

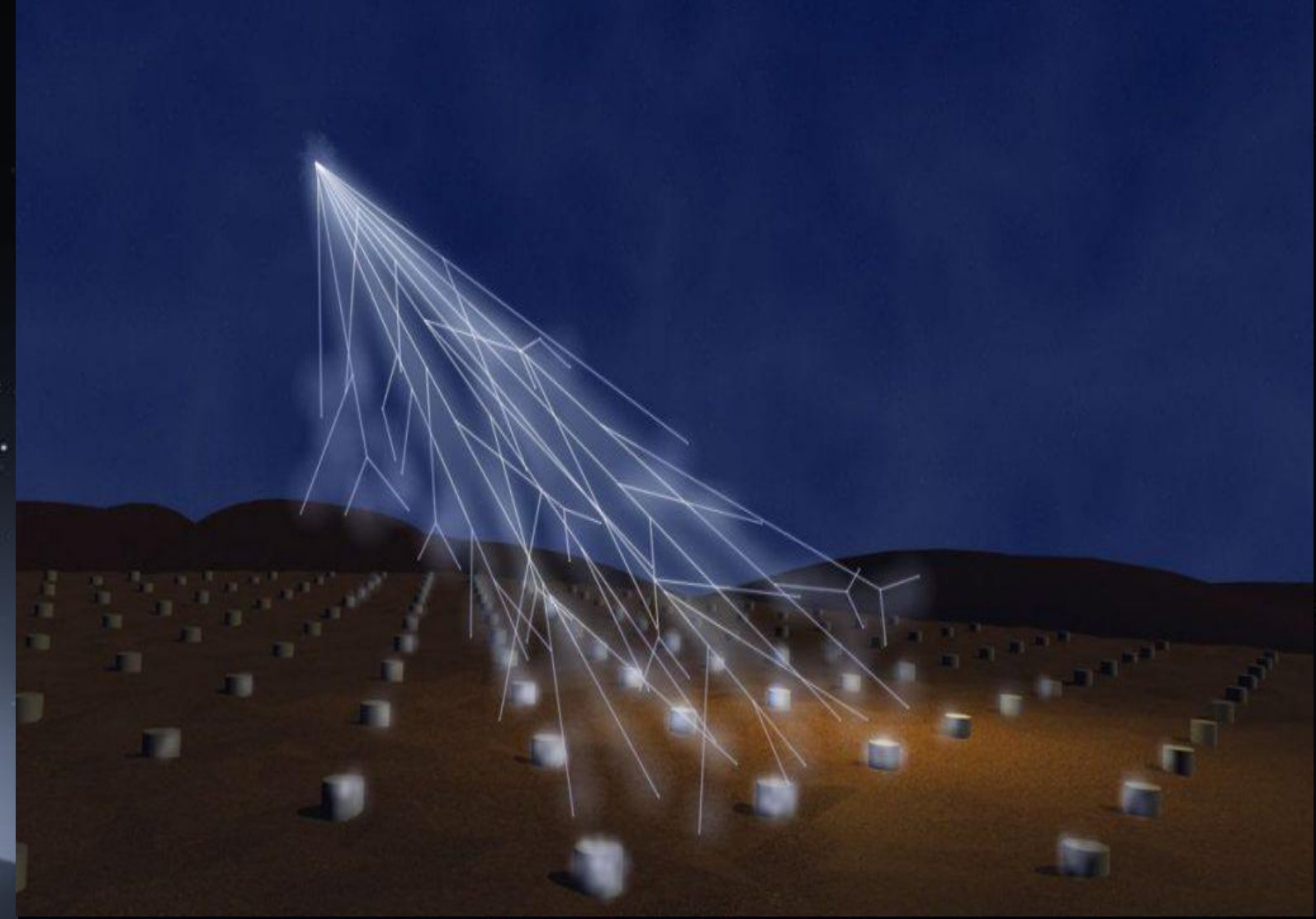
A cosmic background image featuring a dark blue and purple galaxy with intricate filamentary structures. In the upper right corner, a portion of the Earth is visible, showing its characteristic blue oceans and white clouds. The overall scene is filled with numerous small, distant stars.

THE COSMIC RAYS: Origins, Propagation and Revelation Techniques

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Summary

- What are the cosmic Rays? And where they come from?
- How they propagate in the space? And how can we detect them?
- Our Hands-on Experience
- Conclusions and future perspectives



What are the Cosmic rays and where they come from?

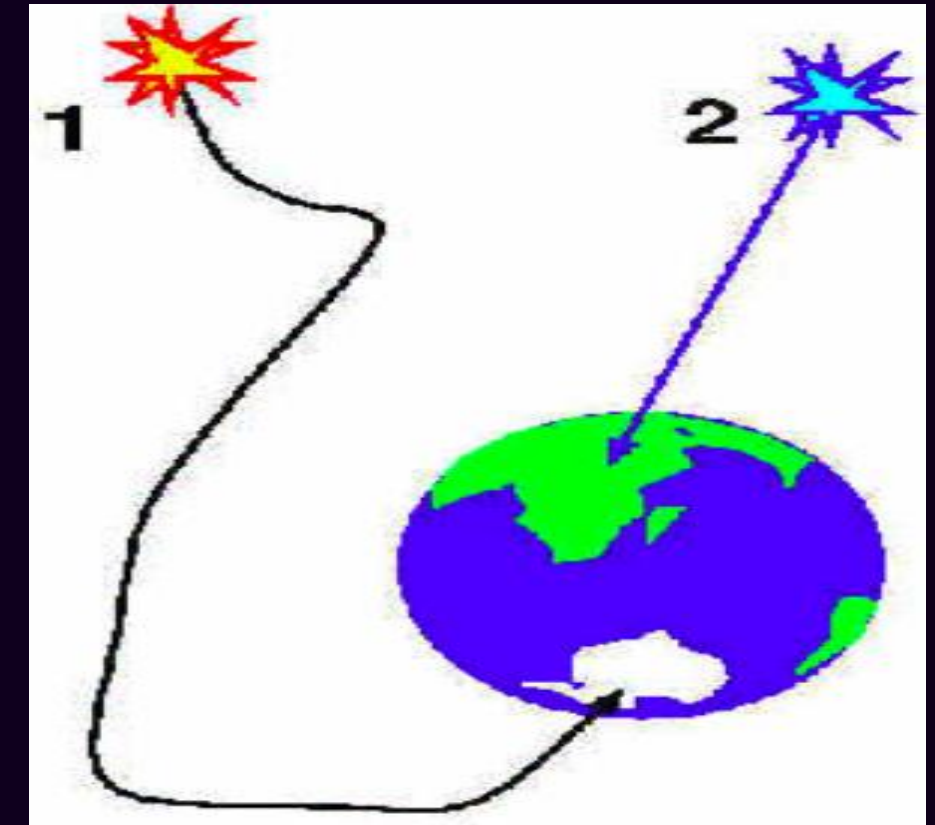


Cosmic rays are high-energy subatomic particles that travel through space and interact with the intergalactic, interstellar, and interplanetary medium before reaching Earth.

Their origin is still not fully understood, but scientists have proposed several theories based on observations and simulations. Some of the most popular theories include: Supernova Remnants, Active Galactic Nuclei and Gamma-Ray Burst.

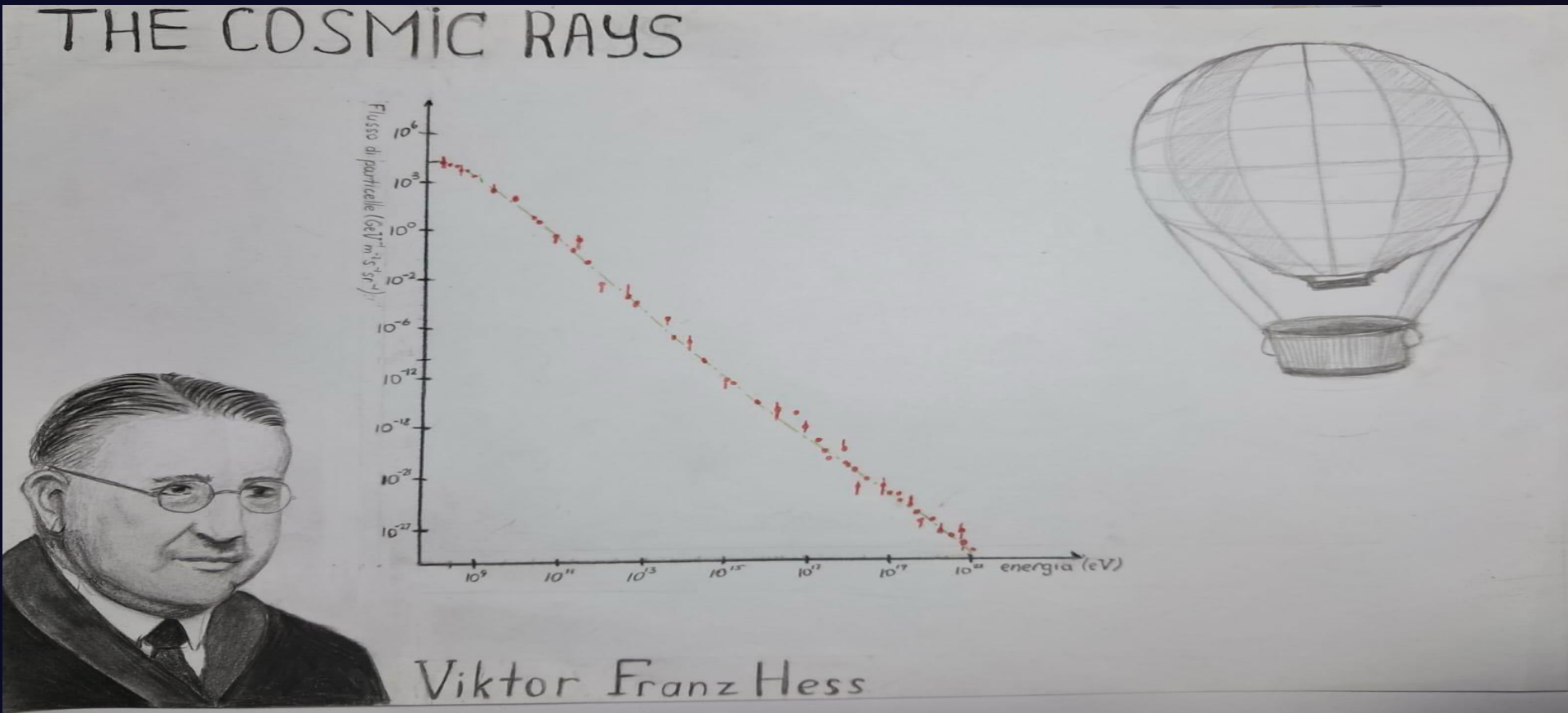
How they propagate in the space?

Cosmic rays are accelerated to high energies, they must travel through the interstellar medium (ISM) to reach Earth. During this journey, they interact with various components of the ISM, including: Magnetic Fields, Gas and Dust, and Radiation Fields.



How can we detect them?

The Cosmic Rays are detected using various techniques based on their interactions with Earth's atmosphere and detectors. The low-energy cosmic rays, thanks to their flow, can be detected outside the atmosphere, while the high-energy ones need to be detected through large SD.



The image, drawn by us, shows: a Hess's portrait and a hot air balloon he used; the graph in the middle describes the cosmic-ray flux which decreases as the energy increases.

Our Day as a scientists: Tracing Cosmic Rays with the Pierre Auger Observatory

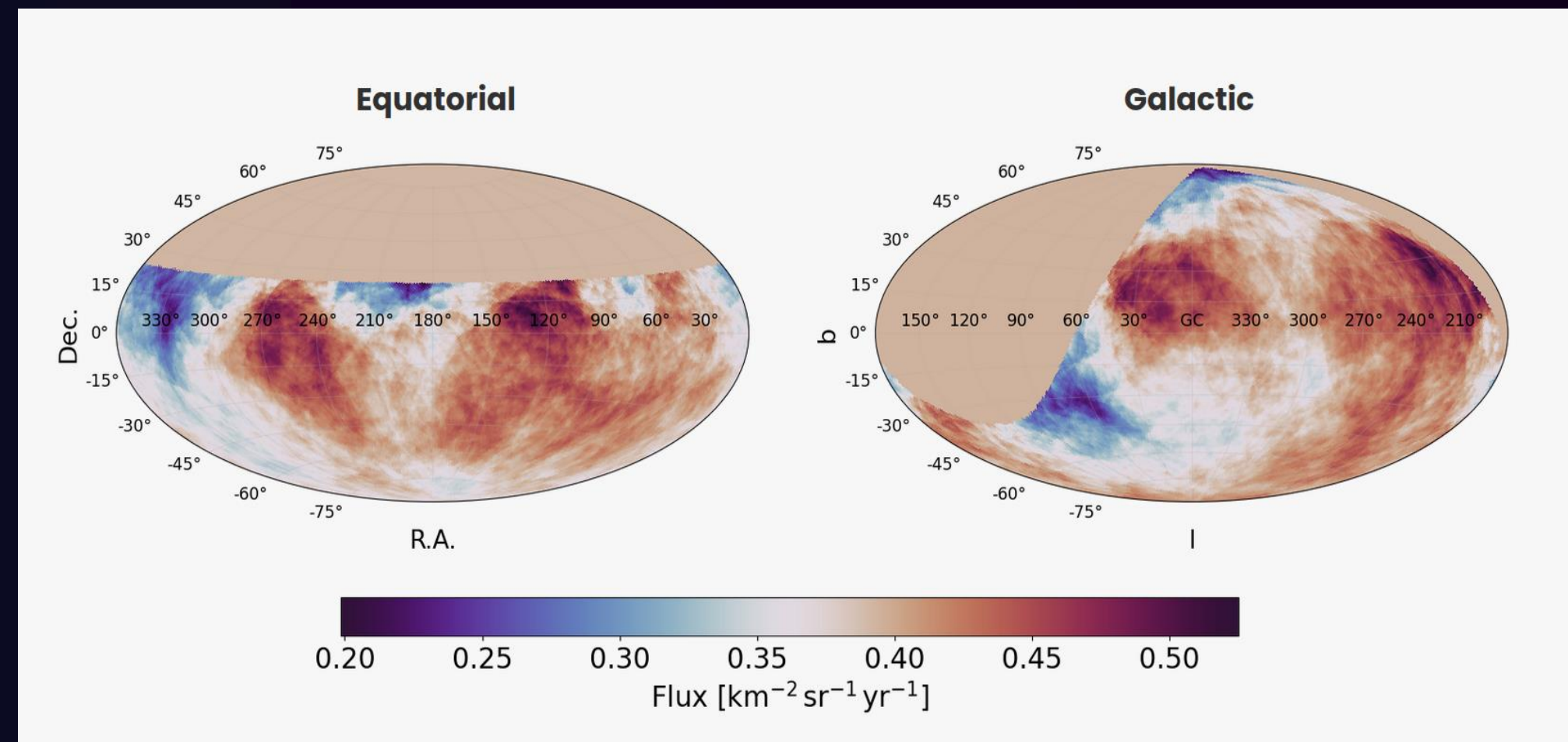
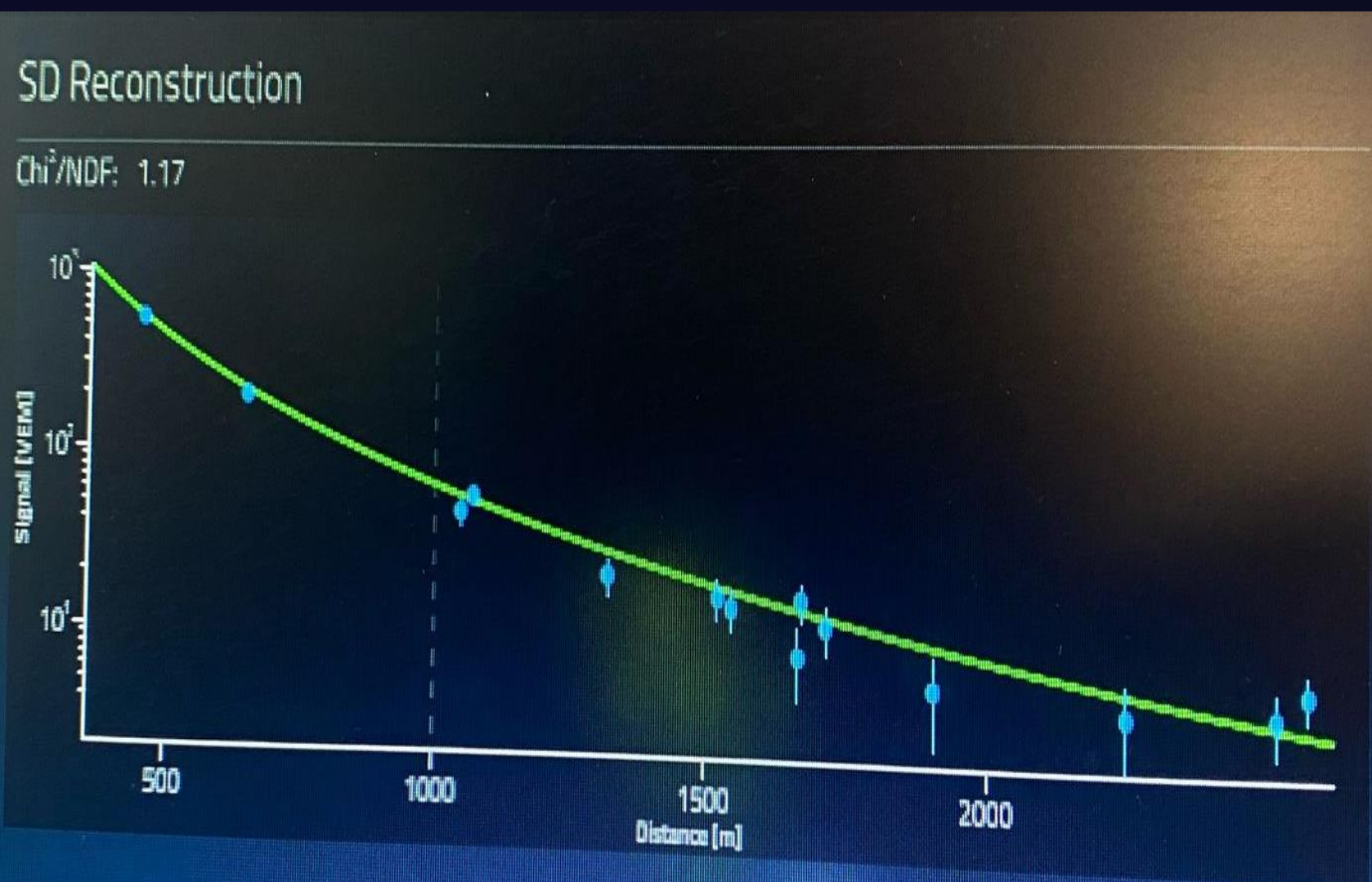
Analyzing real cosmic ray events from the Pierre Auger Observatory was an incredible experience. We worked in group and the task of each group was to reconstruct the arrival direction and energy of up to 50 cosmic ray events, searching for clues about their origins in the universe.

We are going to describe the reconstruction steps for the events collected by the surface detector (SD data) of the Pierre Auger Observatory

To analyse the data series provided us, we had to follow the following steps :

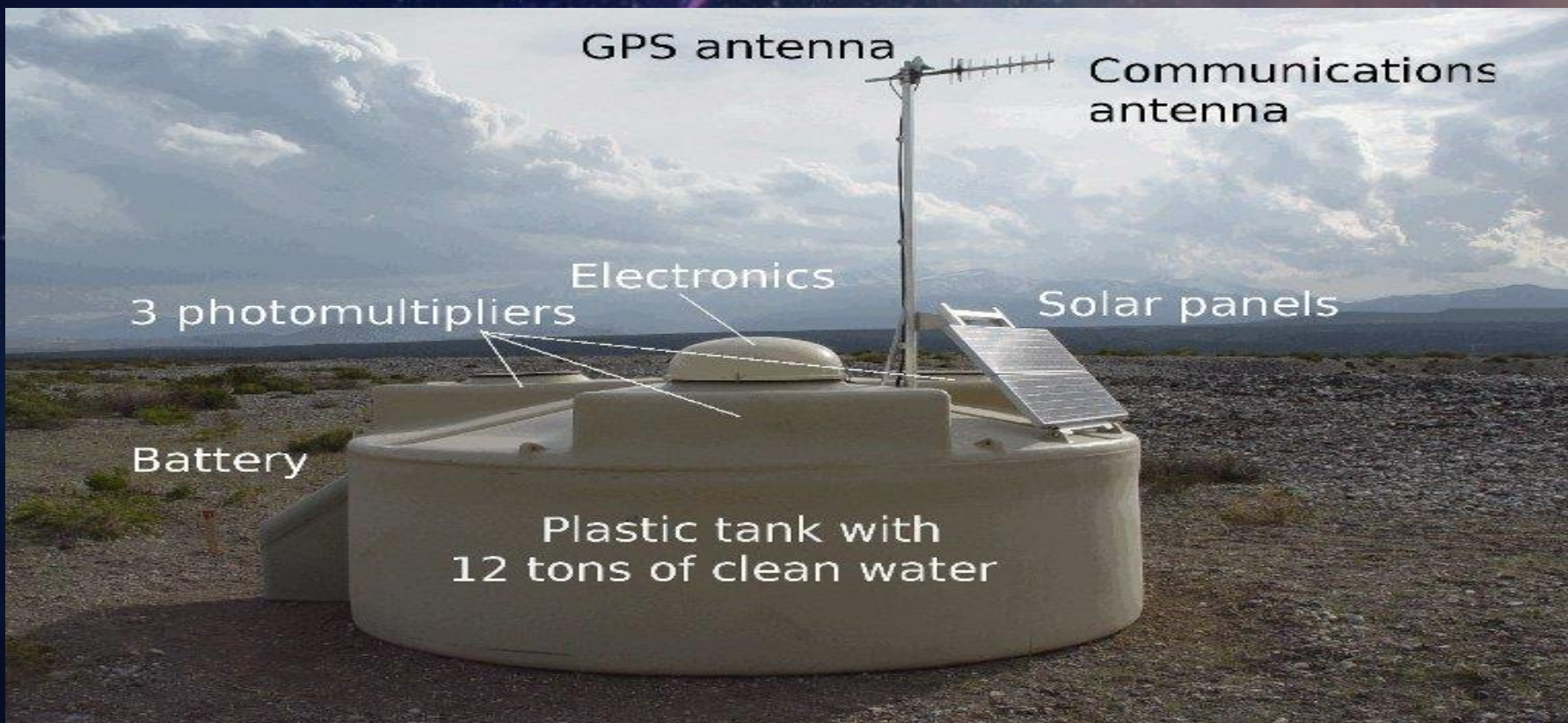
1. Selecting detection Stations;
2. Determining the Arrival Direction;
3. Estimating Energy;
4. Event Selection;

Comparing our results, some cosmic rays appeared to come from regions with active galaxies, suggesting an extragalactic origin.



Conclusions

Cosmic rays are key to understanding high-energy astrophysics, particle physics, and space weather. Their origins range from supernovae to active galactic nuclei, and their propagation through the galaxy involves complex interactions with magnetic fields and matter. While they impact Earth's atmosphere and space missions, their exact acceleration mechanisms and highest-energy sources remain unclear.



This image shows a typical surface detector with its components. Which in future will go through innovations

Future perspectives

As technology advances, cosmic ray research will continue to unlock new discoveries about the universe.

For the future we expect:

- Advanced Observatories: Next-generation telescopes (CTA, SWGO) and space missions will improve cosmic ray detection.

- Multi-Messenger Astronomy: Combining cosmic ray data with neutrinos and gravitational waves will refine source identification.

- Fundamental Physics: Cosmic rays could reveal new physics, including insights into dark matter and beyond-Standard-Model phenomena

- Space Exploration: Better radiation shielding is needed for deep-space missions to Mars and beyond.

As humanity prepares for long-duration space missions, cosmic radiation will pose a growing challenge. Without Earth's atmospheric and magnetic protection, astronauts will face increased health risks.