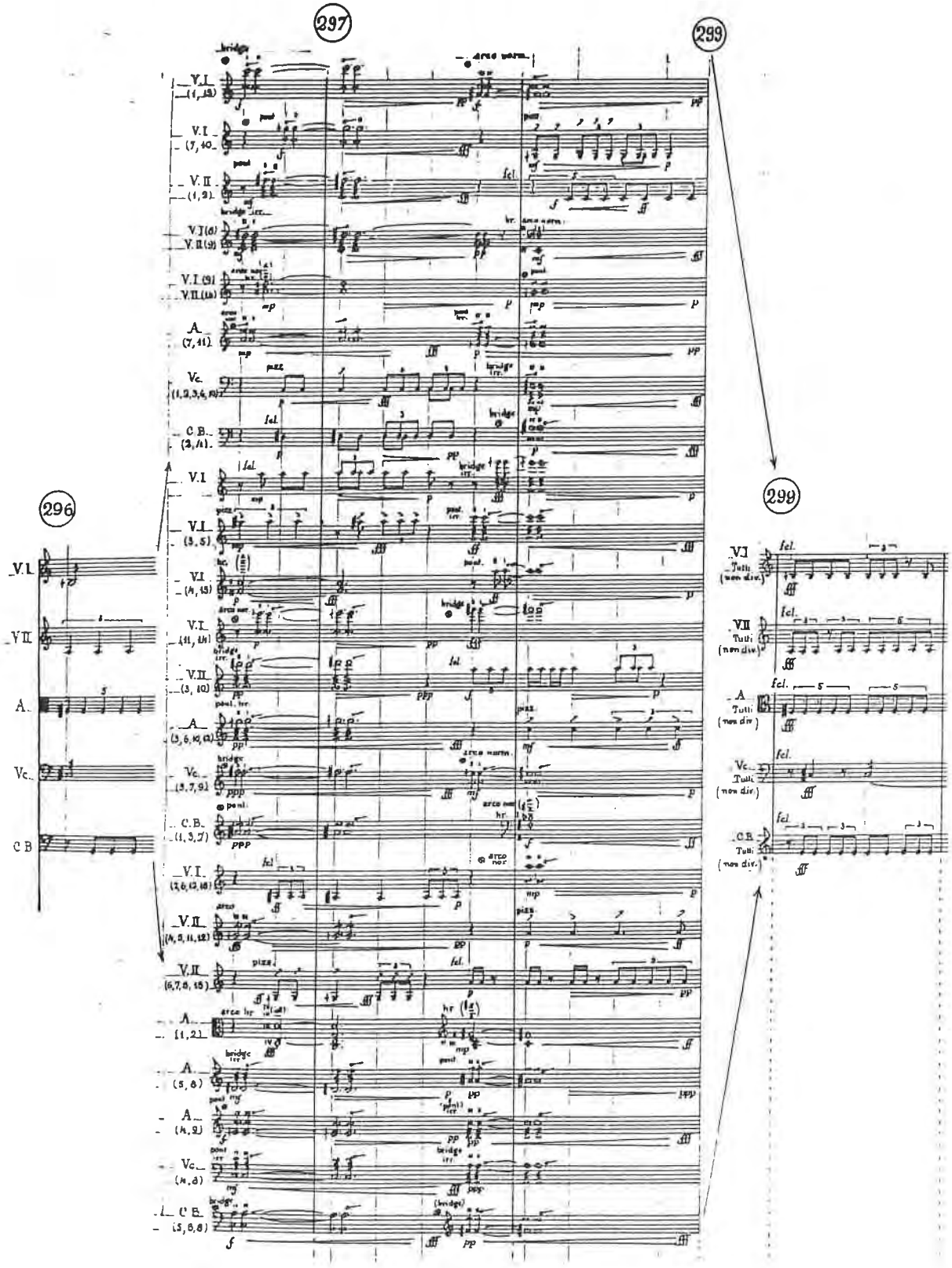
Ex. VII-13: Seating plan of Xenakis's *Nomos Gamma* (1967-68).



Ex. VII-14: Xenakis's sketches for *Nomos Gamma*.

a: A table of sound material (set X);

b: Sketch of alternating spatial textures in the strings.



Ex. VII-15: Shifting textures in the strings in mm. 296-299 of *Nomos Gamma*.

> Group structure means that there are elements which are connected in some way: two elements combined together create another element which belongs to the same set, or group. Suppose that you have a melodic pattern. You can create the retrograde of this pattern thus obtaining two elements, one normal and one backwards. Now, if you take the inversion of the intervals of the normal sequence of notes, you create a third pattern, and if you take the retrograde of the inversion you get a fourth pattern: there are four forms here, no more. . . . These four forms can be combined with each other: the retrograde of the retrograde creates the first pattern, the retrograde of the retrograde inversion brings back one of the four forms again. So the system is closed, it is a set of four elements that can be combined by coupling them. The same isomorphic group (iso means equal) appears in the geometric pattern of the rectangle. If you study the symmetries of the rectangle you may notice that it can be inverted around the middle axis plotted both vertically and horizontally. There are four transformations of the rectangle onto itself, exactly like in the melodic pattern. This kind of group structure can be found in *Nomos Gamma*.
>
> (Xenakis 1992: 10)

According to the composer, spatial sound placement is included among the elements of mathematical group structure. If, for instance, the number of positions of instruments is limited to four and if in each of these positions a different melodic pattern is performed, a systematic exchange of spatial placements of the patterns is made possible by rotations of the rectangle on which these patterns and positions are plotted. In addition to the rectangle, *Nomos Gamma* exploits group tranformations mapped onto "the triangle, the square, the pentagon, the hexagon, the tetrahedron and the hexahedron" (*Formalized Music* 1971: 237). Here, compositional thinking involves a high level of abstraction in manipulating the elements of the music. Nevertheless, the elemental building blocks are quite simple--as can be seen in Xenakis's sketch for *Nomos Gamma* (still titled *Nomos Beta'* in Ex. VII-14a). This sketch contains a table of types of musical material (set X) attainable from the strings,

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been well studied yet. The difficulties of approaching this enormous work are increased by the lack of information about its compositional procedures. While discussing *Nomos Gamma* in *Formalized Music* (chapter 8), Xenakis states that this work "is not entirely defined by group transformations. Arbitrary ranges of decisions are disseminated into the piece, as in all my works." (Xenakis 1971: 238).

wind instruments and percussion, such as, for instance, ordered or disordered tremolos, trills, and various types of pizziccati.[21] These basic types of ordered or disordered materials may be used to create straight, curved or broken lines, as well as various groupings of points--elements for an outside-time musical architecture. By assigning these elements (lines, points) to definite spatio-temporal locations, Xenakis constructs dense sound masses which extend throughout the performance space. These masses of complex texture either slowly evolve in time or rapidly alternate with contrasting spatial and textural patterns.

The second type of spatio-temporal distribution, involving rapid shifts of texture, appears in the strings (cf. Xenakis's outline of material for the strings in Ex. VII-14b). Here, the basic ideas of order and disorder govern the temporal succession of musical sections. The sketch indicates the type of group transformations applied to the material (double tetrahedron, cube) as well as the number of sectors of the orchestra involved (4 or all 8). The alternating sections of unison and of chaotic turbulences plotted in this sketch are realized, for instance, in mm. 296-300 of *Nomos Gamma* (Ex. VII-15). Here, the texture alternates between 5 parts (each section of the strings in unison) to 24 parts (2 to 5 instruments from the same section in each part).

Formalized Music (1971: 236-241) contains two analytical examples from *Nomos Gamma*, that of the work's beginning (mm. 1-22) and of the "sound tapestry" in mm. 404-442. The latter example is more interesting from the spatial point of view: the music has a very complex, evolving and spatially extended texture built from a multitude of sound-elements performed by divisi strings. In addition, this

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[21]Not all instruments are capable of performing all such effects, yet the score of *Nomos Gamma* requires, for example, the winds to imitate pizziccato by means of a special type of articulated attack. In Ex. VII-14a instrumental sonorities are plotted on the vertical axis: strings (playing normally, sul ponticello, sul tasto, harmonics and harmonics sul ponticello), winds (woodwinds and brass), and percussion (skins, wood, metal). The horizontal axis enumerates various articulations: normal, tremolos, trills, col legno or staccato, pizziccato and pizziccato glissando. These ways of playing are subdivided into two categories of lines or points and of order or disorder.

"tapestry" of sound is structured by means of what Xenakis terms "tapisserie du cube" (in the sketches), indicating that group theory provides a detailed organization for the intricate and seemingly unordered texture.

Spatialization in *Nomos Gamma* is not limited to transformations of complex sound-masses. The work concludes with an interesting spatial effect which makes use of percussion instruments (tuned tom-toms and kettle drums) assigned to each of the eight groups of the orchestra (cf. Ex. VII-13). In mm. 445-559, the percussion performs a series of 198 rotations.[22] The velocity of this circular sound movement is stable (at a quarternote = 150 MM) and each rotation, constructed from overlapping tremolos, lasts for just O.8 seconds. To avoid monotony, the timbre changes, usually in an descending pattern; the beginning of each circle is marked by the sonority of the kettle drum in Group 8 (Ex. VII-16).

7.4.

Sound rotations in *Persephassa*

The elaborate construction of velocity patterns in *Terretektorh* utilizes individual segments of spirals; the conclusion of *Nomos Gamma* presents a repeated circular motion of stable velocity. The idea of continuous sound movement is further developed in *Persephassa* (1969) for six percussionists encircling the audience.[23] The percussionists are placed at equal distances on the circle, so that they outline a hexagon (Ex. VII-17). Unpitched instruments of skin, metal and wood are used, some with identical timbre in all locations (e.g. metal or wooden simantras, Xenakis's invention) and some differing slightly (e.g. cymbals or gongs of various sizes).

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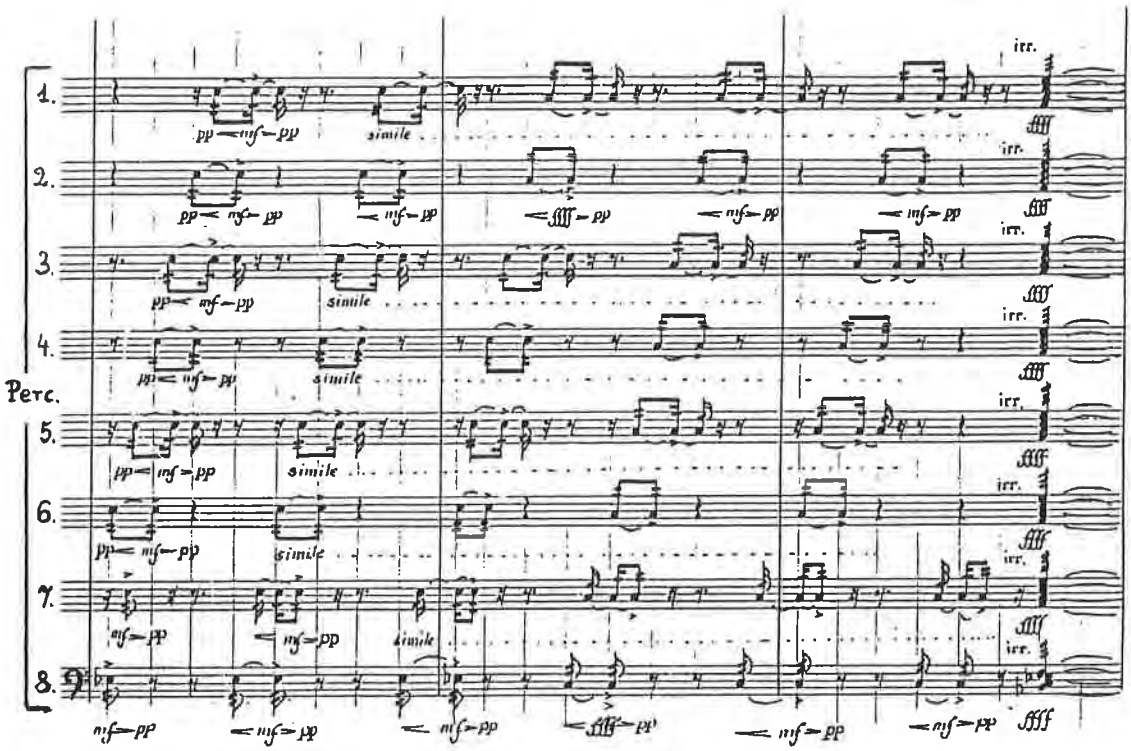
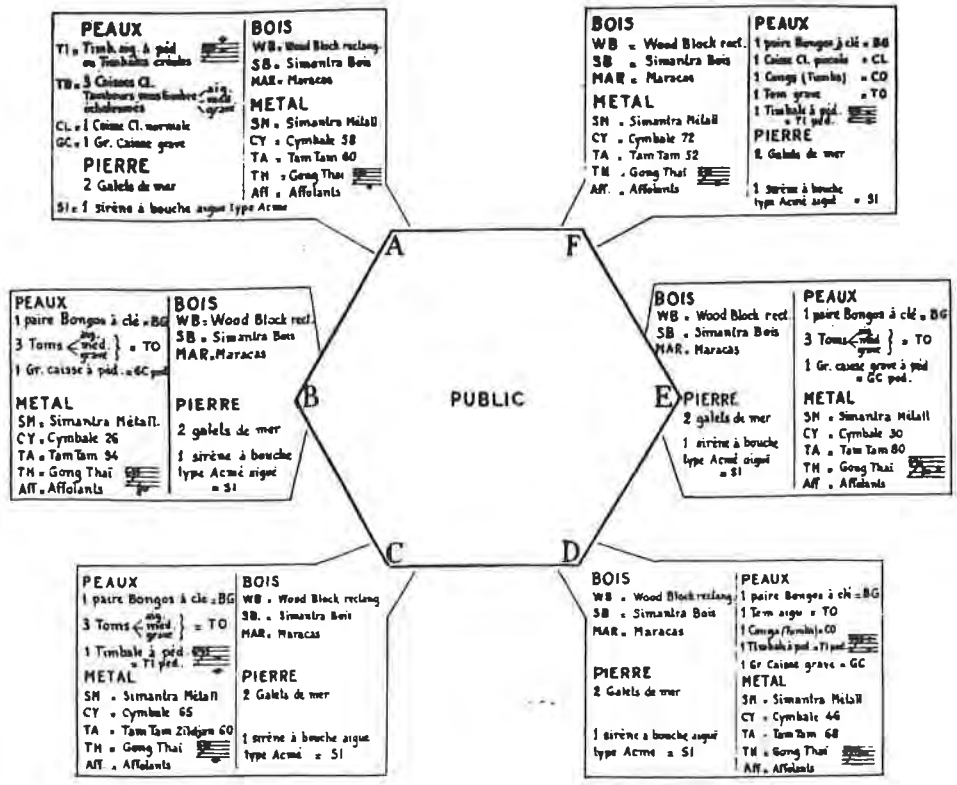
[22]The rotations are subdivided into seven segments consisting of 26, 98, 5, 18, 12, 15 and 24 revolutions.

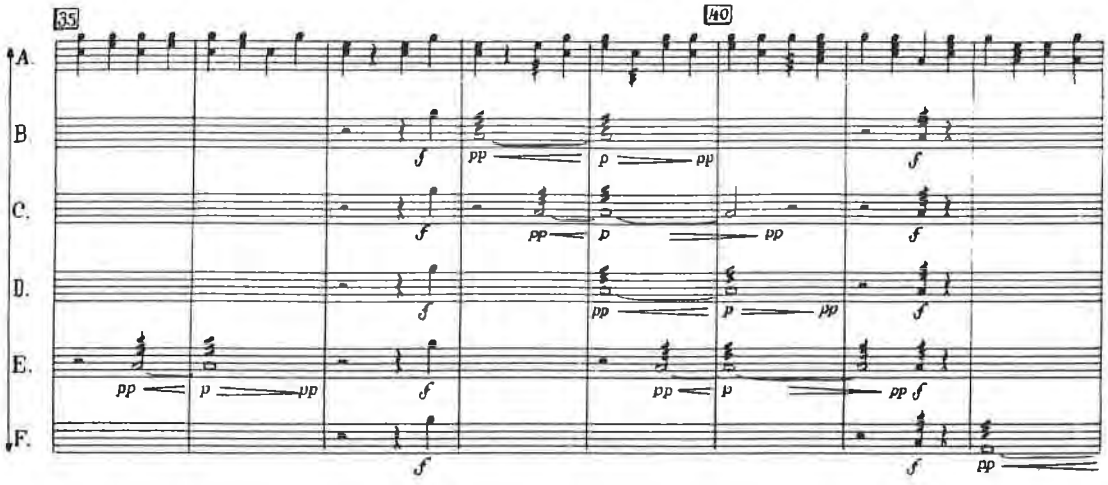
[23]According to the composer, *Persephassa* "exploits in a new manner the Screen Theory of the logical functions of residue classes modulo m, together with space-sound kinematics, as in *Terretektorh*, *Polytope* and *Nomos Gamma*" (liner notes for the recording by *Les Percussions de Strasbourg*, Philips PG 310, stereo 6718040, no date).



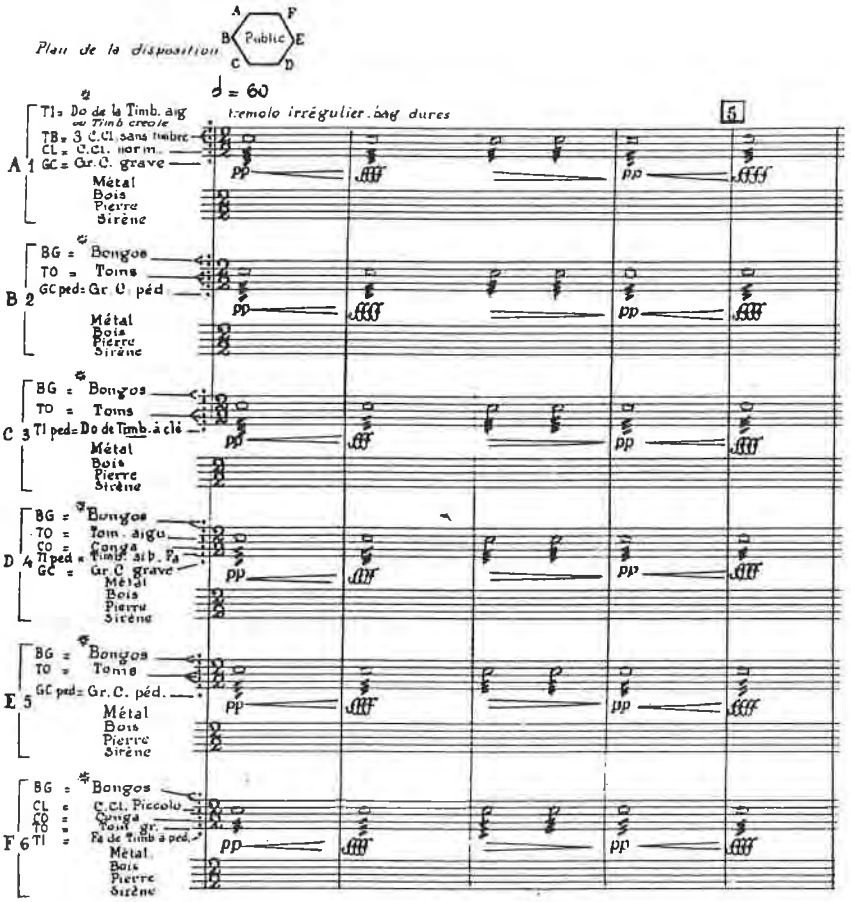
Ex. VII-16: Sound rotations in *Nomos Gamma,* mm. 511-513 (percussion parts).



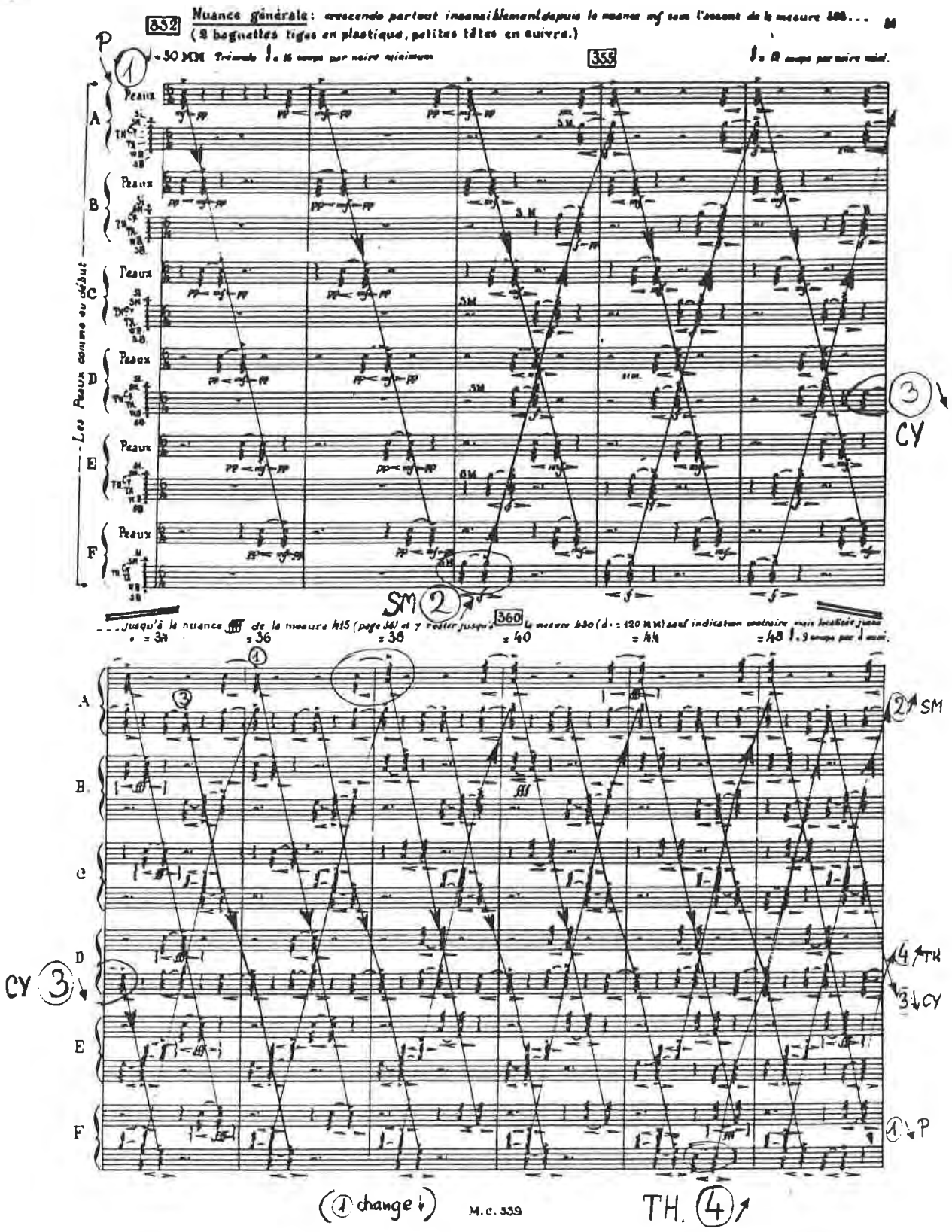
Ex. VII-17: Placement of instruments in *Persephassa* (1969).



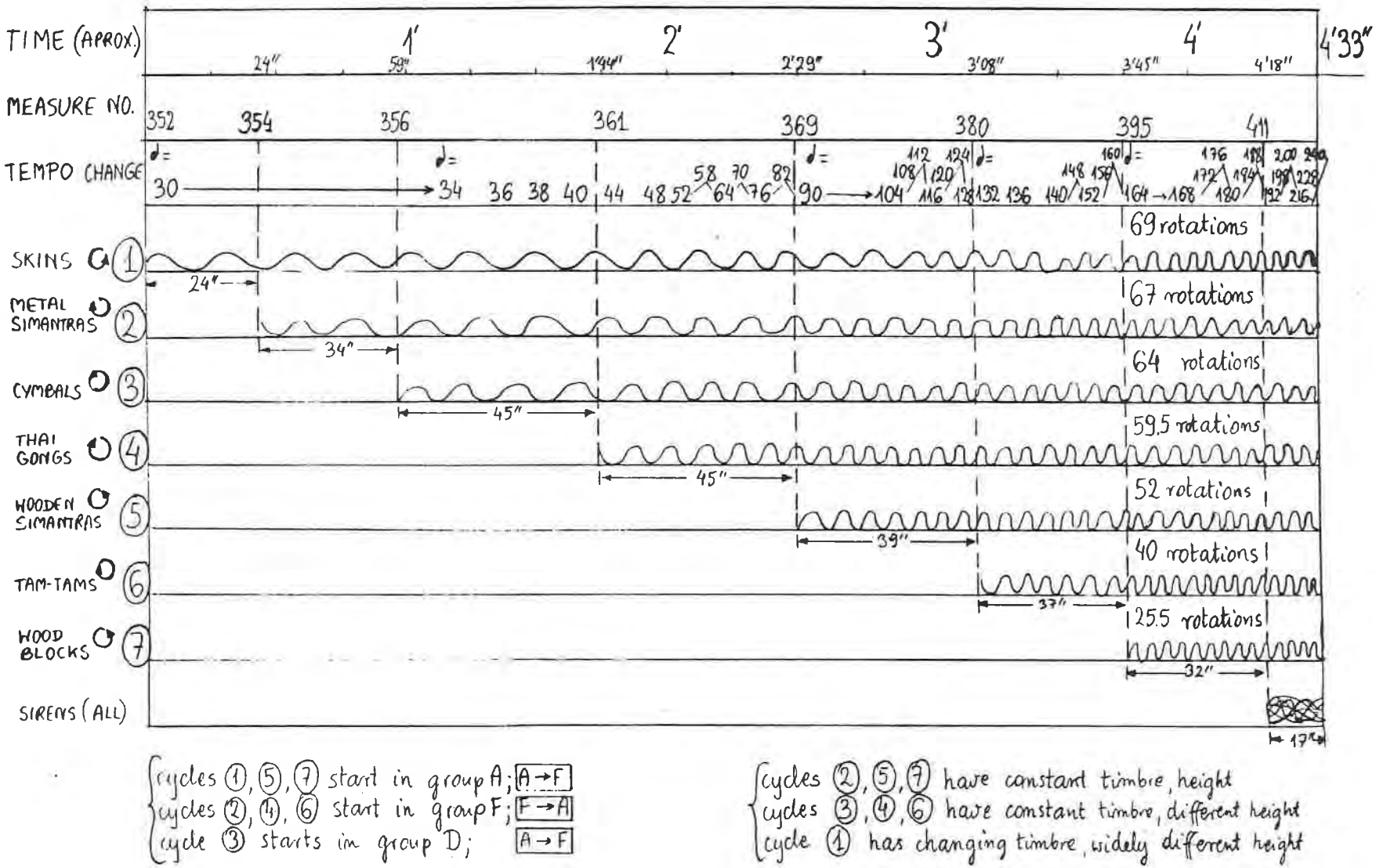
Ex. VII-18: Semicircular movement in mm. 38-41 of *Persephassa*.



Ex. VII-19: Mm. 1-5 of *Persephassa*, percussions A-F in unison.



Ex. VII-20: Entries of 4 layers of rotations in mm. 352-362.



Ex. VII-21: Diagram of all rotations, mm. 352-420.

Spatial sound movement is usually created by means of overlapping dynamic envelopes; the dynamic peaks mark the shift of sound from one spatial location to another. The first instance of such movement in *Persephassa* provides a semicircular background for a more prominent rhythmic pattern in percussion A (m. 38-41; Ex. VII-18). This is only a hint of what will follow in the dramatic climax and finale of the work. Other allusions to a full scale dynamic sound movement are scattered throughout *Persephassa*: brief moments of rotation, patterns shifting in a circle, dynamically shaped tremolos. Even the opening of the piece, with tremolos on the tom-toms (mm. 1-5; Ex. VII-19) brings associations, in retrospect, with the climactic "space-sound kinematics" by following the familiar dynamic pattern of pp--crescendo--ff--decrescendo--pp.

The climax of *Persephassa* (mm. 352-455) begins with a slowly rotating tremolo on the drums (4 tom-toms and 2 snare drums) to which other timbrally distinct layers are gradually added, thus increasing the density of the texture (Ex. VII-20). The superimposed cycles of rotations are performed on metal simantras (from m. 354), cymbals (from m. 357), Thai gongs (from m. 361), wooden simantras (from m. 369), tam-tams (from m. 381), and wood blocks (from m. 395). The seven layers alternate in direction and differ in their starting points. The whole section is characterized by a gradual increase of speed and an overall crescendo, culminating in the eruption of sirens in all the groups in m. 410.

This construction consists of an impressive number of rotations varying from 69 revolutions of the drum layer to 25.5 rotations of the wood block tremolos (Ex. VII-21). Each single rotation is circular rather than spiral, i.e. each one is in a constant tempo. These tempi, however, increase rapidly, from that of one quarternote = 30 MM in m. 352 to 240 MM in m. 420, and to 360 MM at the end of the piece. At this point, (from m. 430 to the end), the complex multilayered texture of the music is reduced to one layer of rotating drum tremolos of varied timbre and erratically changing direction. The rotations, lasting only 1 second each, are interspersed with silences and fortissimo sound clouds. Thus, the accelerating motion ends in a vortex of sound, moving so fast that it seems to become stationary. As the duration of one

complete rotation decreases from 12 seconds to 1.5 seconds during the continuous cycle of rotations (in m. 420), and to 1 second at the end of the work, it is easy to calculate the total increase of velocity. The seven layers of tremolos move 8 times faster at the end of their cycle of rotations than at the beginning, while the following solitary cycle of drum tremolos revolves 12 times faster than the same drums at the beginning. In *Terretektorh*, accelerations are constructed as segments of spirals, here, a large-scale temporal spiral is built from many individual circles of increasing tempi.

The timbral features of the distinct layers are also noteworthy. There are two types of timbral groupings: instruments of exactly the same timbre perform cycles 2, 5, and 7 (metal and wooden simantras, wood blocks), while instruments of the same quality but different pitch are used in cycles 3, 4, and 6 (cymbals, Thai gongs and tam-tams). All these metal instruments differ in size; their dimensions and relative pitch change irregularly from group to group. But it is the timbre of the first layer of drum tremolos that is the most varied: all available skin instruments are ordered in 6 groups according to their relative pitch (higher bongos, lower bongos, high, medium and low tom toms with timpani, low bass drums). The rotating sound gradually descends, with each level presented during at least one complete revolution. Moreover, regardless of the pitch, drums of percussion A always differ in timbre from the remaining ones, in order to articulate the beginning of each rotation. There are, then, two types of spatial motion: (1) of one timbral entity, resembling the motion of a single pitch in *Terretektorh* and (2) of varied colour, analogous to the randomly presented ingredients of the woodwind chord, the second instance of spirals in *Terretektorh.*

It is known from psychoacoustics that the fusion of distinct sound images (here: overlapping tremolos) into one auditory stream (here: the image of continuously moving sound) is possible when the sounds are sufficiently similar (Bregman 1990). The perception of the continuity of movement requires timbral identity of the sound supposed to be moving and Xenakis fulfills this condition, at least in approximation. The difference between various layers in the climax of *Persephassa* is greater than the difference between the elements belonging to the same layer. Naturally, proper

dynamic balance and mutual distances between the instruments are imperative for the perception of the spatial movement to take place.[24]

7.5.

Spatial canons and sound planes in *Alax*

Following *Persephassa*, the 'tour de force' of rotations, Xenakis's compositional interests turned elsewhere, but the technique of 'spatial movement by dynamics' remained his and he used it again, to a different purpose, in *Alax* of 1985. This work for three identical instrumental ensembles placed at the summits of an equilateral triangle explores timbral and spatial interactions of various instruments and their groupings. According to Xenakis, the title means "transformations of planes, disorders, orders, sonorities, structures (inside or outside time)." It also denotes "interchange between the positions of the sound sources . . . and the sound planes."[25]

The familiar overlapping dynamic envelopes reappear to highlight spatially extended sound planes of different timbres in mm. 94-96 (Ex. VII-22). These planes, composed of all the woodwinds, the brass, the strings with harps and all the instruments in turn, intersect or transform into each other. There is no movement from one point in space to another, for all the sound planes are performed by instruments from the three ensembles in unison. In these circumstances, according to Henry Brant, the pioneer of spatialization, a "spill" phenomenon takes place (Brant 1967). Instead of hearing what one might expect, that is, isolated sounds localized

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[24]The preservation of the equidistant placement of the percussionists seems particularly important. This was very evident during one disastrous rendering of *Persephassa* by the Warsaw Percussion Group in the 1980s. The performance took place in the concert hall of the Academy of Music in Warsaw, which allowed neither for a symmetrical placement of the players nor for their sufficient distance from the audience. On another occasion, in a more suitable performance space, the same group presented *Persephassa* in a very convincing manner.

[25]From Xenakis's note in the score of *Alax* (1987).

exactly at their points of origin at the summits of the triangle, we hear diffuse, spatially extended sonorities, aptly named sound planes by the composer.[26]

In *Alax*, timbral similarity is also explored in spatial canons which involve instruments from the three groups (for example all horns, or three solo celli sul ponticello). The structure of a 12-part canon in mm. 44-48 (Ex. VII-23) with voices entering successively in different ensembles at the interval of one thirty-second note leads to an effect of spatial sound movement: each entry of a sustained note is presented in a cascade of dynamic accents around the audience. The instrumentation balances solo horns and trombones with three other instruments playing together (flute, clarinet, harp). The overall dynamic scheme is that of a large-scale crescendo; the movement has a stable background of one "sound plane" of violins and cellos from the three ensembles performing a sustained octave (G5-6).

Obviously, sound movement realized by means of only three ensembles is quite rudimentary, and spatial effects in *Alax* lack the complexity of those introduced in the earlier compositions. This compromise is a consequence of Xenakis's experience with the realities of the concert hall; as the composer confesses with resignation,

> I have changed the conventional location of the musicians in the orchestra by placing brass and woodwinds in different places, the percussion in several spots, etc. I have tried to do that but the musicians hate it. The reason is that they do not have the same acoustic environment as usual, an environment that helps them to play correctly. . . . Even if you have fantastic ideas if you write something that is unusual it will not be played, or maybe just once. And that is not good enough.
>
> (Xenakis 1992: 12)

In *Alax*, orchestral musicians are not exposed to the public as in *Terretektorh* or *Nomos Gamma*, for they are grouped into three separate ensembles. In addition, the score allows for the placement of these ensembles "in a line on stage from left to right." Obviously, the directional quality of the sound does not constitute the most crucial aspect of the music. Nevertheless, Xenakis makes use of a number of spatial

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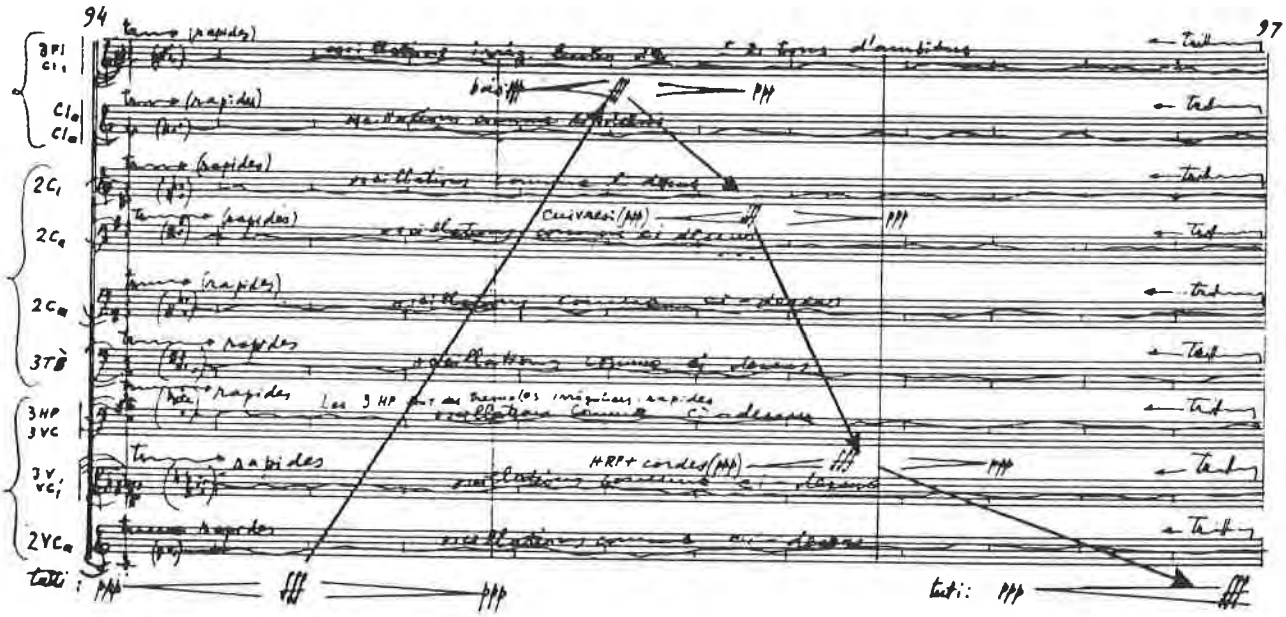
[26]Here, Xenakis uses the same perceptual effect that Brant termed *spill* (Brant 1967; cf. chapter III, 3.2 and chapter VI).

patterns: from complete temporal unison (e.g. all horns and celli playing a series of chords in mm. 88-90), through numerous spatial canons between groups of identical instruments performing similar--but not identical--musical material, such as the brass in mm. 17-22 (Ex. VII-24), three sets of bongos (mm. 25-26) or three solo cellos (mm. 31-33), to complex multilayered textures of the three ensembles playing simultaneously (the conclusion of *Alax,* especially mm. 160-186).

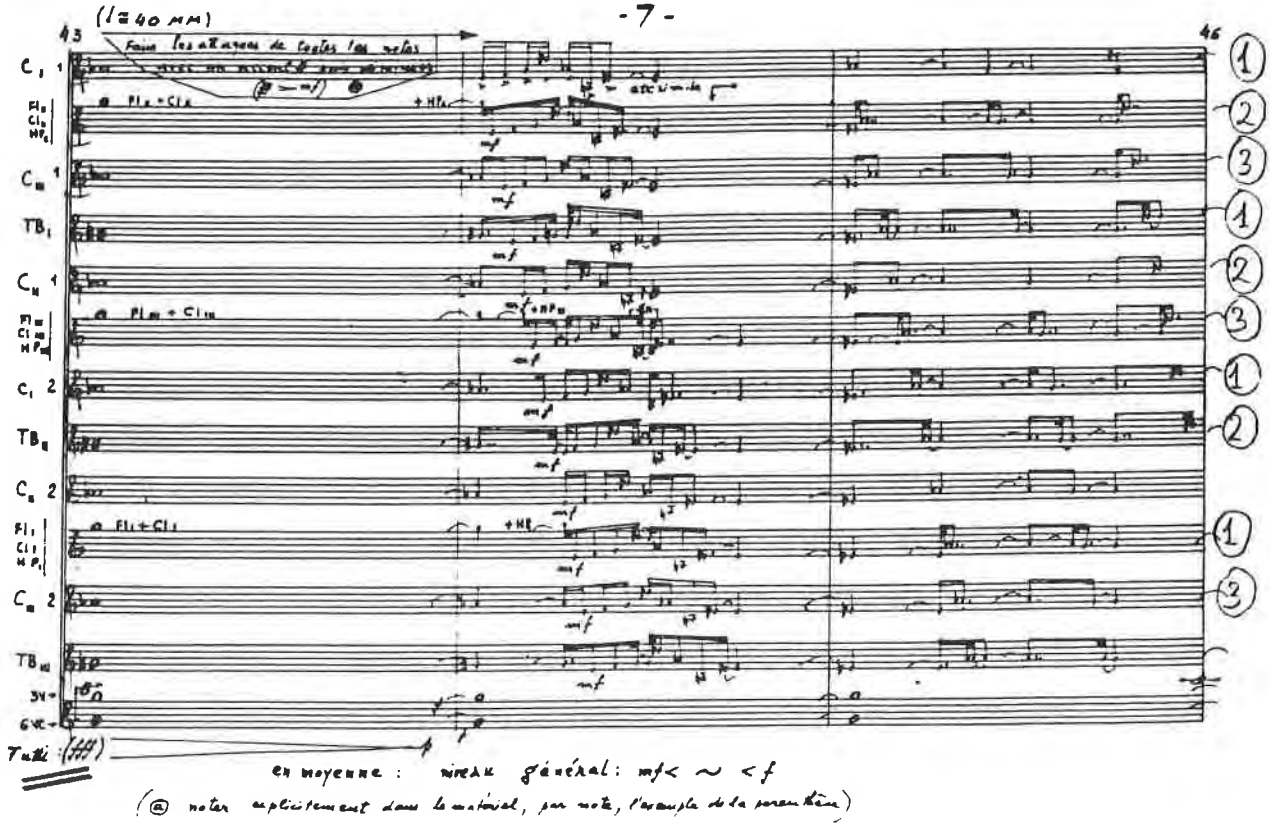
The realization of these effects requires timbral identity and spatial separation of the three groups. Instruments of the same timbre from the three ensembles may have staggered entries, as in the many canons, or may play simultaneously when layers of different timbres are superimposed on each other. In a particularly delicate effect of this kind, in m. 52 (Ex. VII-25) the three violins, clarinets and flutes perform an ascending scale ending at F#6. The scale is slightly asynchronous in the three timbral groups, so that the colour of the music evolves simultaneously with its rising pitch.

Even though the limited number of instrumental ensembles of *Alax* seems to invite comparison with sixteenth-century polychorality, also heavily indebted to canonic techniques, Xenakis vehemently denies the existence of this connection (Xenakis 1992: 11). There may be two reasons for his outspokeness on this subject: his distrust of organized religions (polychoral music was mostly composed for the Church) and his commitment to total creative originality--which precludes conscious links to the musical past, other than Xenakis's own. The composer believes that

> In musical composition, construction must stem from originality which can be defined in extreme (perhaps inhuman) cases as the creation of new rules or laws, as far as that is possible; as far as possible meaning original, not yet known or even foreseeable.
>
> (Xenakis 1971/1991: 258)



Ex. VII-22: Sound planes in mm. 94-96 of *Alax* (1985).



Ex. VII-23: 12-part spatial canon in *Alax*, mm. 44-46.

Conclusion

Xenakis's original contribution to the development of spatialization comprises a variety of techniques, from performer movement, through the use of spatial canons and superimposed cycles of rotations, to carefully structured velocity patterns. From *Pithoprakta* to *Alax*, Xenakis's spatialized music juxtaposes technical sophistication with an overwhelming forcefulness of expression. Evolution of stochastic sound masses in *Pithoprakta* (1955-56) is linked to a rudimentary form of spatial motion of sound on the stage. *Eonta* (1963-64) explores acoustic resonances, movement of the performers on the stage and the directional quality of brass instruments. The conquest of performance space goes one step further in two compositions for large orchestra, *Terretektorh* (1965-66) and *Nomos Gamma* (1967-68). In both works, the orchestral musicians are interspersed amongst the audience and the patterns of sound placement and motion are structured with mathematical means. *Nomos Gamma* concludes with a series of sound rotations around the audience; a similar effect crowns *Persephassa* (1969) for six percussionists. In the climax of this composition, seven distinct layers of sound revolve simultaneously in opposing directions (the technique of 'spatial movement by dynamics'). Spatial design is simpler in *Alax* (1985) for three identical ensembles which articulate spatial canons, interpenetration of sound planes, etc.

In his spatialized compositions, Xenakis does not consciously refer to any tradition, including that of polychorality. Neither is he indebted to his contemporaries, such as Brant (cf. Chapter VII of this dissertation), Stockhausen or Berio (cf. Chapter VI). Although Stockhausen was the first to compose the effect of virtual spatial sound movement in instrumental music (*Gruppen* of 1955-1957), Xenakis's ideas developed independently.[27] The technique of sound movement used by both composers owes its origin to their experience with electroacoustics, i.e. with stereophonic sound projection. However, Xenakis's music benefits from his mathematical and architectural background including his cooperation with Le Corbusier and Varèse on the Philips Pavilion (1957-1958). In addition, the Greek

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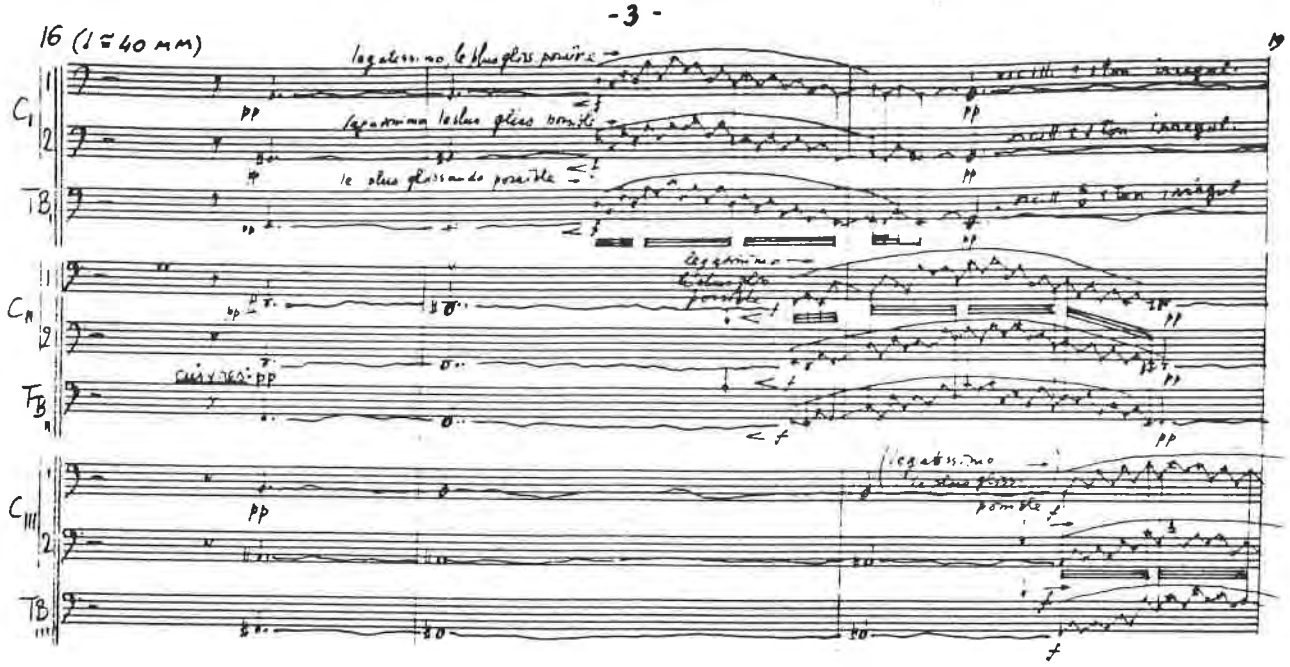
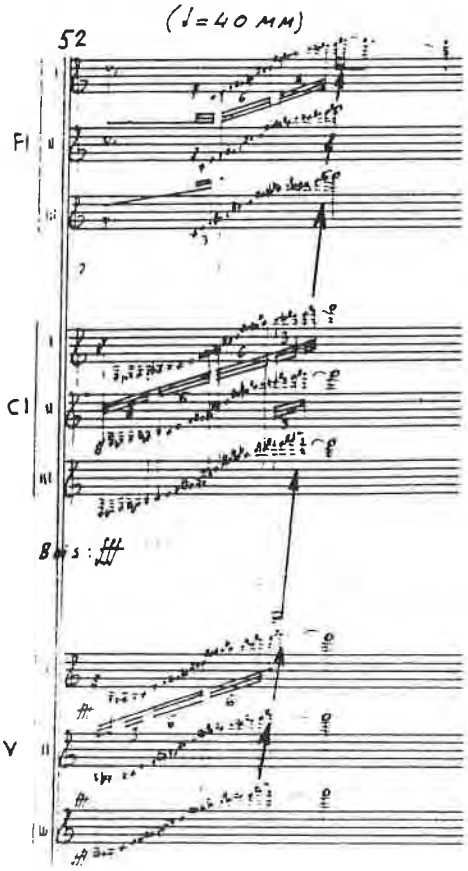
[27]Cf. the discussion of virtual sound movement in chapter V.



Ex. VII-24: 3-part canon of brass glissandi in *Alax*, mm. 17-18.



Ex. VII-25:
Evolution of pitch and timbre,
(violins, clarinets and flutes)
in m. 52 of *Alax*.

composer develops Varèse's notions of "sound mass" and "sound trajectory" in instrumental music. Despite his insistence on total artistic originality and the uniqueness of his style, Xenakis's music does not exist in a vacuum. It belongs to the context of musical objects projected in space (the second large conceptual area within the domain of spatialization; cf. Chapter III, section 3.3). When Edgar Varèse postulated the idea of "the liberation of sound" he envisioned that in the music of the future

> the movement of sound masses, of shifting planes, will be clearly perceived . . . There will no longer be the old conception of melody or interplay of melodies. . . The entire work will flow as a river flows.
>
> (Varèse 1936/1966: 11)

This bold vision has, perhaps, found its true realization in the spatialized music of Iannis Xenakis.