【Grant-in-Aid for Specially Promoted Research】

Unravelling mystery of cosmic particle accelerator PeVatron by highest-energy gamma-ray observation

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Project Information	Project Number : 22H04912 Keywords : cosmic gamma rays, cosmic rays, air showers, muons	Project Period (FY) : 2022-2026

Purpose and Background of the Research

●Outline of the Research

We set up a large air shower detector array and underground muon detectors in the Andes highland in Bolivia (Figure 1). We aim at the highest-energy (0.1 to 1 Peta eV =100 to 1000 trillion electron volts) gamma-ray astronomy as well as at elucidating an enigma over 100 years since the discovery of cosmic rays (mostly protons), i.e., a PeVatron which accelerates cosmic rays up to PeV (Peta eV) energies in our galaxy.

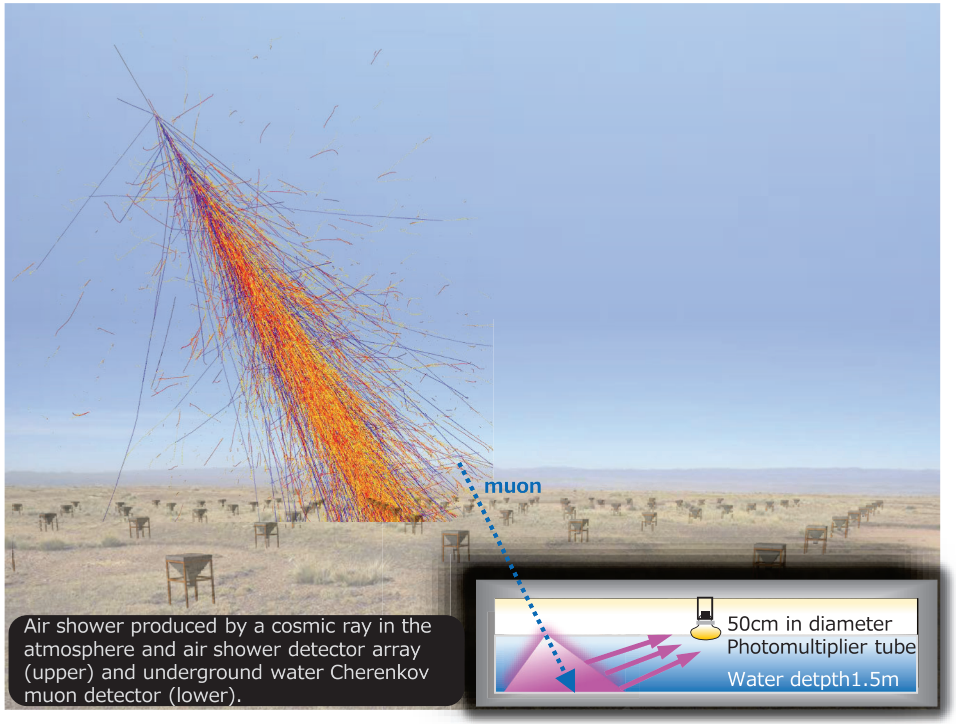

Figure 1. Image of the project

●Importance of observation of cosmic gamma rays

A PeVatron which accelerates cosmic rays up to PeV energies in our galaxy has not been identified. Cosmic rays can't travel straight in the galactic magnetic field and lose directional information, as they have electric charge. Meanwhile, electrically neutral gamma rays, produced by PeV cosmic rays interacting with the interstellar matter (mostly hydrogens) have 0.1 to 1 PeV energies which is 100 to 1000 trillion times as energetic as the optical light. Such gamma rays are the key to discover a PeVatron.

●New energy astronomy in southern sky

A large air shower detector array with underground muon detectors enables us to measure the number of muons in an air shower, improving sensitivity to the highest-energy gamma rays dramatically. We reduce cosmic-ray noise against gamma-ray signal, as a gamma-ray induced air shower contains much less muons than a cosmic-ray induced one. We survey continuously the unexplored southern sky by the highest-energy cosmic gamma rays with a wide field of view and the world-best sensitivity (Figure 2), aiming at studying the limit of cosmic-ray energy and at identifying their origin, PeVatron in our galaxy.

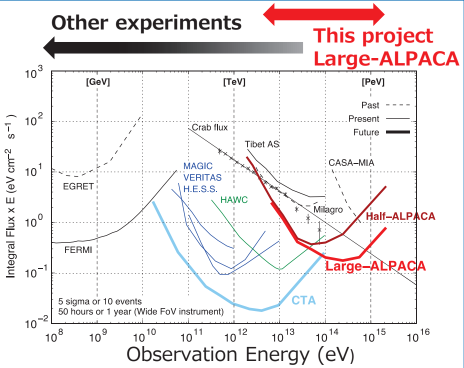

Figure 2. Sensitivity to gamma-ray intensity of cosmic gamma-ray observatories in the world as a function of observation energy.

Expected Research Achievements

●Opening of the highest-energy gamma-ray astronomy

This project opens the highest-energy gamma-ray astronomy in the southern sky. We search for celestial objects emitting the highest-energy gamma rays with the world-best sensitivity in the unexplored southern sky. As is shown in Figure 3, several tens of such celestial objects are expected to be discovered by this project.

●Where do cosmic rays come from?

We aim at identifying the origin of cosmic rays among celestial objects emitting the highest-energy gamma rays. As is shown in Figure 4, for example, the galactic center in the southern sky is one of the most promising candidates for origin of cosmic rays (mostly proton: p), which is difficult to observe in the northern hemisphere. PeV cosmic rays born around the galactic center are expected to collide with the interstellar matter (mostly hydrogens), producing neutral pions (π^0) decaying into the highest-energy gamma rays (γ). We will be the first to detect the highest-energy gamma rays from the vicinity of the galactic center to identify a PeVatron.

Credit : Abdalla et al., A&A 612, A1 (2018)

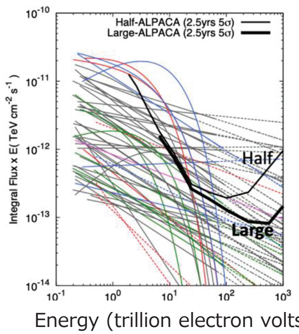

Figure 3. Gamma-ray intensities (colored) in low energy region of celestial objects measured by H.E.S.S. experiment, extrapolated to highest-energy region (dashed). Above sensitivity of this project (thick black: Large), we expect to detect several tens of objects.

Credit : Abramowski et al., Nature 531, 476 (2016)

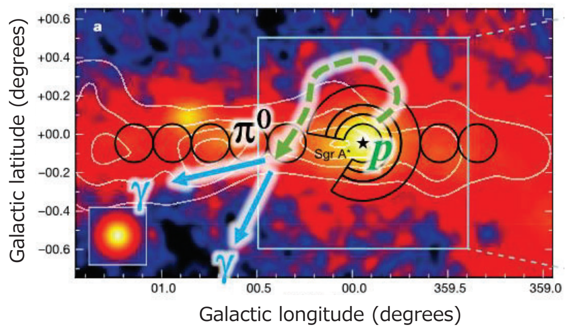

Figure 4. Directional distribution (red) of low energy gamma rays from the galactic center observed by H.E.S.S. experiment.

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