CLOUD CHAMBER: A PERFORMANCE INVOLVING REAL TIME TWO-WAY INTERACTION BETWEEN SUBATOMIC RADIOACTIVE PARTICLES AND VIOLINIST

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ABSTRACT

'Cloud Chamber' is a live performance created by composer Alexis Kirke in which the invisible quantum world becomes visible as a violinist and subatomic particle tracks duet together for an audience. An instrument has been developed which can be "played" live by radioactive atomic particles. Electronic circuitry is being developed which will enable a violinist to use their instrument live to create a physical force field that directly affects the ions generated by the particles. This enables the violinist and the ions to influence each other musically. The whole performance is based around a special piece of equipment which makes radioactivity visible in bright white tracks moving in a glass chamber. These tracks will be projected onto a large screen for the audience. Radium 225 will be placed in the chamber on stage, saturated with ethanol and cooled by liquid nitrogen, which makes the radioactivity and cosmic radiation become visible. Musician John Matthias will play the violin connected electrically to the glass chamber. So the music of the violin will be both heard by the audience and "heard" by the radiation-generated ion patterns in the glass chamber. If John plays in one way the ion particles will behave in a certain way, and if he plays in a sufficiently different way, the particles will behave differently. These particle movement changes will affect the electronic sounds the radiation is generating through their own special instrument; thus there will be a live musical interaction between the atomic world and the violinist during the 15 minute partially-scored performance.

1. INTRODUCTION

There have been a number of performances inspired by particle physics and quantum mechanics [1]. Music has also been used to create an offline audible display or sonification of particle interactions at CERN [2]. There has been work in [3] and [4] to use the equations of quantum mechanics to create sound. [5] used recordings of Geiger Count clicks to build music. What has been less common has been the *live* utilization of particle physics experiments for sonification or for artistic use. Although [6] does discuss the theoretical possibility of a more direct use of particle physics experiments in music composition, there has been no practical work at developing two-way live interactive performances – where not only do the particles influence and create music/sound, but where any accompanying music/sound influences the particles in real-time on a physical level. Cloud Chamber is an attempt to move performance into this area of application. This is done by utilizing tools which make atomic particles visible in real time, visual recognition methods, granular synthesis and electrical field generation from musical instruments.

2. CLOUD CHAMBER

The first cloud chambers were built by C.T.R. Wilson in the late 1890's while attempting to duplicate natural clouds [7]. Wilson's chambers operated by expanding a volume of air previously saturated with a vapor; adiabatic expansion and the associated cooling created supersaturated conditions. In 1911, Wilson demonstrated that a single energetic electron would leave a trail of condensation nuclei, resulting in a track of droplets. Wilson's device was the first to produce a visible record of subatomic particle trajectory, and such chambers were used to discover the positron and muon.

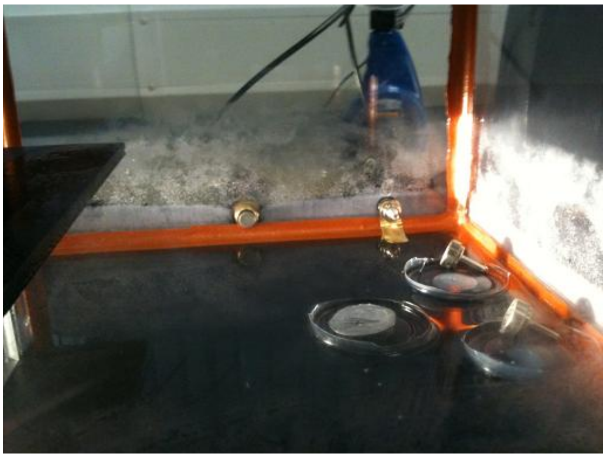

Figure 1. Uranium and other sources tested in the performance chamber.

The diffusion cloud chamber creates a volume of supersaturated alcohol vapor that condenses on ions left in the wake of charged particles. This is accomplished by establishing a steep vertical temperature gradient with dry ice, liquid nitrogen, or mechanical refrigeration. Alcohol evaporates from the warm top side and diffuses toward the cold bottom. The gravitationally stable temperature distribution permits a layer of supersaturation near the chamber bottom. Charged particles passing through the supersaturated air at close to the speed of light leave behind numerous ions along each centimeter traversed. Since each ion becomes a nucleation site for droplet condensation, tracks of alcohol droplets form in this region, indicating the trajectories of the charged particles. The fine, threadlike tracks fall to the chamber bottom, leaving room for other tracks to appear in the next moment. This continuous process yields uninterrupted sensitivity to airborne ionizing events, and provides an enthralling window on the subatomic world.

The Cloud Chamber used in this composition is the Classroom Cloud Chamber supplied by project partners Supersaturated Environment Inc. The chamber contains in the order of 10^{24} particles yet a single electron can leave macroscopic evidence of its passage. The chamber is cooled using about 1.5 litres of liquid nitrogen – which enables temperatures as low as -330^{o}F (-200^{o}C) to be generated onstage. The chamber is saturated using Industrial Methelated Spirits - approximately 90% pure reagent grade ethanol.

3. RADIATION

In the absence of a radioactive source, most events observed in the Cloud Chamber are cosmic rays [7]. About two-thirds of sea level cosmic rays are muons; one sixth are electrons, and most of the remaining one-sixth are neutrons. Neutrons cannot be directly observed, because they will no ionize air within the chamber. Low energy (<100keV) electrons can be identified from the convoluted character of the tracks. Higher energy electrons and muons from straighter tracks.

The majority of background events observed occur naturally. The average annual whole-body radiation dose in the United States is about 60 mrems (per capita, excluding medical exposures). Of this, 28 mrems are caused by cosmic rays, 26 mrems originate from terrestrial gamma rays, and about 0.5 mrems are caused by nuclear weapons fallout of atmospheric detonations.

For the composition “Cloud Chamber” a number of radioactive sources were tested. The sources tried in the chamber were: Americum, Strontium, Radium, and Uranium. The clearest particle tracks were created by the Radium 225 – so it was chosen for the performance. The particles produced are beta particles, high energy electrons, which spread out in a fan of lines from the radium source.

4. CLOUD CATCHER

The Cloud Catcher is a MAX/MSP/Jitter patch developed by Antonino Chiaramonte and Anna Troisi (known collectively as *Electroshop*), with Eduardo Miranda, which provides a real-time audio input granulation [8] driven by live video colour tracking. The patch section which carries out the video colour tracking mainly exploits the features of a Jitter object called *jit.findbounds*, calculating bounding dimensions for a range of values.

A frame of video is represented in Jitter as a two-dimensional matrix, with each cell representing a pixel of the frame, and each cell containing four values representing alpha, red, green, and blue on a scale from 0 to 255 (RGB standard) [9]. The *jit.findbounds* object scans a matrix for values in the range [min, max] and outputs the minimum and maximum points that contain values in the range [min, max] within the matrix [10].
The bounding region is a rectangle, so *jit.findbounds* will output the indices for the left-top and bottom-right cells of the region in which it founds the specified values [9].

Cloud Catcher provides the ability to define the colour range by means of the *colorange* subpatch. In this way focusing on a suitable range is quite intuitive, precise and immediate. Therefore every time a colour in the chosen range appears in the video, it will produce as output two coordinates related to the region boundaries (otherwise it will have no output). These two coordinates are used as input for the *live_cloudy_grain* subpatch. Furthermore the *live_cloudy_grain* subpatch will also take as input the slope of the segment bounded by the two coordinates to effect the real-time audio sample granulation.

The *live_cloudy_grain* subpatch is the audio processing section of Cloud Catcher. As mentioned above, *live_cloudy_grain* uses as input the following values:

1. Top-left boundary x coordinate (x_{LT})
2. Top-left boundary y coordinate (y_{LT})
3. Bottom-right boundary x coordinate (x_{BR})
4. Bottom-right boundary y coordinate (y_{BR})
5. Slope Δ of the segment bounded by the top-left and bottom-right coordinates.

The *emj.grainlive* abstraction is the *live_cloudy_grain* real-time sample granulation core and is based on Nobuyasu Sakonda Max/MSP *Granular 2.5* patch, but provides a more complex output with a real-time granulation of an audio input. A modified version of the Nathan Wolek’s *Gtk.winMaker* abstraction is implemented in order to supply a wide range of grain envelopes, such as different kinds of functions used for the granulation (gauss, quasi-gauss, triangle, 3-stage-linear, hanning, hamming, blackman, blackman-harris, expedec, and recpodec).

live_cloudy_grain features a large number of controls to accurately adjust every available parameter. The most fundamental controls are assignable to a MIDI hardware controller. The five values coming from the video colour tracking are mapped to different audio sample granulation parameters as shown in Table 1. A screen shot of the Cloud Catcher running is shown in Figure 2.

Color tracking parameters	Mapped to granulation parameters
x_{LT} coordinate	if $x_{LT} <= y_{LT}$ then "granulation window lower edge" = x'_{LT} else "granulation window higher edge" = x'_{LT} $x_{LT} \rightarrow x'_{LT}$ linear mapping into real set [0, audio buffer length]
y_{LT} coordinate	if $y_{LT} > x_{LT}$ then "granulation window higher edge" = y'_{LT} else "granulation window lower edge" = y'_{LT} $y_{LT} \rightarrow y'_{LT}$ linear mapping into real set [0, audio buffer length]
x_{BR} coordinate	"panning spread" = x'_{BR} $x_{BR} \rightarrow x'_{BR}$ linear mapping into real set [0, 127]
y_{BR} coordinate	"random pitch" = y'_{BR} $y_{BR} \rightarrow y'_{BR}$ exponential mapping into real set [0, 127]
slope Δ of the segment	"grain duration" = Δ' where Δ → Δ' parabolic mapping into real set [0, 127]

Table 1. Color to Parameter Mappings

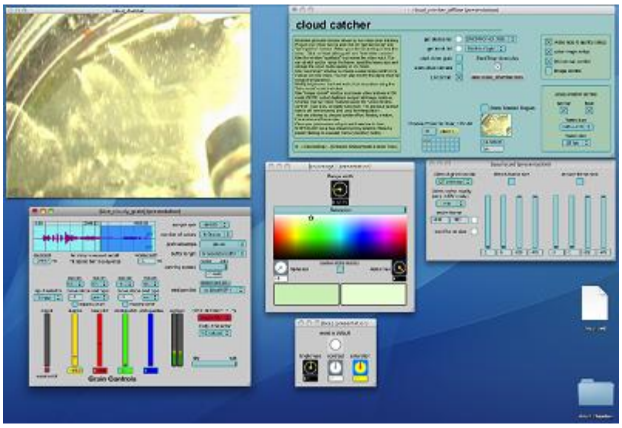

Figure 2. Cloud Catcher software screenshot showing alpha particles from Americum-241 source

The video input for the Cloud Catcher is taken from a camera above the glass cloud chamber, and the Catcher is tuned to pick up the ions created by the radioactive particles. The audio input to the Cloud Catcher is taken from an acoustic violin. So all the audio content of the performance will come from the violin. Though some may be unrecognizable as coming from an acoustic instrument due to periods of more extreme grain transformations, which are partially parameterized by the ion tracks picked up in the chamber.

5. "ATOMOLIN" AND ELECTRODE

The "Atomolin" is a device developed with Nick Fry and Cathy McCabe of the University of Plymouth, which enables a musician to use an acoustic instrument live to create a physical force field that directly affects the ions generated by radioactive particles. The violin can be converted into a low level electrical audio signal using a microphone. In the Atomolin the signal is used to modulate a high voltage power supply, with output adjustable between 1.5 and 3 kV. This connects to a projection field electrode installed in the cloud chamber. Thus the violin playing modulates a positive potential in the chamber top. Applying a varying positive potential to the chamber top will directly change the particle tracks appearing in the cloud chamber. Thus the Atomolin allows the violin player to directly affect the subatomic particle tracks in the chamber through their performance.

6. COMPOSITION STRUCTURE

Cloud Chamber is only semi-deterministic piece of music, given that the particles are generating sounds and the particle production rate is based on non-deterministic quantum principles. At the heart of the structure is the ability of the particle track's sound to influence the violinist musically, and the ability of the violinist to influence the particle tracks physically (which can lead to changes in the sounds they make).
However it also draws on quantum physics for inspiration in its pre-scored structure elements. Specifically by what is known in physics as the Standard Model [11] (see Figure 3).

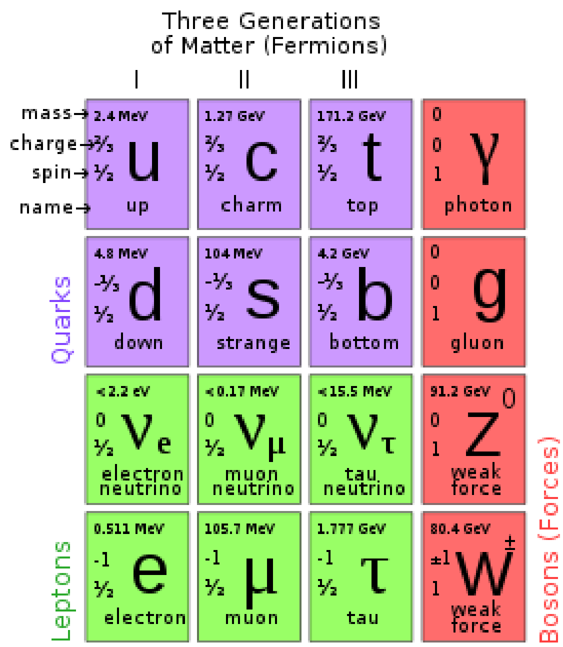

Figure 3. Standard Model of Particle Physic

There are types of particles which are made up of 3 smaller particles called quarks of types called Up, Down, Charm, Strange, Top, and Bottom. Based on this the 15 minute performance is divided into 3 sections, the violin parts of which are summarised in Table 2. The actual motif pitches used to build up the pre-scored elements of the score are partially generated algorithmically using the quark structure of observable Baryons. This is done in Matlab code through the

Matlab MIDI toolbox [12] (using a simple mapping system and constrained by the physical properties of the violin). Some other small-scale structures in the violin score are generated from data provided by project partner ISIS Neutron and Muon Source, from their experiment shining neutrons through liquid crystals [13]. Parallel with this violin score is an electronics parametric score. The purpose of this score is, for each of the sections, to set the broad parameters for the granulation system. Within each subsection itself, the subatomic particle tracks will be allowed to freely influence granulation sound (though they will be influenced to the Atomolin). During improvised sections, the violinist is free to interact with the particles and the particle sounds as they see fit.

Section	**Subsection 1**	**Subsection 2**	**Subsection 3**
1	*"Up"*		
Features	*Pre-scored, accelerating to medium tempo*		
Length	*3 minutes*		
2	*"Down"*	*"Charm"*	
Features	*Improvised, slower, legato, minor*	*Pre-scored, less legato, major modulation*	
Length	*2 minutes*	*2 minutes*	
3	*"Strange"*	*"Top"*	*"Bottom"*
Features	*Atonal, accelerating, lower pitch*	*Improvised, pitch high*	*Pre-scored, deceleration*
Length	*2 minutes*	*3 minutes*	*3 minutes*

Table 2. Overview of the composition "Cloud Chamber"

It should be noted that the use of this approach to generating musical material is not argued as being a meaningful expression of the Standard Model or of quarks. It is mainly used as a framework around which the composer can construct the piece.

7. CONCLUSION

We have introduced 'Cloud Chamber", a composition in which the invisible quantum world becomes visible as a violinist and radioactive particle tracks duet together for an audience. An instrument has been developed which can be "played" live by radioactive atomic particles. A musician plays the violin connected electrically to the glass chamber. So the music of the violin is both heard by the audience and "heard" by the radiation-generated ion patterns in the glass chamber. If the musician plays in one way the ion particles will behave in a certain way, and if they play in a sufficiently different way, the particles behave differently. These particle movement changes affect the electronic sounds the radiation is generating through their own special instrument; thus there is a live musical interaction between the atomic world and the violinist during the 15 minute performance. "Cloud Chamber" was premiered at the 2011 UK Peninsula Arts Contemporary Music Festival [14] (www.pacmf.co.uk) with John Matthias on violin and Alexis Kirke on electronics. Radioactive safety was supervised by Professor Miranda Keith-Richards. More media on the performance can be found at *http://cmr.soc.plymouth.ac.uk/alexiskirke/cloudchamber.html*

8. REFERENCES

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