Stockhausen's *Cosmic Pulses*

ROBIN MACONIE

Some people chase tornados; others go after black holes. From the late 1950s Stockhausen was fascinated by the idea of sounds in rotation and how to realise them in a technical sense, by means of an array of loudspeakers.

Completed in 2007, *Cosmic Pulses* is Stockhausen's final electronic composition.[1] For a number of reasons I believe the composer knew it would be his last. The work was completed in a rush. In many ways, notably in terms of the sound material, which is very basic, it remains a sketch. The music can be described as a massive rotating sound mass, composed in 24 separately spinning frequency layers. The work thickens gradually to 24 layers, then reduces symmetrically upward in an ascending spiral that ends quite abruptly. An audience may experience the sensation of falling headlong into a black hole, or, if one is an optimist, of being carried aloft on the whirlwind like Dorothy in *The Wizard of Oz*.

A tornado is an effect of a natural imbalance between temperature layers in the atmosphere, tipped into motion by the earth's rotation, which moves progressively faster toward the equator. The rotating air mass that results spirals upwards and generates a powerful electrical charge. A black hole by comparison is an effect of gravitation creating an imbalance in spacetime. The rotational process that results spirals downward or inward and leads to the extinction of reality as we know it, or again, if one is an optimist, creates a wormhole leading either into another universe, or into our own universe at

another point in time. Such cosmic associations are in keeping with the composer's superhuman imagination and perhaps an underlying agenda of imminent transmigration.

The dynamics of fluid flow are of fundamental interest to aerodynamics engineers and designers. They apply to the design of passive bodies moving through an airflow at speed, like an aircraft, to traffic management in an airport, and in a different sense to the design of rotating bodies and cavities such as enclosed turbines and propellors which generate thrust in order to create movement. Music has an interest in the dynamics of fluid flow because the oldest surviving musical instruments, bone flutes with clearly defined fingerholes, are also the earliest relics on record that imply the modelling and manipulation of an airflow within a confined space or duct. Consciously or otherwise, a stone age flutist is acquiring the art of regulating an airflow within a resonant cavity to a point where the excess ventilated as tone fluctuates in dynamic but stable relation to the pressure introduced from an external mouth or bellows. The interest of such feedback processes in a primitive sense is of being able to model, and by implication, take control over a force of nature. It is pure science. In a musical sense, it is the pleasure of converting a chaotic flow of air into a structured output of pressure pulses audible as a tone of constant pitch. The attraction of transforming a chaotic flow of energy into an audibly structured flow is that the tone that mysteriously results is beautiful in itself, and can be heard over a greater distance than the voice. Employing a flute is a more energy efficient mode of communication than singing or shouting, and more reliable and easier to control because the pipe is a more rigid and predictable structure than the vocal apparatus, which is made of soft tissue.

It follows as a matter of principle that any musical composition inquiring into the nature of fluid flow and rotational processes is attached to an ancient tradition of studies in time and motion connecting the art of music with the origins of science and technology in human consciousness.

Externally *Cosmic Pulses* resembles a study in turbulence in nature of a kind we recognize in a storm or waterfall as painted, say, by a Turner or Van der Velden. But this is self-evidently a manufactured turbulence, which has contrary implications. Natural turbulence is the expression of a self-regulating process that arises when surplus energy is introduced to a resisting structure, like ignited petrol vapour into a cylinder, or air pressure into a pipe or flute. Under certain conditions, for example when a fluid is trapped between rotating inner and fixed outer cylinders, frictional resistance may lead to the creation of a layered structure, known as Couette-Taylor flow, in the manner of the layered storms that visibly circulate around Jupiter and Saturn, and weather systems on earth.[2] However a composition of 24 layers is more likely to signify a work of theory, or exploratory experimentation, than an attempt to reproduce a natural process. When an eight-channel speaker array is taken into account as the virtual cylinder or container of this acoustic torrent, then the turbulence that results asks to be considered, not simply as musical content for which the speakers provide a delivery system, but rather as the product of an interaction of composite energies of varying amplitude with a resonant container of fixed tuning. In contrast to Stockhausen's earlier works *Kontakte* and *Sirius*, where blocks of complex sound are uniformly rotated, in *Cosmic Pulses* layers of equivalent tone material are independently rotated in a serial polyphony of interval

relations, frequencies, speaker combinations and periodicities. As always, the justification of serial procedure is that if anything interesting emerges from the mix, it can be pinpointed to a precisely quantifiable combination of factors.

MUSIC EXAMPLES

[1] Stockhausen *Cosmic Pulses* at 10′ 00″ Stockhausen Verlag SV 91 1.42

[2] Stockhausen introducing (23) layer 3 of *Cosmic Pulses* SV91 1.03

Assume for the time being that the present 24-layer complex of whirls and eddies is an intellectual construct based on aesthetic theory and not an attempt to replicate a natural process. Such a structure in dynamic but stable multiple rotations may then be said to imitate a mechanical invention like an early pendulum clock. The 14th-century Beauvais timepiece, representing a planetary system with rotating moons, orbiting around a gravitational centre, was constructed to signal religious festivals celebrating the seasons of the year, and motion of the cosmos, rather than "the time of day", a concept which did not then exist. Reflecting on this marvel of intermeshing cogwheels, set in harmonious motion by weights, the philosopher Buridan declared that henceforth the universe was powered not by divine impulse but by gravity, a thought anticipating Newton by several hundred years. From the same late medieval perspective *Cosmic Pulses* can be construed as a device for modelling the music of the spheres, and to that extent a controversial assertion of human science in opposition to divine will: an invention for regulating and controlling the flow of cosmic time.

Whether sounds are natural or artificial in origin, the key to constant rotation,

for any process in cyclic oscillation, is a singularity or unified power source. In the harmonic language of music, that unifying source is usually expressed as the fundamental tone. However there are problems that can arise in the makeup of rigidly harmonic structures forced to resonate at high intensities. A wineglass that shatters at the sound of a high pure note, or a suspension bridge that collapses under the resonances excited by a constant gale (as in San Francisco) or troops marching in time, does so from a buildup of sympathetic vibration that eventually discharges explosively rather than gradually and safely. The medieval makers of cathedral bells understood this. In a classic bell partial vibrations are deliberately inharmonic, which means that they oscillate at different speeds within the structure. This prevents harmonic stresses from building up and allows the excess energy to dissipate slowly and gradually, creating interesting inner fluctuations that by coincidence also make the bell tone sound more voice-like at a distance.

Problems facing the artificial simulation of moving sounds in acoustic space, and technical issues relating to the breakup of such sounds reproduced at high speed, are the subject of the present paper.

Conventional concert music and associated recording techniques are predicated on fixed tonal and spatial relationships. The players sit relatively still, the environment is of fixed dimensions, the audience is seated, and microphones or speakers are at fixed locations.

In real life however people and sounds do not stay in one place. Objects move from place to place while we are listening, or alternatively we move and the whole acoustic environment changes, often both at once. The most

complex acoustic experience available to most of us is also one of the most common and least recognized. It is of standing at a busy intersection in a city high street and waiting for the lights to change: a constant polyphony of sounds moving in different directions, appearing and disappearing like a flowing river, the *Blue Danube* of musical metaphor. In real life, when a sound is moving in relation to the listener its inner structure is heard to change in subtle but meaningful ways which for the sake of simplicity we can call red- and blue-shifting. If a sound is approaching a listener, its harmonic structure is compressed and higher in frequency, a blue-shift. The harmonic structure of a sound drawing away from a listener is stretched and lowers in frequency, a red-shift. For a sound rotating near or around the listener at increasing or decreasing speed the resulting phase distortions relative to its frequency spectrum at rest are modulating continuously in a highly complicated and non-uniform manner.

For the 1940 Disney movie *Fantasia*, a system for recording and rotating the sound of a symphony orchestra was developed by RCA. The system employed a form of optically controlled amplitude modulation, or pan-potting. Pan-potting is still the technology of choice in the modern studio, but is unrealistic by virtue of insensitivity to modulations in the higher frequency range on which human perception of fine movement in nature actually relies. In the 1950s the American composer Henry Brant wrote up a programme of experiments in recording and reproducing the sound of musicians moving in space at different speeds.[3] The idea of a concert performance in which the participants are all moving is reinvented in Andrew Lloyd Webber's *Starlight Express*, although the interesting challenge of reproducing in surround sound a singing chorus on roller skates, spinning in different directions like particles

in an accelerator, is avoided through the use of individual radio microphones. The chorus members of Stockhausen's *Michaelion* from the opera *Wednesday from LIGHT* are also required to spin and orbit independently, like the moons of Saturn, to a scrupulously notated script and with somewhat greater decorum, but the technical issues of conveying the rotations in live or recorded form remain unaddressed.

When continuous sounds are rotated at speed within a fixed speaker configuration they start to break up. The process begins as a flap as the sound passes from speaker to speaker.

[3] Stockhausen *Kontakte*; Wergo 6009-2 (1) at 00. 39 1.01

When the interval between speakers exceeds a threshhold of 15–20 cycles a second, the flap becomes audible as a tone. Two things happen: one, the time slot through which the sound can pass gets shorter and shorter, in relative terms, the faster the rotation; two, the transition from silence to sound becomes progressively more abrupt and more audible. This "siren effect" of rapid rotation was investigated by Helmholtz in the 19th century, rejected as inappropriate by Meyer-Eppler and Eimert, and employed by Stockhausen in the German Pavilion at the Osaka Expo '70 for which a spherical auditorium, and manual "sound grinder" for rotating sounds in various configurations were specially constructed to the composer's specification.

[4] Stockhausen *Kontakte* pulse stream; Wergo 6009-2 (2) at 18.45 1.44

In nature the same process obtains, when a flow of air from the lungs is

modulated by the tissues of the larynx, or the reed of an oboe, or the player's lips under pressure in the mouthpiece of a trumpet or horn, to generate a musical tone. A siren breaks a relatively inaudible continuous flow of air into pulses which radiate as audible pressure waves. For electronic sounds in rapid rotation the speakers correspond to the perforations in a siren. In the instrumentarium of the Cologne Electronic Music Studio founded by Eimert and Beyer in the early 1950s, the so-called *impulse generator* employed for the equivalent purpose as in the example just heard is an electronic off-on noise gate controlled by a square wave that can be varied in duration and periodicity, a technology first employed by Stockhausen for the impulse showers of *Gesang der Jünglinge*. For the opening and closing greetings of Stockhausen's *Sirius* higher speed rotations at audio frequencies were recorded by means of a specially constructed sound turbine, and reproduced through a horizontal 8-channel circle of speakers surrounding the audience. This high-speed rotation creates a subjective impression of static shimmering columns of sound subject to spontaneous alterations in direction and harmonic frequency with every head movement of the individual listener. In these moments, as Stockhausen observes, the sound "starts dancing completely irregularly in the room—at the left, in front, it's everywhere"—even changing in pitch.

[5] Stockhausen: *Sirius* (Capricorn) at end; SV 59 (69) at 22.15 2.42

Whether the composer fully understood how this effect was achieved is not entirely clear. But he treated it as a significant discovery and it is reasonable to suppose that part of his motivation in composing *Cosmic Pulses* using digital processing to achieve similar results on multiple levels, may have been

an attempt to achieve a similar epiphany of tongues of flame, but on a richer and more varied scale. The dancing columns of sound described by Stockhausen amount to *eigentones* or eigenfiguren: complex standing waves created from the momentary intersection of harmonic components from opposing speakers on either side of the listener, meeting and reinforcing each another in amplitude while appearing to cancel one another directionally.

When sounds that supposedly originate in the centre of a sound field are reproduced from successive points at the periphery of the field it is not surprising if discontinuities occur. To put this into historical perspective, Stockhausen was creating rapidly rotating sounds in four channels for *Kontakte* in the studio at Cologne, in 1960, an era when balance engineers Arthur Haddy, Roy Wallace and others at Decca in the UK were only just perfecting a method for capturing very much slower, real time side to side movements of singers in opera, in order to reproduce the natural impression of a live performance on stage without voices getting lost in the stereo "hole in the middle". Responding to the same challenge, in 1960 Luciano Berio composed *Circles* for soprano Cathy Berberian, in which the singer is asked to move back and forth, in a formally determined way, among a group of instruments whose sounds imitate different elements of voice production and sounds of the alphabet.

The siren distortion of high-speed movement, if we can call it that, arises from focusing the moving sound into a single narrow beam like a lighthouse, and rotating it from speaker to speaker so that only one speaker is carrying it at a time. In real-world audio a rotating sound caused by a slingshot or bull-roarer is continuously audible in every direction, with only its location and

centre of pitch appearing to shift relative to the individual listener. The rotating sounds of *Kontakte* are initially mono tracks, output to a speaker mounted horizontally on a manually rotated turntable, the sound directed outward and rerecorded by a square formation of inward-facing microphones. The rotating speaker was enclosed in a conical baffle tapering outward instead of the traditional flaring megaphone—in an attempt perhaps to focus the emerging signal, but ultimately to emphasize the flap effect by accenting the discontinuity from one speaker to the next. The flap effect may even have been reduced or eliminated had the speakers been equipped with a flaring baffle like a trombone or clarinet bell, acoustic features designed to ensure a smooth transition of pressure and avoid sudden discontinuities. That Stockhausen adopted the turntable arrangement in the first place tells us that he either wanted the effect to resemble a Helmholtz siren-like perforated airflow, like an impulse-generator translated into the spatial domain; or that he did not know how to make the rotations move more smoothly. It does indicate all the same that he consciously intended to record the subtle acoustical transformations of sound in motion rather than rely on pan-potting, and thus was acting under technical advice, probably Meyer-Eppler's, since he has opted for the far more difficult process of physically rotating and re-recording the sound, rather than simply using a joystick to move it from channel to channel. Despite the process adding an extra tape generation to reach the master tape, recopying each layer as a physically rotating movement at least allows the rerecorded sound to acquire a hint of the red-shift and blue-shift of Doppler modulated sounds in nature, and for those subtle shifts in frequency to be reproduced in playback.

In 1984 an opportunity arose for Stockhausen to spend two weeks at IRCAM

in Paris. He decided to take advantage of the enormous computing power of the 4X, which became the 4C processor, to synthesize an alternate version of *Kathinkas Gesang* for flute and electronic sound in which rotating complexes of sound are built up layer by layer out of separate but coordinated harmonic layers, each individually red- and blue-shifted in frequency. "The most essential aspect is the six-layered space-polyphony of controlled phase-rotations of harmonic spectra", he later wrote. "Simultaneous phase-rotations of phase-synchronous partial groups of rich overtone-spectra . . . can be of a beauty such as has never before been experienced. . . . One can accurately follow quarter, third, and above all half-phases; and the coincidence of the maxima of all of the overtones (where a sharp explosion occurs at the point of phase synchronization) is perceived each time as a liberating new beginning."[4]

[6] Stockhausen "Kathinkas Gesang" (*Samstag aus LICHT*) SV28B 1.31

The effect is distinctive and luminous, like a hologram in sound, but curiously static. It raises the question whether all of that effort is really leading to a naturalistic effect of movement, or whether normal human beings actually process complex moving sounds in a different way. Bearing in mind that movement in the movies is an illusion arising from natural delays in human sensory processing of optical information, it raises the question whether the goal of recreating acoustical movement can perhaps be better met by replacing the intellectual goal of continuous flow with a granular imagery to be processed impressionistically, like a painting by Manet or Seurat. In Stockhausen's *Carré* for four orchestras, composed at the same time as *Kontakte*, it is noteworthy that the broken textures of the

turbulent X-moments inserted into the orchestral fabric are more effective in conveying dynamic movement than the static combinations elsewhere, which rely on imitatation pan-potting in amplitude and timbre:

[7] Stockhausen *Carré* Moment 82X; SV 5 (78) 1.57

The deliberately granular textures of Barry Truax's composition *Riverrun*, a composition dating from the same period as the electronic version of *Kathinkas Gesang*, may actually be designed to achieve the same goals as Stockhausen, of describing the dissociation and reconfiguration of a rotating harmonious entity while at the same time conveying a more tangible sense of physical movement.

[8] Truax, *Riverrun* (1986) (2) at 8.51 Harmonia Mundi LOC 278055 2.01

Composed at roughly the same time as *Kathinkas Gesang*, with less sophisticated software but having the added value of ambisonics processing, and using tone material and a granulation technique similar to Truax, my own composition *Touché* for computer generated sounds was mixed in a basic horizontal surround sound with the aid of an Ambisonic UHJ transcoder, technology offering the prospect of improved spatial coherence and directional clarity in sound projection. It includes a brief whirlwind passage:

[9] Maconie, *Touché* (1983/84) (3) 0.00 (unpublished) 1.39

The advantages of ambisonics are that the technology is uncomplicated and geared to human hearing, and that when a sound field is rotated, the

movement is not reduced to a succession of single channels but remains continuously audible in all speakers. Most importantly, changes of phase and phase relationships at higher frequencies are faithfully reproduced.

Cosmic Pulses is clearly the final chapter of a sequence of studies throughout Stockhausen's life motivated by atom-splitting ideas of breaking down and reforming timbres, of moving sounds in space, and of delving into the inner components and universal laws governing the cycles of natural phenomena from galaxies in the cosmos to nuclear particles. From one perspective *Cosmic Pulses* can be read as the act of an aggrieved disciple of Goethe flushing all of Empiricist science and technology, Newton's universe, down the toilet. The relatively crude tonal material and its lack of variety and lack of finish compared to *Kontakte* or *Kathinkas Gesang* could be indicators of genuine haste, but the absence of distracting aesthetic qualities has the effect of focusing attention on outstanding technical issues. Unresolved technical issues remain with other compositions, for example *Mikrophonie I*, how to record *Indianerlieder* so that the two voices interact, and the ring-modulation of *Mixtur*. Since the tone material in *Cosmic Pulses* is neither richer nor more interesting than Truax in *Riverrun* or my own *Touché*, the composer is not trying to score glamour points for instrumental colour or style. What is left is a schema of multiple rotations at speeds up to and including audible frequencies, and ranging in pitch over seven octaves from the lowest audible tones to well above 5 kilohertz, outside the human range of pitch discrimination. These cycles of speaker rotation and their interactions have to be the intellectual core of the composition. When rotation of a single sound mass among the full 8 speakers is involved, as in *Sirius*, unavoidably the sound will break up, although interesting results are obtained. But when

multiple rotations of mid- to high tone sequences at audio speeds are attempted among only 3, 4, or 6 out of an array of 8 speakers, the breakup is inevitably more pronounced. There are possible solutions, but the present version is not one of them. It is as though the composer is making a final effort to harness digital processing to achieve results that had so far eluded him in the analogue domain. His reported misgivings as to whether the work should be called *music* or merely a sketch, reinforce these suspicions.

My other area of criticism has to do with the reliability of some technical advisers and experts on Stockhausen's music. A paper by Michael Clarke and Peter Manning was published in 2008 in the journal *Organized Sound* under the interesting but longwinded title "The influence of technology on the composition of Stockhausen's *Octophonie*, with particular reference to the issues of spatialisation in a three-dimensional listening environment". It is a thorough and, to a specialist, potentially useful report of Stockhausen's intuitive use of hybrid, and often obsolete, electronics to achieve his compositional aims, and the composer's sometimes doubtful or less than accurate claims for the results. I am not a subscriber to *Organized Sound* but was impressed by the title and asked one of the authors to send me a copy, which he did.[5]

Given the title, I asked my correspondent what he thought about *Cosmic Pulses* and the problems of filtering and distortion related to rotating sounds in a fixed configuration of speakers at high speeds. He promptly referred my question to his coauthor, whose reply was amiable but vague, as though he had no idea what I was talking about. Their paper is ostensibly about controlling the movement of sounds in an 8-channel three-dimensional sound

space. It actually has nothing to say about the different acoustical approaches of Stockhausen's work, their practical implications, or relative success, despite alluding to both *Sirius* and *Kathinkas Gesang* at length and in detail. The composition of *Octophonie*, and the amazing effect of a rotating sphere of sound at the very end of *Dienstag aus LICHT*, deserve attention because in the latter case it appears as though Stockhausen has realised a long-held goal of creating sounds "suspended like globes in the room" as he reported the recorded sounds of a Bösendorfer piano floating in space from a 1958 visit to a private studio in the United States.[6]

[10] Stockhausen "Farewell" (*Dienstag aus LICHT*) (99) SV 43B 2.04

A reader expects such a paper to be informed, not only about the names and dates of items of equipment, but the implications of what they are expected to do. I regret that in this case the technical descriptions do not begin to deliver. The piece has nothing to say about the composer's objectives, or how they differ from piece to piece, or how aesthetic and conceptual differences can be related to changes of equipment and/or procedure. I can only account for the discrepancy between what the authors claim and what their paper actually delivers, as due to a lack of real-world experience in technical listening, recording, and reproducing sound and music in a natural environment.

The knowledge gap is both alarming and widespread. As part of the London South Bank "Klang" Festival on 7th November 2008 I was scheduled to give an hour-long paper on rotational processes in music leading up to Stockhausen's electronic music. I arrived an hour early at the Purcell Room to check the onstage stereo sound system only to find Gregorio Karman testing

an eight-channel sound system for a paper on *Cosmic Pulses* to be presented later that afternoon. The Purcell Room is a smallish concert chamber with shallow raked seating, not the ideal location for a performance of electronic music in the round. For the presentation two speakers were mounted at the back of the chamber against the wall, two more identical speakers against the walls to either side, and the remaining two on four-foot high stands respectively to left and right of the stage, forming a roughly octagonal array, on an upwardly inclined plane for the sound to pass at a constant level just over the heads of a seated audience.

Gregorio Karman was one of two audio specialists commissioned to assist Stockhausen in the realisation of *Cosmic Pulses* in 2007. Gregorio has written at length about the experience, and photographs of the team were posted on the Stockhausen website and elsewhere at the time. When I entered the Purcell Room he was standing with his back to the stage, talking to an invisible colleague in the projection booth. As I took my seat in the "sweet spot" or acoustic centre of the speaker array, he was calling "Up 0.7 dB; down 0.35 dB" and so on, listening to each individual speaker in turn. I was surprised. It is not usual practice to balance a surround sound speaker array one speaker at a time. After a while in which all one heard were bursts of sound from here and there, he caught me looking at him and perhaps seeing the look on my face he smiled and said, "Do not worry, I can hear this" and carried on for another quarter hour, fine-tuning the individual speaker levels, until ready to test the system as a whole.

In checking out a sound system of this kind, to balance by ear is essential. You cannot just put the speakers up and expect everything to work, because

every building, even a concert chamber, has its anomalies, and particularly given that it was not a function of the Purcell Room's design to project sounds from the side and rear walls. All the same, to attempt to balance eight speakers one at a time is, shall we say, counter-intuitive. When the system was finally tested with a continuous stream of sounds in rotation, I was sitting in the best seat in the house, and what I heard was a smooth circular rotation to the sides and rear, but not in front. In front the sound swept past my nose like an express train. The orbit was not an O in shape but more a rear-facing D, as if one's nose were pressed against a glass wall. For a while I could not understand it. I asked Gregorio to sit next to me and see if he agreed that something was not quite right. And when he heard what I was hearing, he panicked, and began to demand increased power to the two speakers on stage.

[11] *Cosmic Pulses* tutti segment SV 91 (1) at 20.40 2.09

This was the curious thing. You might imagine that a balance engineer might have wanted to make the stage speakers softer, rather than louder, to make the sound in front appear to move further away. But the problem was not that the channels in front were too forward, but that their ambience was totally dead. Suddenly the penny dropped, and I said to him "Hold on: it's not the speakers, it's the drapes." I should have noticed it before. The problem was simple. The two front speakers were located at the front of the stage, some four metres away from a rear concrete wall lined with heavy black drapes. The remaining speakers to the sides and rear were all mounted directly against bare wood panel and concrete walls. The amplitude of a speaker mounted directly against a wall is roughly double that of a free-

standing speaker, since sound normally radiates in a sphere, thus for a speaker mounted against a solid reflecting surface the 50% of the sphere of energy that otherwise would go backward is immediately reflected forward and reinforces the sound from the front, doubling the amplitude and also reinforcing the signal in the midrange. That explains why Gregorio had been attempting to raise the amplitude of the two front speakers in a vain attempt to compensate for the lack of wall reflection, added to the deadening effect of the stage curtains.

There was not much time left before the presentation was due to begin. I suggested that the curtains be pulled right back and the two front speakers be placed up against the wall at the rear of the platform. But he didn't want to distort the symmetry of the array. I then suggested flat reflecting screens to be placed directly behind the two front speakers, to provide extra surface area. No, no, there was no time. The only option left was to boost the two front speakers to compensate, even though this was not an appropriate response, since it ran the risk of introducing distortion and did not address the real problem, inequality of reflecting surface area.

So why am I telling you this? This was a member of the original team who had actually contributed to the realisation of *Cosmic Pulses* under the composer's direct supervision. Getting the acoustics of a hall right is a basic issue for a sound technician, especially for electronic music. The acoustic anomaly arising from having the stage area lined in sound-absorbing drapes should have been instantly obvious to a trained audio technician and balance engineer. Failure to notice is a sign he was unaware of the practical realities of sound projection, or had not been trained in acoustics. Such basic

knowledge requirements are essential if electronic music is ever to achieve credibility and financial support within the industry. Only then can its public spokespeople and representatives claim authority to pass judgement on more subtle issues of spatial movement, balance and design.

NOTES

1. Karlheinz Stockhausen, *Nr. 91 Cosmic Pulses. 13th Hour of KLANG* (2006–07). http://www.stockhausen.org/cosmic_pulses.html (07.12.2009). *See also* Ingvar Nordin, *Stockhausen Edition no.91 (Cosmic Pulses)*. http://home.swipnet.se/sonoloco25/stockhausen/91.html (07.12.2009).

2. James Gleick, *Chaos: Making a New Science*. London: Heinemann, 1988, 128–29.

3. Henry Brant, "Space as an Essential Aspect of Musical Composition". 223–42 in *Contemporary Composers on Contemporary Music* ed. Elliott Schwartz and Barney Childs. New York: Holt, Rinehart and Winston, 1967.

4. Karlheinz Stockhausen, "*Kathinkas* Gesang: Composition and Realization". Booklet to cd *Prix Ars Electronica 90*, Austrian Radio LC7532. *See also* Robin Maconie, *Other Planets: The Music of Karlheinz Stockhausen*. Lanham MD: Scarecrow Press, 2005, 446–50.

Barry Truax, *Riverrun* (1986). Compact disc *Cultures Electronique /6*, Harmonia Mundi LDC 278055, 1991.

5. Michael Clarke and Peter Manning, "The influence of technology on the composition of Stockhausen's *Octophonie*, with particular reference to issues of spatialisation in a three-dimensional listening environment". *Organized Sound* 13 (3) 177–187, 2008.

6. Karlheinz Stockhausen, "Musical Impressions of an American Journey", *Texte zu eigenen Werken . . . . Band 2* ed. Dieter Schnebel. Cologne: M. DuMont Schauberg, 1964, 228.

27 July 2009; corr. 05 August 2009; 07 February 2010; 26 February 2014