Cosmic Revelation: Making Astroparticles Visible

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Summary

Cosmic Revelation is a prime example of a successful art and science project connecting art and astroparticle physics. One of the main reasons for its success might be that the collaboration between the KArlsruhe Shower Core and Array DEtector (KASCADE) experiment and Tim Otto Roth is both a minimalist light art project and a scientific experiment. In a field of 16 flashing mirror sculptures connected to the KASCADE detector field at KIT (Karlsruhe Institute of Technology, Germany) the impact of high energy cosmic rays on Earth can be experienced directly. In just one year the project has developed from the initial concept to its first presentation in a public space in autumn 2008. We explain how the project developed, and also highlight the practical and conceptual conditions for its realisation.

Forty thousand square metres were lit at KIT in March 2009, bringing science to life. *Cosmic Revelation* changed KASCADE into a light installation unique in its size for Germany, making the cosmic rays that originate in the depths of space visible as they interact with our planet. A couple of times a second the "cosmic energy" flared as bright, momentary flashes over sixteen "cosmic mirrors" — light sculptures created especially for the project.

Cosmic Revelation[1] showed that, though invisible, we are always in the middle of a giant astrophysical experiment. Particles are not only created artificially, as in the Large Hadron Collider (LHC) at CERN in Geneva[2], but are also abundant in the Earth's atmosphere. Large-scale international astroparticle experiments such as KASCADE show that on Earth we experience a continuous flux of high energy radiation "raining" down from space, hitting the atoms in the atmosphere as well as our own bodies with their secondary products. These atomic nuclei (mainly hydrogen, but also helium and heavier elements up to the mass of iron are present in the cosmic rays), can reach very high energies — a million times more energetic than particles in manmade accelerators. When such high energy particles hit the terrestrial atmosphere, the cosmic particles interact with the atomic nuclei of the atmospheric gases. The energy released by these collisions is transformed into a variety of elementary particles initiating a particle cascade — extended air showers. KASCADE consists of an array of several hundred stations equipped with particle detectors registering the resulting muons and electrons arriving at the Earth's surface[3]. By reconstructing the energy spectrum and elemental composition of cosmic rays, the experiment aimed to explain the origin, acceleration

Figure 1. One of the 16 light sculptures from Cosmic Revelation *in the KASCADE field. Credit: M. Breig/ Karlsruhe Institute of Technology.*

and propagation mechanisms of cosmic rays, still not fully understood even 100 years after their discovery[4].

Cosmic Revelation changed the KASCADE detector array, with its 252 gauging stations housed in little cabins, into a flashing field of light. If a highly energetic shower hit a detector cluster of 16 gauging stations it triggered the high power strobe in the "cosmic mirror" connected with that cluster. So the incoming air showers flooded a field as big as four football pitches (200 x 200 metres) with light and a massive 24 000 Watts of power. Associations with Walter de Maria's *The Lightning Field* in New Mexico (1977) are elicited[5]. The flashing "cosmic mirrors" could be understood not only as formal response to de Maria's approach, but also as a kind of scientific explanation: recent theories suggest that cosmic particles deliver the initial energy that triggers lightning in the atmosphere[6].

Sixteen tiny red flashing lights triggered the idea for a light orchestration of much larger proportions. The artist Tim Otto Roth and the scientist Andreas Haungs met for the first time in autumn 2007 during an interview series with scientists and astronauts, reporting on the impact of high energy cosmic rays in Earth and space. At the interview in the large open–air detector field of the KASCADE experiment they passed by an old minimalist event display from KASCADE consisting of 16 blinking light emitting diodes to document the impact of cosmic particles from space on Earth in real time. This display of four by four red light diodes was used to indicate that an air shower had hit that part of the detector field. Most interesting were the situations when more than one light flashed simultaneously, hinting that an air shower had hit. If all the lights flashed simultaneously, signifying an event of the magnitude of a collision in a particle collider, Haungs couldn't hide his excitement even after so many years working on the experiment. It was that excitement for the minimalist play of light that seeded the idea to use powerful lights to show the energy of air showers directly in the detector field.

For the scientists the motivation was to create a spectacular visualisation of the measurements after a decade of running KASCADE and receiving thousands of scientific and public visitors at the experiment. As KASCADE will end soon, the idea was to combine outreach with something new, going beyond a pure event, as a finale. *Cosmic Revelation* allows not only the public, but also the scientist to have a new visual experience of the physical phenomena. Above all, *Cosmic Revelation* can be considered as an approach of meta-communication, bringing something to the public that would normally only appear in the scientific literature, but is essential for the scientist's motivation to explore new boundaries.

The steps towards the realisation of this display were more down-to-Earth: developing a technical solution to bring a lot of light to an outdoor location and finding an event as a "host" for the project. From an organisational point of view there was the problem that the KASCADE field is located on the northern campus of the KIT, a restricted area not open to the public. So a double strategy was conceived: present the project during an event when the campus is open to the public and make the installation flexible and transportable, so that it could also be shown in other places.

The technical solution resulted from linking the artist's experience with earlier light projects to the profound expertise of the research centre, including electronics and carpentry workshops. This helped to reduce costs, mainly on the cost materials, and also brought various parts of the institute together in the project[7].

Although the cosmic mirrors housing the high power light sources look like a purely aesthetic solution, the design resulted from various pragmatic and technical considerations. Favouring high power strobes as light sources, the question was how to direct the bright flashing light and how to design the housing. The cosmic mirrors are a robust construction to protect the strobes not only against rain, but also from careless visitors. The strobes hang between two round plates (diameter, 95 cm), which are completely covered with blue mirror

Figure 2. KASCADE field during the winter. Credit: KASCADE collaboration.

Figure 3. Cosmic Revelation *at DESY Zeuthen, 25 February 2010. Credit: S. Niedworok/DESY Zeuthen.*

foil, and a convex mirror to spread the narrow beam of light. Four adjustable stainless steel feet give stability on the uneven ground. The blue back-reflecting foil on top gives an extraordinary and dynamic appearance to the sculptures, even during the day when the strobes are out of action.

The 16 cosmic mirrors used stroboscopes with 1500 Watts of power as a light source. The strategy was to use relatively inexpensive strobes commonly utilised by the event industry and to adapt them to the needs of the project. The strobes were controlled via the DMX512 protocol, a standard for digital communication networks and commonly used to control stage lighting and effects. The protocol is easily modified because it is based on an industrial standard also used in science. Finally the electronics were modified to improve the synchronisation. The control computer uses the KASCADE online display and analysed the data of the gauging stations in real time. When detecting an event the control software sent signals to the corresponding flash units. The signal carried not only the digital information of whether it was hit or not, but also information about how many detectors were triggered per station and the time sequence of the fired clusters. This information was used to adjust the brightnesses of the individual flashes. The online control software also allowed us to present the project in remote places, as for the premiere at the Karlsruhe University Forum (Germany) or recently in the winter of 2010 at the Deutsches Elektronen–Synchrotron DESY in Zeuthen close to Berlin on the occasion of the 6th Astroparticle Workshop discussing the status and perspectives of astroparticle physics in Germany.

Work on the first prototype started in July 2008. Finished two months later, the prototype attracted a lot of attention. People passing by the carpenters' workshop wondered about the UFO in there, and even the physicists were excited about the sculpture design. On 10 November 2008 the project premiered as a remote installation in the city of Karlsruhe at the inauguration symposium of the KIT Centre for Elementary Particle and Astroparticle Physics[8]. During the day the bluish shimmering cosmic mirrors looked like they were from another star on the autumnal lawn of the Karlsruhe University Forum. Nightfall signalled first light for the whole cluster of 16 light sculptures — and it looked great! But the premiere revealed many surprises. Interestingly the machine eyes of video and photo cameras had more problems capturing the light play than human viewers. The CCD webcam failed completely to record the scenery with its fast-changing contrasts.

Finally, the major challenge was the realisation of *Cosmic Revelation* in the KASCADE field on the occasion of the closing symposium at the end of March 2009. After the difficult test at the University Forum, a couple of improvements were made in the electronics. But the unknown element was the final effect of the light sculptures on the KASCADE field, which is at least 20 times bigger than the University Forum. After a successful light test at the beginning of March, with four light sculptures in the detector field, the atmosphere was quite optimistic: the detector housings reflected the light of the nearby sculptures and drew attention to their presence.

On 31 March *Cosmic Revelation* made the final point of the closing symposium, presenting the experiment's results and giving insight into the history of KASCADE. About 200 guests from all over the world could follow how, after a sunny day, the flashing cosmic rays gained more and more power as night fell.

Although the project could be watched by only a relatively small number of people, the project received a lot of media attention. "*A new art encodes a new science*," summarised Martin Kemp in his review in *Nature* in April 2009[9]. Further articles appeared in *Symmetry Magazine*[10] and *Leonardo Magazine*[11]. An audio and a video podcast were produced by *Welt der Physik*[12].

The resonance is also due to its novelty. The cosmic mirrors create a new kind of display that lets people experience cosmic energies not just as a flat picture, but in time and space. The novelty of this unique art and science project is not just to illustrate the invisible effects of cosmic radiation, as in previous art projects. What makes *Cosmic Revelation* so different is that it makes not only single events visible, but also the air showers and their direction[13]. This pictorial reflection distinguishes *Cosmic Revelation* as an art and science project from pure science events. For instance the Opéra cosmique ignored the spatio-temporal relationship of cosmic rays in autumn 2009 when sending a laser beam over Paris that depended on quite arbitrary muon measurements on the Montparnasse tower[14]. In *Cosmic Revelation*, sometimes a light wave passes through the field, following the track of a strike. This originality was awarded an honorary mention in September 2009 by the Ars Electronica in Linz, the world's biggest festival for media art. *Cosmic Revelation* was represented in the festival's exhibition by two flashing light sculptures connected online with KASCADE[15].

Finally there are parallels between a physics experiment like KASCADE and so-called land art. Larger physical and astronomical experiments have artistic and architectural components. Observatories appear like cathedrals in the void of a desert[16], like the big brother of KASCADE — the Auger

experiment, which opened recently in the Argentine pampas[17]. But it is generally the playful approach to the ephemeral in nature that connects the cosmos-related scientific projects to land art experiments like the Roden Crater project by James Turrell[18], who is turning an old volcano crater in the Arizona desert into a naked-eye observatory for certain celestial phenomena.

As seen with KASCADE, you don't necessarily need an "earthwork as artwork"[19] or sublime nature as surroundings to be connected with the ephemera of the cosmos. So in a way *Cosmic Revelation* brings a new form of invisible land art even to an urban space by using light as a plastic medium of expression. The sky is everywhere all the time — this opens up new forms to bring the miracles of astroparticle physics to the public, also in forms beyond the museum and high quality glossy brochures.

The Americas might also be an option for *Cosmic Revelation*: recently the Pierre Auger Observatory South has opened its doors in Argentina. Its counterpart in the northern hemisphere is currently at the planning stage for Colorado (USA). These two giant cosmic ray experiments give a new dimension to the exploration of cosmic radiation and open a new window to the Universe. *Cosmic Revelation* could draw back the curtain on that cosmic spectacle, by adding light to an interaction of land and nature.

Notes

[1] *Cosmic Revelation* is the second successful collaboration by KASCADE and Tim Otto Roth. *With I See What I See Not* Tim Otto Roth created a walk on the retinas of the extreme sciences by changing the 76 neon light panels of a light façade in Munich into a cosmic matrix, showing the most advanced results of the imaging machines in astronomy and elementary particle physics. In the winter of 2004–05 the data of KASCADE's central calorimeter were transmitted in real time to the public light wall of the Art Façade at the House of Communication in Munich. See: http://www.kunstfassade.de/tor/i-see-what-i-see-not.html (retrieved on 4 June 2010)

[2] The European Organization for Nuclear Research CERN (2008). The highest energies of cosmic radiation are a million times higher than the energies produced currently in the largest particle accelerators on Earth. This is why the concerns raised in the debate in autumn 2008 about mini black holes at CERN in Geneva are unfounded. If the postulated mini black holes resulting from collisions in the new Large Hadron Collider (LHC) at CERN were really so dangerous, such a mini hole would have been created by a cosmic particle long ago and sucked up the whole planet.

[3] KASCADE started operations in 1996 and will be discontinued in 2010 after 14 years. KASCADE was the first experiment reconstructing the energy spectra of individual primary cosmic ray particle types showing that the so-called "knee" in the cosmic ray energy spectrum is due to a decrease in the flux of low-mass nuclei accelerated in the Milky Way. The knee is a puzzling kink in the power law that is otherwise structureless over many decades. KASCADE (2009) http://www-ik.fzk.de/KASCADE_home.html (retrieved on 4 June 2010)

[4] In 1910 Theodor Wulf measured an increased ionisation of the air on top of the Eiffel Tower in Paris. Then, in 1912, Victor Hess proved, using high altitude balloon flights, that this increased radiation — which he named *Höhenstrahlung* — must originate from space.

[5] *The Lightning Field* creates a spectacular sculpture to observe the phenomenon of lightning in the high desert of New Mexico. It consists of 400 polished stainless steel poles about 6 metres in height distributed on an array of about 1.6 square kilometres. Dia Art Foundation (2009), http://www.lightningfield.org

[6] Gurevich A. V. & Zybin, K. P. 2005, *Runaway Breakdown and the Mysteries of Lightning*, Physics Today 58, 5, 37, http://www.phy.olemiss.edu/~jgladden/phys510/spring06/Gurevich.pdf (retrieved on 4 June 2010)

[7] Acknowledgement: without the quite sceptical, but basically positive attitude of the entire environment at KIT and the KASCADE collaboration — the institute, the workshops etc. *Cosmic Revelation* would not have been possible. Many thanks for all the help, in particular to Johannes Blümer, Bernd Hoffmann, Andreas Theel and Hans Pohlmann.

[8] The KIT Center for Elementary Particle and Astroparticle Physics combines experimental and theoretical research and education at the interface between astronomy, astrophysics, elementary particle physics and cosmology.

[9] Kemp, M. 2009, *Flashes of cosmic brilliance*, Nature, 458, 836

[10] Kunz, T. 2009, *Cosmic rays spray art across a lawn*, Symmetry Magazine, 6, 1, 5

[11] Roth, T. O. & Haungs, A. 2009, *Cosmic revelation*, Leonardo 42, 3, 288

[12] *Welt der Physik* on Youtube: http://www.youtube.com/watch?v=Pz79JqgQ3I8 (retrieved on 4 June 2010)

[13] In the context of the KASCADE experiment CORSIKA was developed to simulate the development of air showers in the atmosphere. The project page provides illustrations and animations of air showers. CORSIKA (2008) http://www-ik.fzk.de/corsika

[14] Opéra cosmique 2009, http://www.opera-cosmique.fr (retrieved on 11 June 2010)

[15] Ars Electronica Linz, Cyber Arts 2009, http://www.aec.at (retrieved on 11 June 2010)

[16] For instance the architecture of the Paranal Observatory of the European Southern Observatories (ESO) interacts in a very special way with the void of Chile's Atacama Desert. Whereas the telescope buildings on the mountain appear more like techno cathedrals, the monastery-like Residenzia in the base camp built by the German architects Auer+Weber integrates fully into the landscape. ESO (2008), http://www.eso.org/public/images/eso-paranal-02/ (retrieved on 4 June 2010)

[17] Pierre Auger Observatory: The Pierre Auger Observatory South extends across a terrain of 3000 square kilometres in the Argentine pampas. The Auger Observatory is a "hybrid detector", employing two independent methods to detect and study high energy cosmic rays. One technique detects high energy particles through their interaction with water placed in surface detector tanks. The other technique tracks the development of air showers by observing ultraviolet light emitted high in the Earth's atmosphere. Whereas KASCADE measures galactic cosmic radiation, Auger focuses on higher energy radiation originating from regions beyond our Milky Way. http://www.auger.org

[18] Turrell, J. 1986, The Roden Crater Project, exh. cat. (Tuscon: University of Arizona Art Museum)

[19] Jori Finkel, J. 2007, *Shh! It's a Secret Kind of Outside Art*, New York Times, 25 November 2007 http://www.nytimes.com/2007/11/25/arts/design/25fink.html?ref=arts (retrieved on 4 June 2010)

Biographies

Tim Otto Roth is known for his large art and science projects in public space. He has collaborated with various scientific institutions around the world, for instance with the Max-Planck Institute for Radioastronomy (D), Bibliotheca Alexandrina (EG), High Altitude Research Station Jungfraujoch (CH), Brookhaven National Laboratory (US), Fermilab (US) and KEK Tsukuba (JP). He has received numerous awards, including the International Media Art Award by the Centre for Art and Media ZKM Karlsruhe and the German Light Art Award in Lüdenscheid. He lives in Cologne and Oppenau (Black Forest).

Andreas Haungs is the representative of the KASCADE cosmic ray experiment and group leader at the Institute of Nuclear Physics at the KIT. He works on the development of detection techniques and data analysis in the field of high energy astroparticle physics and is also member of the Pierre Auger Observatory. He chaired in 2008 the working group on cosmic rays for the Roadmap Astroparticle Physics in Europe.

Harald Schieler is operations manager of the KASCADE cosmic ray experiment and member at the Institute of Nuclear Physics at the KIT. He works on the development of detection techniques and data acquisition systems in the field of high-energy astroparticle physics and is also a member of the Pierre Auger Observatory.

Andreas Weindl is a member of the KASCADE cosmic ray experiment and member at the Institute of Nuclear Physics at the KIT. He works on the software development of data acquisition systems in the field of high energy astroparticle physics and is also a member of the Pierre Auger Observatory.