Cosmic Rays

The Earth continuously receives showers of high-energy charged particles, or cosmic rays, from a wide range of cosmic accelerators corresponding to violent phenomena in the Universe.

The first studies of cosmic rays date back to the early 20th century, shortly after the discovery of radioactivity. Electrometers were used to detect ionising radiation produced by radioactive substances. Oddly enough, these devices always detected radiation, even in the absence of a radioactive source. What was the source of such radiation? Was it emanating from the Earth's crust? To find out, the Austrian Viktor Hess made a series of balloon ascents between 1911 and 1913, one of which took him higher than 5,000 m. He observed that above 2,000 m the two on-board electrometers detected an increasing flux of this mysterious radiation, proving that it originated largely from space.

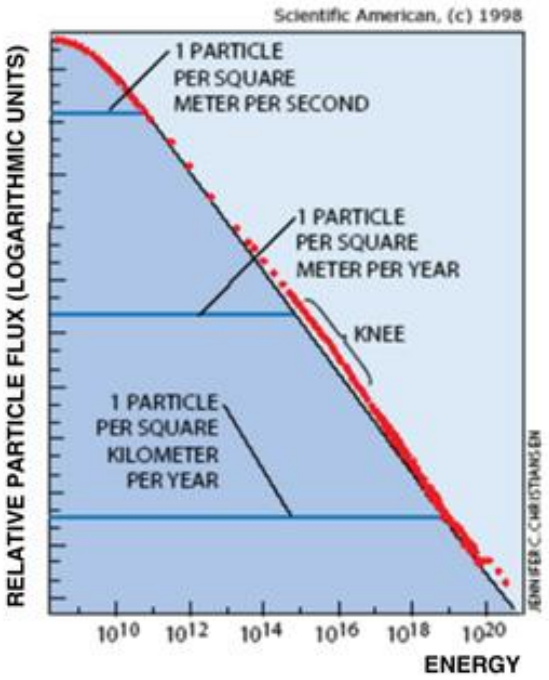
Viktor Hess standing in his balloon

View of the basket of Viktor Hess's Böhmen balloon after landing at Piekow, Germany

Credit : Wikipedia

In the 1920s the flux of cosmic rays was shown to vary from one point of the planet to another, depending on the geomagnetic latitude of the location. As they approach the Earth, cosmic rays interact with the planet's magnetic field, proving that they are electrically charged particles. We now know that they are mainly protons. At the end of the 1930s Pierre Auger demonstrated that the particles detected on Earth were the by-products of a chain reaction: when the most energetic cosmic rays coming from space hit the atoms in the upper atmosphere, they develop showers of secondary particles which can reach the ground. Auger deduced that some cosmic rays carried energies of the order of 10^{12} eV (1 TeV), an astonishing value for that time!

Through the study of these showers, physicists discovered many subatomic particles, such as positrons, muons or pions. Since the 1950s, the fine structure of matter has rather been studied with particle accelerators. What remains to be identified, however, is the stars and mechanisms that produce primary cosmic rays. To that end, we try to reconstruct the properties of the cosmic particles before they enter the atmosphere, such as their incidence direction and their nature (proton or a more complex nucleus). Taken together, these data make it possible to establish the spectrum of the cosmic radiation, that is, the evolution of the number and nature of the collected particles as a function of their energy. The spectrum's analysis provides information about the astrophysical mechanisms producing cosmic rays.



Credit: HAWC Observatory

Origins of ultra-high-energy cosmic rays

Flux of cosmic rays as a function of their energy. Both axes have logarithmic scales.

As the only sample of matter from beyond the solar system, cosmic rays form a genuine link between our planet and outer space. Cosmic rays play a part in the evolution of species by travelling through living organisms and disrupting their biological processes – during a night's sleep, your body is penetrated by more than three million ionising particles. They are also the source of the lightest elements, lithium, beryllium and boron, which they patiently form in space by breaking up more massive nuclei.

Translated from 'Les rayons cosmiques',* Passeport pour les deux infinis, *IN2P3/Dunod, https://pass2i.ijclab.in2p3.fr/ (French); updated with ICHEP2024 conference (https://ichep2024.org) for IPPOG