Form 8

Research Result Report
ICRR Inter-University Research Program 2023

Research Subject:

Energy Spectrum of Ultra High Energy Cosmic Rays

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Summary of Research Result

Though cosmic rays were discovered about 100 years ago, their source and acceleration and propagation mechanisms are still not known clearly. Cosmic rays with energy greater than 1 EeV are most energetic particles ever detected on earth and can not be generated by accelerator experiments. Detection becomes very difficult as the flux of Ultra High Energy Cosmic rays (UHECRs) rapidly decreased as energy increases, therefore we need very broad detection area to detect UHECRs.

Through the Telescope Array (TA) experiments in the northern hemisphere over the past decade, rapid advances in UHECR research have been made. The TA collaboration, which participated in the research team's data analysis of UHECRs collected over the past five years in 2014, observed that 19 of the 72 triggered UHECR events with energy above 5.7×10^{19}eV, are concentrated in specific direction. The arrival direction of these UHECRs observed was especially limited to the size of the edge of the Ursa Major, about 20 degrees. The arrival direction distribution of UHECRs will be correlated with the source of the UHECRs. The probability of such a hot spot being made from an isotropic source is approximately 4×10^{-4} (~3.4 sigma).

To expand the detection area, TAx4 was proposed and collaborators built 260 surface scintillation detectors (SDs) and 2 fluorescence detector stations in early 2019, and that facilities are constantly working in Utah, USA.

Sungkyunkwan University (SKKU) participated in building and deploying SDs and maintenance. From continuous management, TAx4 SDs steadily accumulate data. We monitor the status of newly deployed SDs in cooperation with ICRR researchers. We have continued SD data analysis and hybrid detection for TAx4 as before, and the analysis results from TAx4 are added to TA data, which makes a big progress about anisotropy of UHECRs arrival directions, energy spectrum and mass composition of UHECRs. To summarize,

1. TAx4 SD data analysis: TAx4 SDs data is being accumulated from 2019, and reconstruction to estimate energy and arrival direction is done. Many things are updated including calibration and Monte Carlo simulation. We check the anisotropy of UHECRs from TAx4 data such as the TA hotspot reported in

2014 to see evidences or hints about the source of UHECRs.

2. TAx4 Hybrid detection: Advantages of TA is the hybrid detection of SD and FD. From hybrid detection, shower lateral development can be studied, and this property can show mass composition of UHECRs. We obtain more hybrid events. In 2023, we worked on energy spectrum and mass composition of UHECRs by hybrid detection of TAx4.
3. TA hotspot: TA collaborators reported a cluster of UHECR events, with energy greater than 57 EeV in 2014. Studies to find correlation between this hotspot and source candidates are made by checking statistically the existence of the hotspot.
4. An extremely energetic cosmic ray observed by TA surface detector: TA recently published in Science paper about the detection of an extremely energetic particle recorded by the surface detector array of the Telescope Array experiment. We calculate the particle's energy as 244 ± 29 (stat.) +51−76 (syst.) EeV. Its arrival direction points back to a void in the large-scale structure of the Universe.

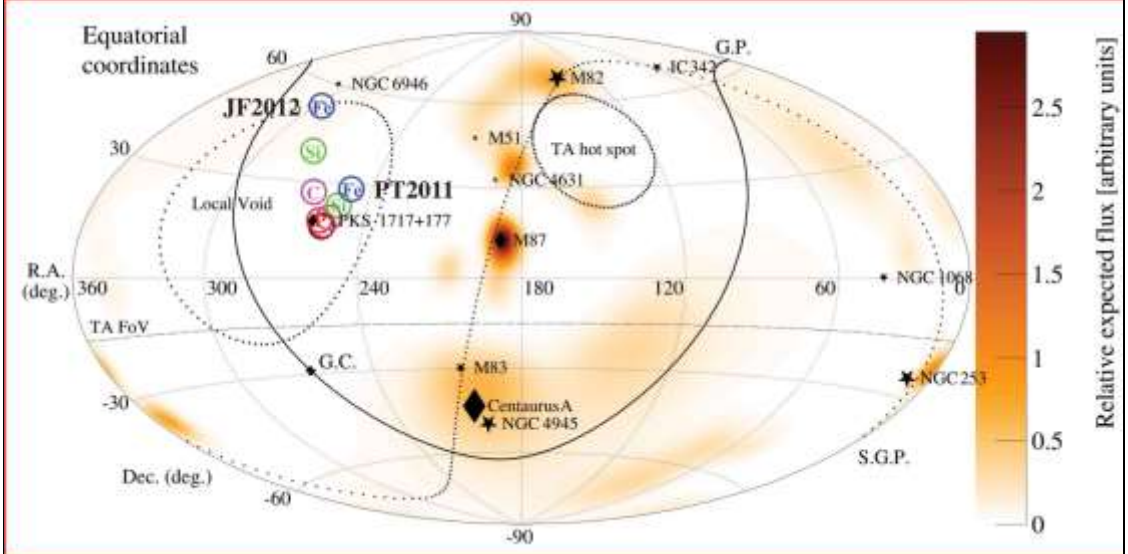

Fig. 1. Arrival direction of the high-energy event compared with potential sources. The arrival direction of the 27 May 2021 high-energy cosmic-ray particle (black circle) on a sky map in equatorial coordinates. Colored circles indicate calculated backtracked directions assuming two models of the Milky Way regular magnetic field, labeled JF2012 and PT2011. Refer to Telescope Array Collaboration, Science 382, 903−907 (2023) 24 November 2023 for details.

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