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

Establishing a new concept in cosmic ray physics from the Earth and Heliosphere to the Milky Way through long-term CALET observations

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Purpose and Background of the Research

●Outline of the Research

The CALorimetric Electron Telescope (CALET) is a cosmic ray and gamma ray instrument, installed on the International Space Station in collaboration with JAXA, NASA and ASI. For over eight years, we have been making full use of our excellent capabilities to obtain observational results which give a clue to solve unresolved problems from the Earth and Heliosphere to the Milky Way. In this research project, we will utilize results obtained from the new high-precision observations to construct a conceptual foundation that will become a new standard in cosmic ray physics. The challenges to be addressed in the observation of Galactic cosmic rays are 1) verification of the shock wave acceleration hypothesis in supernova remnants (SNRs), and elucidation of the acceleration source and propagation process in interstellar space; 2) confirmation of positron sources, and identification of nearby acceleration sources through electron+positron (all-electron) observations; 3) modeling the solar modulation of Galactic cosmic rays in the Heliosphere, and 4) determining the origin of the relativistic electron precipitation (REP) phenomenon.

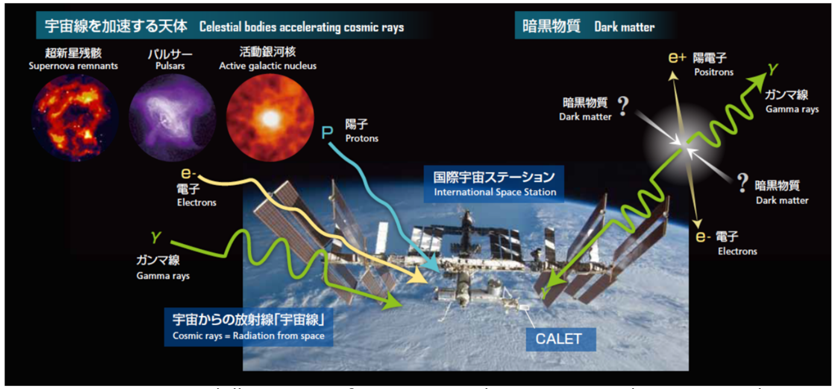

Figure 1. Conceptual illustration of cosmic-ray observations with CALET on the ISS.

●Research Approach

CALET, launched in 2015, is the first imaging calorimeter in space that actually visualize cosmic ray showers. Figure 2 shows the overall conceptual diagram. In addition to the main calorimeter detector, the mission is equipped with a gamma-ray burst monitor (CGBM). High-precision, long-term new observations by CALET are essential for establishing new concepts in cosmic ray physics from the Earth and Heliosphere to the Galaxy. The research is uniquely capable, in the world, to realize this kind observation, and we aim to achieve world-class observational results brought about by CALET's excellent observational performance and highly optimized on-orbit operations, as well as its comprehensive theoretical approach. In this way, this research will develop the fundamental concepts that may become a new standard in cosmic ray physics.

●Observation Method

CALET(calorimeter) consists of a charge detector (CHD), an imaging calorimeter (IMC), and a total absorption calorimeter (TASC). When high-energy cosmic rays or gamma rays are incident, shower particles are generated, and data from each detector can be acquired to obtain information on particle types such as electrons, gamma rays, protons, and atomic nuclei, direction of arrival, and energy as shown in Figure 3.

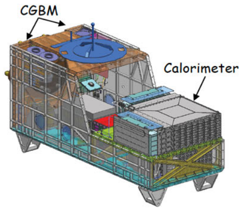

Figure 2. Overview of CALET payload.

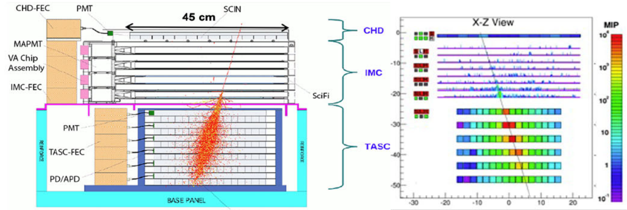

Figure 3. Schematic side view of calorimeter with a simulation example (left) and an actual electron observation event (right).

Expected Research Achievements

Through high-precision, long-term observation of cosmic rays from the Earth and the Heliosphere to the Milky Way, we will elucidate the following unresolved problems that cannot be understood, so far, and construct new concepts in cosmic ray physics.

● Galactic Cosmic Rays

The most likely hypothesis for the acceleration mechanism of galactic cosmic rays is shock wave acceleration in SNRs, but the details remain unclear. In this model, the energy spectrum of each cosmic ray component has a single power-law distribution. However, observations to date have shown that the cosmic ray spectra contains complex structures (see Figure 4) such as hardening and softening which cannot be explained by a single-power law. Further, observations of the all-electron component make it possible to evaluate whether or not the excessive positron events observed by AMS-02 originate from pulsars or WIMPs, which are the most likely candidates for dark matter. Finally, observation of the electron spectral structure in the teraelectron volt (TeV) region is a unique measurement that allows us to study electrons accelerated by nearby sources. Figure 5 shows the results compared to the predictions assuming pulsars as positron sources and the Vela SNR as a nearby source (red shaded area).

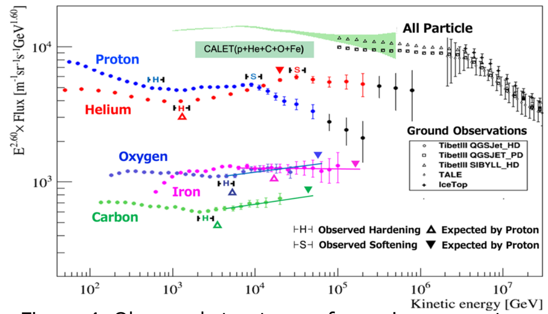

Figure 4. Observed structures of cosmic ray spectrum.

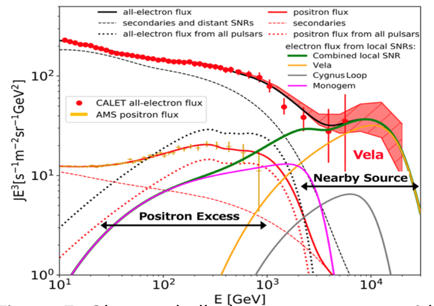

Figure 5. Observed all-electron spectrum with an interpretation assuming pulsars and SNRs.

● Earth and Heliosphere

To date, we have observed the solar modulation of low-energy electrons and protons over about half a solar cycle (~11 years), including the minimum period of solar activity (2019), and investigated the dependence of their charge (positive and negative). In this study, we will establish a drift model and clarify the influence of solar activity on the Earth's magnetosphere by continuing observations during the next half-cycle, when the polarity of the solar magnetic field reverses from positive to negative.

Homepage Address, etc.	https://calet.jp https://humans-in-space.jaxa.jp/biz-lab/experiment/ef/calet/