【Grant-in-Aid for Scientific Research (S)】

Broad Section B

Title of Project : Novel Development of Highest Energy Gamma Ray Astronomy

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【Purpose and Background of the Research】

Cosmic rays, high-energy particles composed mainly of protons and nuclei, are flying from space. They are thought to be accelerated up to 10^{15} eV (peta electron volts, 1 PeV) around celestial bodies in the Milky Way. Various candidate bodies such as supernova remnants, pulsars, and black holes are listed as their origin, but their origin is still unknown. PeV is more than 100 times higher than the acceleration limit of 7 TeV of the highest energy accelerator Large Hadron Collider (Europe) built on the ground. The acceleration of cosmic rays should be related to extreme electromagnetic and gravity fields that cannot be realized in ground laboratories.

"What kind of celestial bodies accelerate particles by what mechanism?"

"What is happening in the extreme environment of the universe?"

are the core questions of this research. In this study, a new cosmic ray observation apparatus will be constructed in the Andes highland (4700 m in altitude) in Bolivia, South America, aiming to discover galactic celestial bodies accelerating cosmic rays up to PeV energies by the highest energy (sub-PeV region: 10^{14} eV - 10^{15} eV) gamma-ray observation. Answering the question of "what kind of celestial body" and clarifying its energy spectrum, will lead to elucidation of extreme phenomena that occur in individual celestial bodies.

【Research Methods】

We will build a new cosmic ray air shower observation apparatus near the Chacaltaya Cosmic Ray Observatory in Bolivia to explore the highest energy gamma rays from celestial bodies. The overall picture of the idea of this study is shown in Figure 1. High-energy charged cosmic rays and gamma rays are detected as "air showers," a group of particles that repeatedly generate secondary particles in the Earth's atmosphere, and the ground scintillation detectors determine the energy and arrival direction of incident particles. However, with only the ground scintillation detectors, charged cosmic-ray-induced air showers (noise) overwhelm gamma-ray-induced air showers (signal). Muons are contained in large quantities in charged cosmic ray air showers that repeat hadronic reactions, but rarely in gamma-ray air showers developed by electromagnetic interactions. Hence, underground muon detectors enable us to distinguish between charged cosmic-ray air showers and gamma-ray ones.

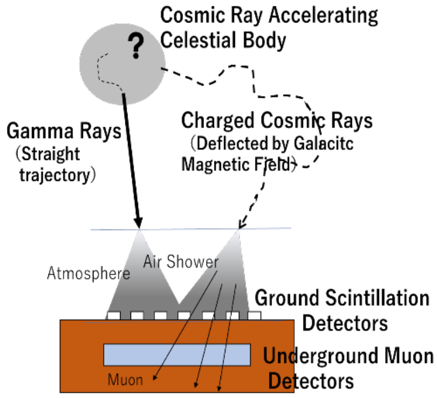

Figure 1 Overall picture of this research. Ground scintillation detectors determine the direction and energy of an air shower, while underground muon detectors discriminate charged cosmic ray noises.

【Expected Research Achievements and Scientific Significance】

This is the first experiment with sufficient sensitivity to discovery of sub-PeV gamma-ray celestial bodies in the southern hemisphere. From the southern hemisphere, important cosmic ray acceleration candidate bodies such as the galactic center and many supernova remnants can be observed, and it is expected to make a dramatic contribution to identifying cosmic-ray acceleration sites, the mystery since the discovery of cosmic rays in 1912.

【Publications Relevant to the Project】

- M. Amenomori, …, M. Takita, …, et al., “First Detection of Photons with Energy beyond 100 TeV from an Astrophysical Source”, Physical Review Letters, 123, 051101-1-6, (2019)
- T.K. Sako, …, M. Takita,…, et al., “Exploration of a 100 TeV gamma-ray northern sky using the Tibet air-shower array combined with an underground water-Cherenkov muon-detector array”, Astroparticle Physics, 32, 177-184, (2008).

【Term of Project】 FY2020-2024

【Budget Allocation】 152,300 Thousand Yen

【Homepage Address and Other Contact Information】

https://www.alpaca-experiment.org/