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COSMOPHONY

or

how to listen to cosmic rays

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Abstract

We present a device[3] designed for detection and instantaneous sound restitution of cosmic rays around the audience. Such a "cosmophone"[4] can be built using standard techniques of elementary particle physics and computer music. The variety of cosmic induced phenomena measurable at sea level together with the installation modularity allow applications ranging from large concert halls to personal micro-devices.

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[3]This installation is laureate of the Prix "Création" de la Culture scientifique et technique 1999, awarded by the French Ministry of Education, Science and Technology. It is patented by the CNRS.
[4]"cosmophone" is a trademark of the CNRS.

1 Cosmic Rays

Interstellar space is filled with a permanent flux of high-energy elementary particles called "cosmic rays". These particles are predominantly made of protons, i.e. nuclei of hydrogen atoms. They are the remnants of violent phenomena which have created and accelerated them somewhere in the universe. Most of them are produced within our galaxy, for example when an old massive star explodes into a supernovae. They stay confined in the galaxy for millions of years by the galactic magnetic field.

All around the earth cosmic rays impinge upon the atmosphere and create showers of secondary particles. Though partly absorbed by the atmosphere, these showers induce a large variety of phenomena which are measurable at sea level, including:

- a large flux of *muons*. A muon is a kind of a heavy electron absent from usual matter because of its short life time. Muons are produced at a large rate in cosmic atmospheric showers. They are able to reach the ground thanks to their outstanding penetrating power. Their flux at sea level is of the order of 100 muons per second per square meter.

- secondary showers induced by muon interactions within the neighbouring matter. A frequent example is the radiation of *electromagnetic showers*, i.e. showers of electron/anti-electron pairs, when muons pass close to atomic nuclei. The structures of a typical building induce around one such electromagnetic shower per minute per ten square meters.

- bunches of several muons with the same direction and a few meters from each other, produced in energetic atmospheric cosmic showers. The number and density of the muons within a bunch provide some information on the energy of the primary cosmic ray. Within an array of 100 square meters, the rate of multi-muon bunches decreases from 1 per second for bunches of 2 to 3 muons, to one per minute for bunches of 10 muons or more.

Most cosmic induced muons and electromagnetic showers have directions close to vertical, but a significant fraction show inclinations of up to 45 degrees or more.

2 The Concept of Cosmophony

The human body is insensitive to elementary particles produced in cosmic showers. A cosmophony consists in making the flux and properties of cosmic rays directly perceptible within a 3-dimensional space. This is done by coupling a set of elementary particle detectors to an array of loudspeakers by a real time data acquisition and sound synthesis system. The pieces of information received from the detectors instantaneously trigger the emission of sounds which depend on the parameters of the detected particles.

The rate of cosmic induced phenomena and the range of associated parameters allow a large variety of sound effects. Depending on the size and the complexity of the detectors, it is possible to render the trajectory, direction, energy, nature or size of cosmic showers. For example, a sound emitted in space and moved from top to bottom while shifting its frequency (Doppler effect) can materialize the trajectory and speed of a muon. Fluctuations in the occurence of different kinds of phenomena are an essential source of randomness in a given listening sequence.

3 Device Layout

The device is named "cosmophone". It is based on arrays of detectors and loudspeakers which surround the listening space (see figure).

Taking into account the ear's ability to locate sound sources, the instrumentation sampling can be as low as one detector per square meter, or even less for large scale installations. For a stable sound spatialization, loudspeakers must have a similar sampling as detectors. Whenever possible detectors and loudspeakers should remain invisible in order not to interfere with the perception of the sound effects.

Several kinds of detectors can be used for cosmic particle detection, for example plastic and liquid scintillators, wire chambers, Čerenkov light detectors, etc... The detector signals are processed by a real time data acquisition system such as commonly used in particle physics experiments. The time coincidence of several detector signals discards the local radioactivity background and acts as a signature for cosmic induced particles. Such a coincidence triggers the readout of all detector signals, which are then processed and transferred to a real time sound synthesis system. The sound synthesis system controls several channels which allow the generation of spatialized sound effects depending on the available information from the detectors. It can be based either on commercial MIDI programmable synthesizers, or on fast micro-computers running sound processing and synthesis software. The latter solution allows to develop complex algorithms such as the simulation of the Doppler effect mentioned above.

4 Domains of application

The hardware modularity and the simplicity of a cosmophone allows application of this concept in a wide range of domains, for example:

- the permanent instrumentation of a dedicated large space, with a set of detectors able to register all kinds of measurable phenomena (isolated muons, electromagnetic showers and multi-muon bunches) with a significant rate. Such a device would allow a large variety of spectacular sound effects. It would be used for public shows which could evolve in time as function of the artistic sensibility of the composers involved. The musical shows could also be completed by visual effects or include the live performance of actors, dancers or musicians.

- A movable installation for similar shows performed in various places, for example in open air under the stars. For an easy adaptation to local topologies such devices must put emphasis on the robustness and modularity of the hardware pieces.

- a didactic installation of a few ten square meters for science museums or similar institutions.

- small scale devices of a few square meters for ornamentation of public halls or even private use.

- personal micro-devices such as "cosmophonic headphones" equiped with a set of small detectors.

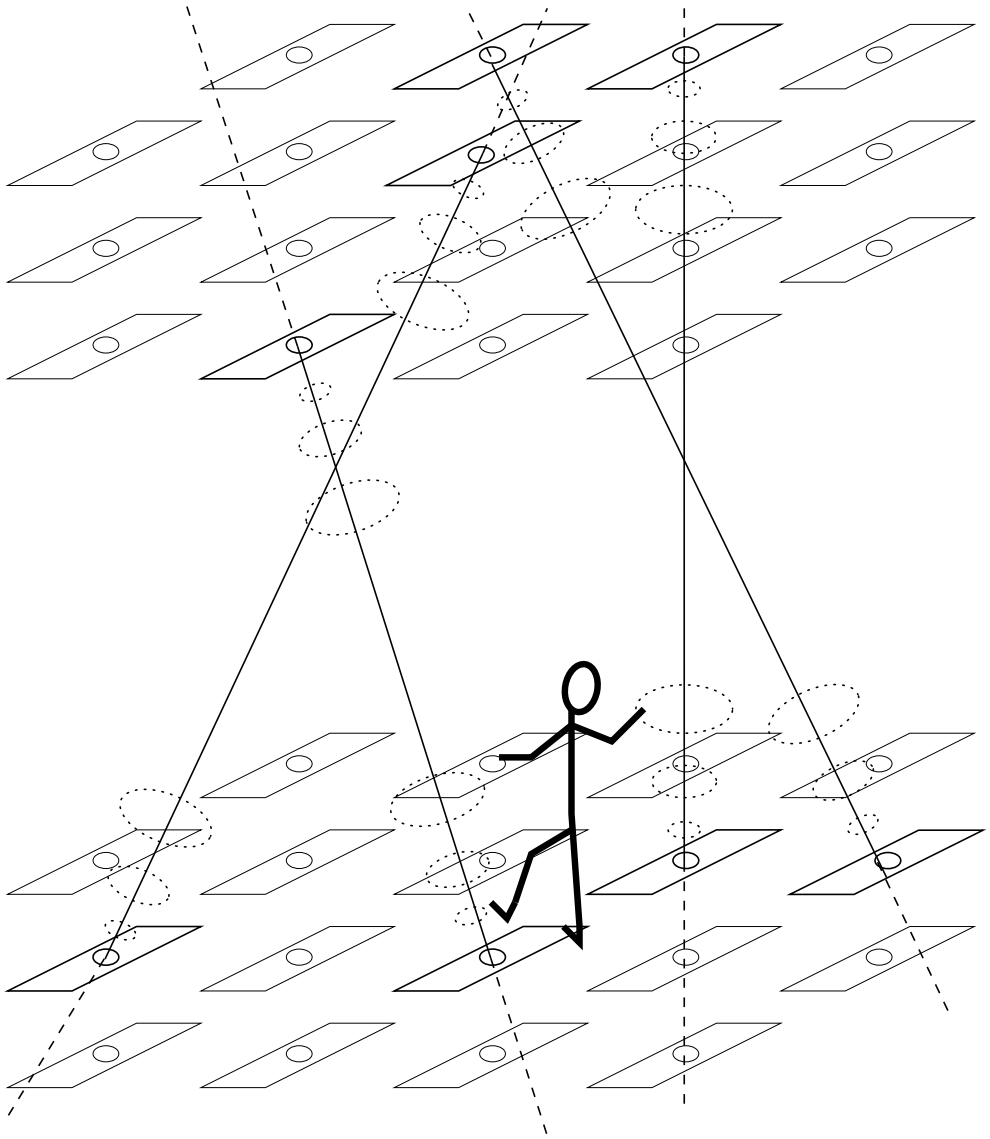

Figure 1: Schematic layout of a mid-scale cosmophone. The rectangles and circles stand for cosmic particle detectors and loudspeakers respectively.