Memory Vapor

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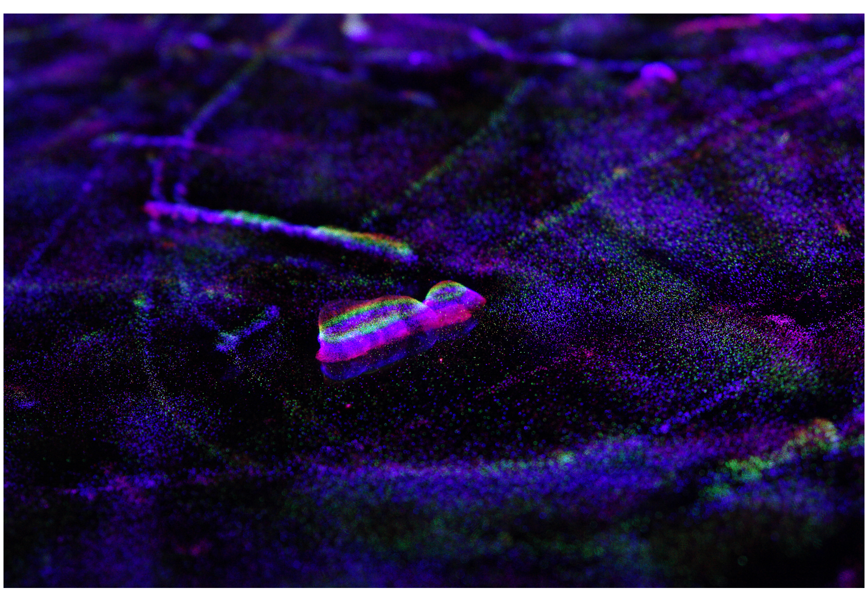
Abstract

Though initially intended for studying cloud nucleation, the cloud chamber accidentally lead to the pivotal discovery of cosmic rays: a continuous cascade of subatomic particles, arriving to Earth from outer space. In the authors' artwork, *Memory Vapor*, the ephemeral condensation trails seeded by these particles are scanned and illuminated by a white laser sheet, transforming the cloud medium into a dynamic prism that vastly extends the spatio-temporal resolution of particle trajectories. Conceived for Leonardo's *Water is in the Air* Workshop, the article also recounts the authors' prior aquatic and gaseous endeavors.

Although most of us are quite familiar with the effects of solar radiation on our biosphere and atmosphere, such as aurora borealis or australis, the effects of extra-solar radiation are far less sensorially or even theoretically familiar. At this very moment, we are being bombarded by billions of charge carriers coming from every possible direction in outer space. The immense diversity of energy signatures corresponds to the scope of cosmic origins, ranging from solar emissions and those of other stars to hitherto uncharted physical processes at the edge of the perceivable universe. Some of these cosmic bullets reach speeds that are a thousand times faster than anything ever launched at the Large Hadron Collider, and approximately once a year, a particle that is 10 million times more energetic arrives. Their origins are presumed to be supernovas and active black holes. One such candidate**,** supernova 1054, exploded so intensely that in the year from which it gets its name, Chinese and Arab observers noted that it was bright enough to see in broad daylight for 23 days. Its remnants comprise the Crab Nebula. Significantly outlasting the timescale of stellar and galactic explosions, the highest energy cosmic rays unfold over multiple stages, entailing an accumulation of accelerative processes.

As soon as a cosmic ray reaches the ionosphere, the upper layer of our atmosphere, it ripples into a billion other particles, comprising a ubiquitous subatomic cascade. This cosmic shower can reach the senses by means of an experimental environment called a cloud chamber, invented by Charles Wilson in 1894 (perfected in 1911) to study the nucleation of atmospheric clouds -- an idea that came to him during his mountaineering trips when he observed such phenomena as auroras and glories. Two years later, in 1896, Henri Becquerel discovered radioactivity, the source of which was suspected to be radioactive elements embedded in the Earth. This was the dominant theory until 1912 when Victor Hess measured four times more radioactivity at a height of 5300 meters than at ground level. Making further measurements during a near-total eclipse, Hess also dismissed the Sun as a potential source of this highly penetrative radiation. In 1925, Robert Milikan definitively labeled these ionizing emissions *cosmic rays*. While using a cloud chamber to determine the precise charge of a single electron, Milikan came across a plethora of other charge carriers. He interpreted them as the photonic "birth cries" of new atoms ceaselessly created by God to counteract the entropic heat death of the cosmos. Such assumptions put a rapid end to Milikan's scientific career.

Fig. 1. Prismatic trails of subatomic particles in the installation, Memory Vapor. (Photo © Evelina Domnitch and Dmitry Gelfand.)



Recently, the Cloud Project [1] at CERN and a multitude of parallel research groups have revealed the significant role of cosmic rays in atmospheric and biological processes. Variations in cosmic ray showers have been found to affect tree growth more than changes in temperature or precipitation [2]. The phenomenon known as *relativistic runaway electron avalanche,* hypothesized to seed lightning, has been directly linked to decaying cosmic rays -- as has the seeding of clouds.

In the artwork, *Memory Vapor* (2011), a cloud chamber combined with a particle accelerator is illuminated by a scanning white laser sheet, transforming its -200° C gaseous contents into a dynamic prism. Ionized nuclei, muons, antiprotons, electrons and positrons are trailed by a thread of condensation droplets, each of which the laser transforms into a luminous micro-lens. Resultantly, the spatio-temporal perception of particle tracks is vastly enhanced -- an unusual sensation of iridescent depth unfolds. It is necessary, here, to retrace some of the antecedent investigations that led to these surprising observational capacities. While developing several performances involving the acoustic suspension of matter in thin air, *Sonolevitation* (2007) and later *Mucilaginous Omniverse* (2009), we stumbled upon a recent discovery in non-linear optics: a laser beam can get trapped inside of a floating liquid droplet, causing the droplet to behave like an optical resonator capable of modulating the emission frequency and intensifying the beam up to hundreds of times [3]. The light gets trapped due to whispering chamber modes, with which, perhaps, you have been acquainted acoustically through certain examples of curvaceous architecture -- especially common among gothic cathedrals. You can hear a whispering voice coming from a distant corner of the interior as if the voice were right beside you. Bouncing across a parabolic surface, the sound travels without any perceivable loss of intensity. Laser light can analogously get reflected off the inner surface of an optimally spherical droplet (untainted by the elongating effects of gravity). As the reflections accumulate, the light is amplified, turning the droplet into a laser cavity.

We have applied similar laser techniques to illuminate clouds of hydrogen bubbles in an installation entitled *Hydrogeny* (2010). When the Earth's aqueous envelope is irradiated by sunlight, water is split apart into hydrogen and oxygen gas. Among the planet's quintessential processes, solar water splitting is the source of most of the oxygen in the atmosphere, and the origin of all earthly hydrogen, which helically conjoins every pair of DNA. Astonishingly, the electromagnetic fields imparted by sunlight can linger in water for hours or even days after their initial appearance. One significant application of electrolysis of water and artificial photosynthesis or photoelectrolysis is to extract hydrogen as an energy source [4]. Currently, researchers inspired by photosynthesis in nature, such as quantum chemist, Daniel Nocera (MIT), and biophysicist, Raoul Frese (Vrije Universiteit), are able to achieve a nearly lossless translation of sunlight into biosolar fuel by means of artificial photosynthesis.

The original precursor to *Memory Vapor* was our first exhibited artwork, *Wakening Shrouds* (2000), an installation comprised of extremely fine water droplets and light. The droplets are so tiny that they are only rendered visible when illuminated by highly focused light with a very specific angle of incidence. Evocative of the charged vapor cloud experiments conducted by Robert Millikan and earlier by JJ Thomson's Cavendish lab, the vapor as in the case of the latter, emanates from an electrolysis cell.

In direct counterpoint to illuminated water clouds in the air, another predecessor of *Memory Vapor* comprises clouds of light-emitting air bubbles within a body of water. *Camera Lucida: Sonochemical Observatory* (2003), which was our 4th water-based endeavor, renders sound waves visible by means of an exotic phenomenon known as sonoluminescence. Microscopic gas bubbles, naturally dissolved in water, are sonically incited to collapse at which point they reach temperatures as high as are found on the Sun and emit flashes of light with a duration of less than a billionth of a second. Because the flashes repeat per sound cycle, which (in the case of this artwork) is from 40 to 100 thousand times per second, the light is perceived to be relatively continuous. However, it is so faint, that one's eyes must adapt for at least 5 minutes in total darkness in order to see the fleeting configurations of glowing sound fields.If you imagine the sinusoidal valley of a sound wave in three dimensions, you arrive at a pocket of empty space or semi-vacuum. If the wavelength is short enough, or in acoustic terms, if the frequency is high enough, then this semi-vacuum becomes sufficiently small enough to enter the skin of a microscopic air bubble -- far tinier than the dissolved bubbles you are used to observing in beer and champagne. As soon as the pocket of emptiness penetrates, the bubble rapidly implodes at speeds of up to 1 k/s, many times the speed of sound. Upon collapse, the gas inside the bubble shrinks into a core so dense that it can reach 10,000° C and emit light. Initially, we were told by experts in the domain of sonochemistry, that we were wasting our time and would never be able to reach the scale of sonoluminescence that we had envisioned. Nonetheless, we trusted our intuition and eventually made a pivotal leap with the generous help of Werner Lauterborn, the then Director of the Physics Institute of Goettingen University and a team of researchers at the Institute for Advanced Science and Technology, Nagoya, Japan. At that time, approximately a decade ago, numerous physicists were hypothesizing that sonoluminescence might be a means of procuring nuclear fusion, bubble fusion as it was termed. The temperatures were later determined to be not quite high enough for fusion to arise and no tell-tale neutron emissions could be detected. Hence, nearly all funding for the research of sonoluminescence suddenly evaporated. However, one of the scientists with whom Evelina and I have had the pleasure of collaborating, quantum chemist, Shin Ichi Hatanka, is still deeply pursuing the phenomenon. He has recently made a breathtaking discovery: two-colored sonoluminescence [6].

I would like to conclude with the words of theoretical physicist and philosopher, David Bohm, so eloquently emphasizing the senses and the innersenses as the optimal instruments for tuning into hidden frontiers:

> While humans' scientific instruments do constitute an effective extension of their bodies and sense organs, there are no comparable external structures that substitute for the inward side of the perceptive process (in which the invariant features of what has been experienced are presented in the "inner show"). There is always finally a stage where an essentially perceptive process is needed in scientific research - a process taking place within the scientist [7].

References and Notes

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