

Cosmic Intruders under Observation

Atomic nuclei, photons and neutrinos rain down continuously on the Earth from space. At the Pierre Auger Observatory in Argentina researchers study these high-energy particles with unprecedented precision – and hope to uncover some of the universe's secrets

By Bianca Keilhauer
and Johannes Blümer

Anyone who drives through the Argentinian Pampas, along the foot of the Andes Cordillera, and approaches the small town of Malargüe in the Mendoza Province from the north, will notice large plastic tanks at regular intervals at the roadside – lined up like a string of pearls. 1,600 of these tanks, each 3.4 metres in diameter and around 1.5 metres tall, form the 3,000 square kilometre detector array of the Pierre Auger Observatory. The tanks are supplemented by telescopes positioned at four different points around the detector field boundaries: on clear, dark nights they observe cosmic rays with unprecedented precision. Here, more than 400 scientists from 17 nations investigate the most energetic cosmic rays.

Cosmic rays in the form of high-energy atomic nuclei, photons and neutrinos constantly bombard Earth from space. Their energies range from the rest energy of a hydrogen nucleus up to macroscopic values of several Joules – concentrated in a single particle! The measured record corresponds to around 300 times the collision energy of the LHC particle accelerator at CERN in Geneva, which entered service on 10 September 2008. However, the intensity of cosmic rays decreases rapidly with energy, making observations of events enormously difficult.

The majority of low-energy particles originate in our own Milky Way, where they are probably catapulted to the observed energies in the “shock fronts” of supernova explosions. The galactic magnetic field deflects these particles numerous times during their journey, making their sources impossible to identify. However, this changes drastically at the highest energies: there are no known objects in the Milky Way capable of generating

the kind of energies recorded and the galaxy itself cannot capture such particles magnetically.

It was not until November 2007 that the Pierre Auger Observatory managed to recognise a relationship between the arrival directions of the most energetic cosmic particles and the positions of extragalactic objects in the southern sky. Apparently active galaxies, with black holes of several hundred million solar masses at their centres, can provide the extreme conditions in their environs re-

quired for the observed accelerations.

Above the mid-energy range cosmic ray events are too rare for direct observation using balloon or satellite experiments. But higher energies allow new, indirect methods of detection. The primary particle collides with an atomic nucleus in an air molecule when it penetrates Earth’s atmosphere and thus generates numerous secondary particles. These, in turn, retain enough energy to participate in energetic interactions and create further particles.



Illustration: Karlsruhe Research Centre

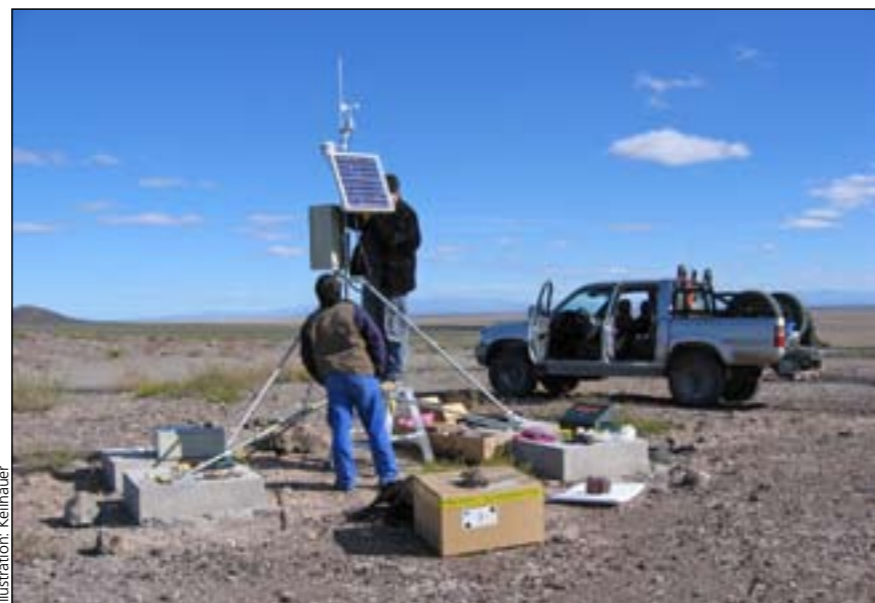
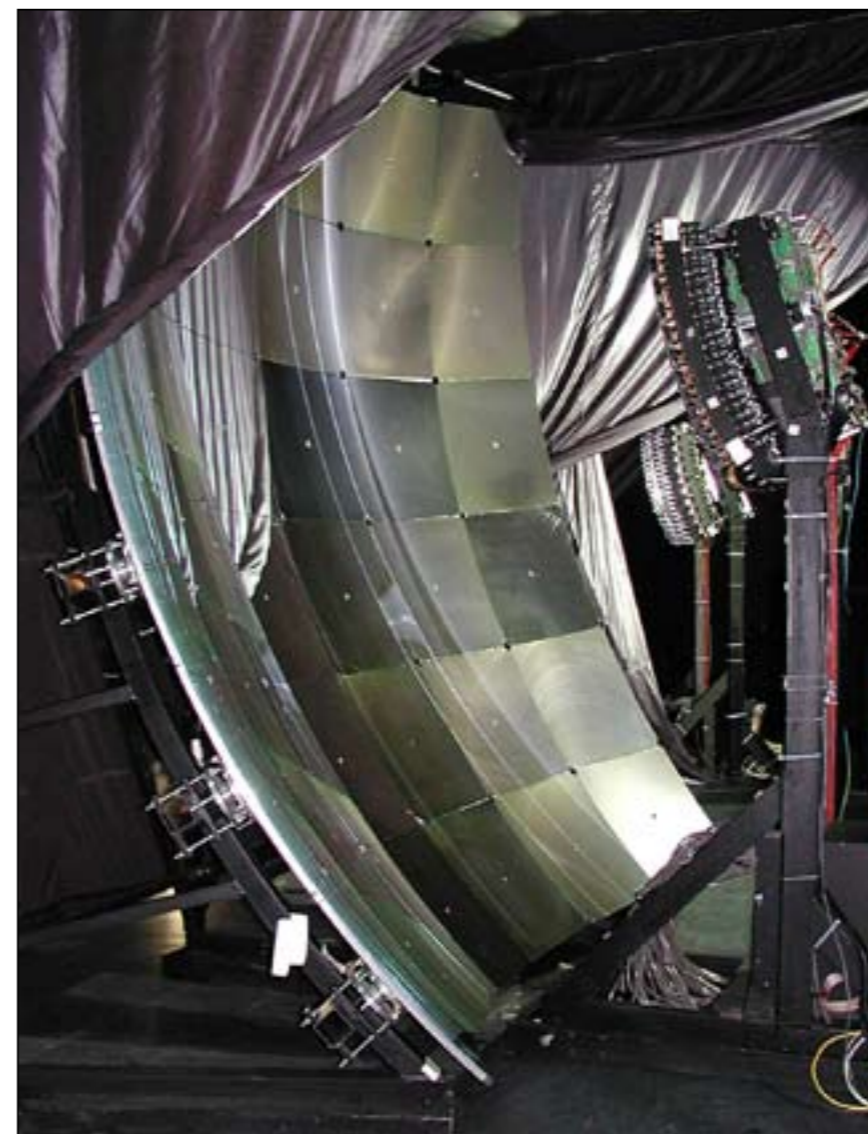


Illustration: Keilhauer

1,600 water Cherenkov tanks – with a spacing of 1.5 kilometres between tanks – have been installed in the expanses of the Argentinian Pampa Amarilla, forming the detector array of the Pierre Auger Observatory. Bottom: Two observatory engineers erect a weather station.



Inside the “Los Leones” telescope station: Light enters the detector building from the right, falls onto the large, spherical mirror and is then bundled onto the camera. The fluorescence detector of the Pierre Auger Observatory comprises four buildings with six individual telescopes each.

This light, which is radiated along the particle cascade, is also detected by the electronic reflecting telescopes at the Pierre Auger Observatory. The combination of both of these methods of detection allows extremely precise measurement of the development of extensive air showers in the atmosphere, and the number and distribution of secondary particles at ground level.

The type, energy and direction of origin of the primary particles can be deduced from the data collected. These data will be collected by the Pierre Auger Observatory over a period of around twenty years, allowing possible sources of cosmic rays to be identified. A second installation is planned for 2010 in the northern hemisphere. The fluorescence telescopes play a key role in understanding these complex phenomena.

In contrast to the usual laboratory experiments under well-defined environmental conditions, an extensive air shower traverses the entire atmosphere from top to bottom. Temperature, pressure, density and humidity are continuously changing, introducing variability to particle interactions and

also influencing the fluorescent light. In addition, changes in the atmosphere over periods of days, or the seasons of the year, have a great impact.

The effects of these atmo-

spheric factors on a precise reconstruction of the extensive air showers are at the focus of a DFG-funded research project. The Pierre Auger

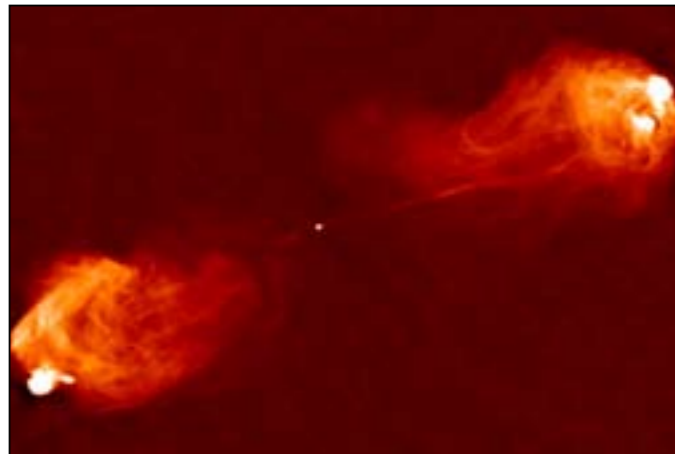
The primary particle thus initiates a cascade of secondary particles, which propagate towards the Earth’s surface at almost the speed of light. After 10 to 15 particle generations the energy is distributed among so many secondary particles that no new particles are formed and the shower gradually dies out due to ionisation losses, or it reaches the Earth’s surface. This phenomenon was discovered in 1938 by Pierre Auger and is known as an “extensive air shower”.

At the highest energies, billions of secondary particles reach the ground and allow sparse sampling of the air shower in large detector arrays, for example at the Pierre Auger Observatory. Furthermore,

the continuous energy lost by the secondary particles in the atmosphere also excites nitrogen molecules, the main constituent of air.

Excitation means that some of the molecule’s orbiting electrons are raised to a higher energy level. These states are unstable and the electrons almost immediately begin to spontaneously fall back to lower energy levels. The energy thereby released is uniformly radiated in all directions as UV fluorescent light.

The data collected by the observatory provide insight on the type, energy and direction of origin of the primary particles



Illustrations: Archive

Observatory data are analysed for this purpose and weather stations are deployed at several locations in the 3,000 square kilometre detector array in order to continuously record the air conditions on the ground.

The measurements of the vertical atmospheric profile are much more complex. Temperature, pressure and humidity are determined as functions of altitude using meteorological radio probes attached to helium-filled weather balloons and lifted to heights of 25 kilometres. The journey takes around two hours and the radio probe data are transmitted to the receiving ground station every three to five seconds.

These radio soundings are dispatched approximately every five days by a specially built balloon launching station. Dedicated measuring campaigns were initiated, for example to find an answer to how the atmosphere changes between the hottest time of day, i.e. generally early afternoon, and the coolest time of day, just before sunrise, both close to the ground and at higher altitudes.

Following the on-site campaigns the recorded atmospheric data are analysed in Germany and stored in databases. It was thus possible to refine the reconstruction of extensive air showers using the previously captured weather data. Moreover, work is ongoing on the theoretical principles behind the fluorescence



Illustration: Karlsruhe Research Centre

Top: Objects in the Universe under discussion as sources of cosmic rays – here, impressive ‘jets’ issuing from active galactic nuclei. Bottom: A radio probe just before being launched. It hangs on a helium-filled weather balloon to record meteorological data.

emissions as a function of the real ambient conditions, and the results are verified in smaller experiments.

One result: the light yield depends critically on temperature and humidity, meaning that these aspects also need to be taken into consideration for air shower reconstruction. The uncertainties involved in the reconstruction of the cosmic ray’s primary energy and the type of primary particle are related to fluctuations in atmospheric conditions. However, model atmospheres developed previously can only be improved for the reconstruction after several years of weather data recording in the Argentinian Pampa.

The use of real-time atmospheric data in reconstructions of highest-energy air showers remains an open objective for the future. This objective may help to interpret these extremely rare and therefore “valuable” events with the highest possible precision – and thus to obtain new understanding.

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Illustration: Rom e.V., Cologne

A large group of children follows a bear tamer. This photo was taken in Berlin in 1927. Most of the Roma who came to Germany from Eastern Europe in the early 20th century earned a living as showmen and entertainers.

“Warning! Gypsies!”

Between fascination and destruction: Society’s way of dealing with the “Travellers” has undergone many changes over the centuries. Even today, stereotypes influence our views of the Sinti and Roma

By Herbert Uerlings and Iulia-Karin Patrut

How have people treated the poor and aliens over the past two centuries? Alongside the Jews, the “Gypsies” are one of Europe’s oldest ethnic minorities. The history of both of these groups over the centuries has been one of unpredictable alternation between social inclusion and exclusion – going as far as the inhumane genocide of the Holocaust in the 20th century.

The social status of the Gypsies has been influenced by a wealth of changing projections, images and stereotypes among the majority of the population. For example, the Gypsy Romance movement in 19th century Europe reflected the longing to break out of the restrictive bourgeois conventions of the age. One of the best known fictional Gypsies, Bizet’s *Carmen*, both fascinated and threatened the middle-class audiences of her time. Early 20th century criminologists, on the other hand, categori-

cally viewed every Gypsy they set eyes upon as a delinquent by birth. In retrospect, the Gypsies’ social status became ever more precarious as the establishment of nation states on the European continent progressed, and the more efficiently a given territory could be controlled. Change did not set in until decades after the Second World War.

When they arrived in Europe in the Late Middle Ages, it was initially easy for the Gypsies to be integrated into the prevailing view