

THE COSMOPHONE

PLAYING WITH PARTICLES, THE COSMOS AND SOUNDS

<http://cosmophone.in2p3.fr>

THE INFINITELY SMALL, THE INFINITELY LARGE AND THE HIGH ENERGY DENSITY FRONTIER

Fundamental physics explores areas of nature which are more and more distant from common sense and usual representations of reality. In the past decades, high energy particle accelerators have revealed a new world of sub-atomic particles and forces which govern the behaviour of matter. These objects are described within the frame of quantum mechanics and Einstein relativity, which dilute the usual concepts of determinism, localisation, time and energy. It was recently recognised that the properties of sub-atomic particles are intimately related to the behaviour of the Universe in its very first moments. Within the Big Bang model, now corroborated by numerous observations, the energy density was so high in the first fraction of second that all kinds of sub-atomic particles existed together, forming a gas of matter, anti-matter and radiation interacting in the same way as they do in present high-energy accelerators or violent cosmic phenomena like quasars or super-novae. This conjunction of cosmology and particle physics is one of the most striking trends of present fundamental research.

THE COSMOPHONE

The cosmophone is a tentative to reveal this close connection between the infinitely small and the infinitely large in a sensuous way, by detecting and imaging the continuous flow of elementary particles originating from our entire galaxy: cosmic rays. Figure 1 gives a general sketch of the concept and Figure 2 a schematic view of the technical implementation.

COSMIC RAYS

Our planet is continuously bombarded by cosmic rays made of protons and atomic nuclei which are emitted from throughout our galaxy. These particles can be accelerated to very high energies when they encounter gases in expansion as produced by super-novae. They are confined within the galaxy by the galactic magnetic field and travel typically several millions of years before reaching the earth. As they hit the upper atmosphere, cosmic rays create avalanches of elementary particles. The most penetrating of these are "muons", which can reach sea level. A muon is a type of heavy electron not found in ordinary matter because of its very short life time. The human body is insensitive to muons, even though several muons pass through us every second. Muons can show up in three ways: either individually (the most frequent case), or as a bunch originating from a particularly energetic cosmic proton, or as an electromagnetic shower of electrons, anti-electrons and photons in case the muon interacts with matter above the installation.



Figure 1 : overall concept of the cosmophone

PARTICLE DETECTION

The cosmic particle detection is based on standard techniques used for decades in high energy particle physics. Muons are detected by the very faint bluish light they generate in plastic scintillator strips deployed as two detector arrays located on the ceiling and the floor of the installation. The tiny light flashes are converted into short electric pulses by photo-multipliers. Parasitic noise from terrestrial natural radioactivity is discarded using the fact that muons travel at a speed close to the light speed, and therefore cross the installation quasi-instantaneously: a muon signature consists in two sensors hit simultaneously on the ceiling and the floor. The positions of the hit sensors give the direction of the muon trajectory in space. In case of electromagnetic showers, several contiguous sensors are hit in both detector arrays. The electromagnetic shower size variations are an essential additional source of randomness in the detected phenomena. The signals of all detected phenomena are readout by a fast data acquisition system, converted in MIDI format and transmitted almost instantaneously to a real time sound synthesis system.

SOUND SYNTHESIS

The aim of the sound synthesis is to instantaneously materialise the trajectories of cosmic particles in space as they move through a given point, and to offer additional features to composers for special effects. The sounds are produced

digitally in real time by a computer which operates two arrays of loudspeakers directly hooked up to the detectors. Sound synthesis is technically handled with the program MAX-MSP, which is interfaced to the cosmic particles input parameters

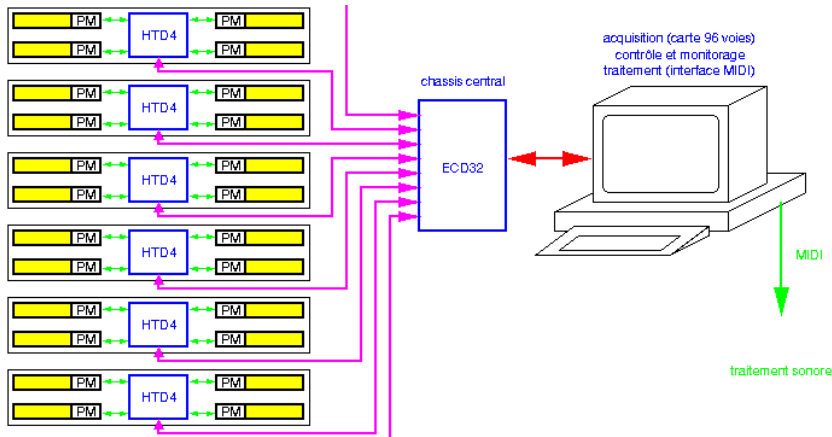
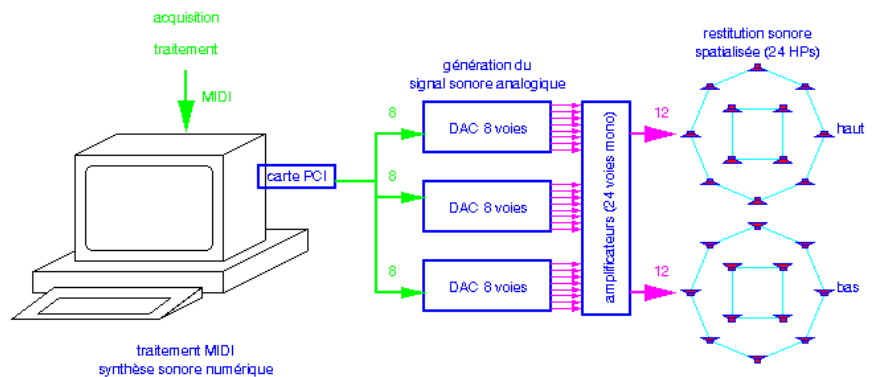


Figure 2a :

Technical implementation of the cosmophone : particle detection

Figure 2b:

Technical implementation of the cosmophone: sound synthesis



through a more general framework, allowing the composer to drive the music as function of the occurrence of cosmic phenomena. The generation of sounds in three-dimensional space makes a heavy use of the laws of psycho-acoustics, but full freedom remains to the composer to interpret the cosmic phenomena in a personal way and let his imagination wander.

ARTISTIC CONTEXTS

The cosmophone can be declined in various artistic contexts, ranging from museum installations to more general implementations serving as framework for public artistic shows.

MUSEUM INSTALLATION

As a museum device, the cosmophone acts as a three-dimensional installation whose goal is to materialize the features of the detected phenomena in the most evocating way. As an example Figure 3 gives a view of the cosmophone

built for the Cité des Sciences et de l'Industrie in Paris. In such an installation isolated muons are reproduced by activating the two loudspeakers associated to the top and bottom hit detectors. The sound is moved in space from the muon's entry point down to its exit point, while shifting its frequency as would occur with a real moving source (Doppler effect). Impact sounds are added at the entry and exit points to improve the spatial localisation of the trajectory. Electromagnetic showers are materialized by trickling and streaming envelopes whose texture can depend on the size of the showers.

In such an installation, the choice of sound as a medium is essential for several reasons. First of all, sound is transmitted as a mechanical vibration, providing a direct contact with the distant phenomenon. The moderate ability of the ear to locate sound sources is also well matched to the rather coarse space sampling allowed by simple particle detectors and loudspeakers. Finally the present sophistication of numerical sound synthesis techniques allows a flexible real-time three-dimensional imaging of particle properties. Such an environmental reproduction is essential to the emotional impact of the physics phenomenon. These principles could be extended to the reproduction of many other physics processes.



Figure 3:
the cosmophone built
for the Cité des Sciences
et de l'Industrie in Paris

ARTISTIC SHOWS

The cosmophone can serve as a general framework to public artistic shows involving composers, choreographers or other artists. Such a large cosmophone, covering an area of up to 100 squared meters and initially built for the 50th anniversary of CERN (the European Centre for High Energy Physics located in Geneva), is now exploited by the Music Company UBRIS STUDIO led by Jacques Diennet. Potential performances include pure electronic compositions, mixed compositions with musicians improvising within the cosmophone, or even dancers acting as function of the detected phenomena. The public can stand either within the cosmophone, or outside like in front of a conventional stage. In all cases, the cosmophone offers artists an opportunity to express how the extreme worlds of sub-atomic particles and cosmic phenomena stimulate their imaginations.

The first use of the cosmophone in such a context was pioneered by Jacques Diennet at the 50th anniversary of CERN in October 2004. In this occasion his piece "La Paix des Etoiles N⁰ 2" was created in Geneva with the large cosmophone

exploited by UBRIS STUDIO. This is a 10 minutes pure electro-acoustic composition which attacks one of the central question of music: the control of the musical process. In the present case and in line with the principles initiated by John Cage, the spacialised sound effects are driven by the real time random occurrence of cosmic phenomena, within a pre-defined sequence programmed by the composer.

UBRIS STUDIO also offers artists the possibility to exploit the cosmophone within their own aesthetic principles. An opportunity to extend the artistic use of the cosmophone was given by the "Groupe de Recherche et d'Improvisation Musicales" (GRIM) in Marseille, where several concerts and workshops were organised in January 2006. In this occasion three new pieces were created: one electro-acoustic piece from Michel Pascal, "Leçons de choses", combining a pedagogic text on cosmic particles with sound effects, and two pieces involving for the first time live musicians interacting with the cosmophone. The first one, "Téléphone maison, variation cosmique sur un theme populaire" from Pascal Gobin, presents a brass ensemble which improvises within the cosmophone as function of the detected phenomena. In the second one, "Intraçables N° 1" from Jean-Marc Montera, the words of a poem from late writer Tarkos are scattered apart within the room by the random occurrence of cosmic muons, whereas Jean-Marc Montera improvises on a traditional Corsican guitar, a cetera. Figure 4 shows a photo of this performance during one of the GRIM concerts.

The positive reaction of the public as well as of the press to these exploratory attempts have confirmed the relevance of the artistic exploitation of the cosmophone, and UBRIS STUDIO is presently developing new partnerships for further projects.

Figure 4:

Jean-Marc Montera improvising on a Corsican cetera guitar within the cosmophone, during a concert given at GRIM in Marseille in 2006.



SUMMARY

The cosmophone is a meeting point of advanced basic sciences (astrophysics and particle physics), new technologies (real-time digital sound synthesis and sound spacialisation) and contemporary art (environmental music and systems), fields where mutual fertilisation offers a potential source of innovative developments. By putting spectators at the junction of the infinitely small and the infinitely large, the cosmophone brings the listener into direct contact with our galaxy and the violent phenomena that take place there, creating a new world of stimulation to artistic creation.

THE COSMOPHONE: authors biographies



Jacques Diennet, French, 1947

Composer, Artistic Director of the Music Company UBRIS STUDIO, ubris.studio@wanadoo.fr

Got familiar with digital composition during several stays in the USA and Canada, as Robert Ashley's guest in the Mills College Studios and as John Appleton's guest at the Dartmouth College Studios. Laureate of several international prizes including: First Prize of the town of Varèse Competition Ruigi Russolo and First Prize of work for multimedia at the Bourges International Competitions in 2000.



D' David Calvet, French, 1970

Researcher at the French National Centre for Scientific Research (CNRS),

Laboratoire de Physique Corpusculaire de Clermont-Ferrand, <http://clrwww.in2p3.fr>, calvet@in2p3.fr

Has participated to several High Energy Physics experiments at the European Centre for High Energy Physics (CERN, Geneva) and the Deutsches Elektronen Synchrotron (DESY, Hamburg). Has worked on several projects related to science popularisation, and designed the particle data acquisition of the Cosmophone. Laureate of the Communication Prize awarded in 2000 by the CNRS High Energy Physics Institute IN2P3.



D' Richard Kronland, French, 1957

Researcher at the French National Centre for Scientific Research (CNRS), Head of the group "Modeling, Synthesis and Control of Sound and Musical Signals", Laboratoire de Mécanique et d'Acoustique de Marseille, <http://www.lma.cnrs-mrs.fr>, kronland@lma.cnrs-mrs.fr

Doctor in acoustics from the University of Aix-Marseille II (France), his primary research interests include analysis and synthesis of sounds with particular emphasis on musical sounds. Has participated to several artistic projects and coordinated the development of the sound synthesis framework of the Cosmophone.



D' Claude Vallée, French, 1958

Researcher at the French National Centre for Scientific Research (CNRS), Centre de Physique des Particules de Marseille, currently Spokesman of the H1 Collaboration at the Deutsches Elektronen Synchrotron, Hamburg, <http://marwww.in2p3.fr>, vallee@cppm.in2p3.fr

Former student of the Ecole polytechnique in Paris, he has participated to several High Energy Physics experiments at CERN and DESY and has initiated the development of the Cosmophone in 1998. Co-laureate with Richard Kronland of the "Prix Création de la Culture Scientifique" awarded in 1999 by the French Ministry of Research.



Thierry Voinier, French, 1953

Researcher at the French National Centre for Scientific Research (CNRS), Laboratoire de Mécanique et d'Acoustique de Marseille, <http://www.lma.cnrs-mrs.fr>, voinier@lma.cnrs-mrs.fr

Expert in real-time sound synthesis techniques and algorithms, he was involved in many sound analysis and synthesis projects, developing several digital musical instruments and digital audio effects for composers. Designer of the moving source synthesis engine of the Cosmophone.