Form 8

Research Result Report
ICRR Inter-University Research Program 2023

Research Subject: Ultra-high-energy cosmic-ray origin studies with the Telescope Array and TAx4 surface detector

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Summary of Research Result：

One of the key problems in modern astroparticle physics is the origin of the ulta-high-energy cosmic rays. Two large-scale experiments – the Telescope Array and Pierre Auger Observatory have recorded the unprecedentedly large statistics of the extensive air shower events induced by the ultra-high energy cosmic rays. The Telescope Array (TA) Surface Detector (SD) is an array of 507 stations, each containing two layers plastic scintillator with an area of 3 m^2. The results of the 14 years of TA SD observations (2008-2022) are used for the analysis within the project.

We have performed the search for photon-induced events in the data, collected by Telescope Array's Surface Detectors during the last 14 years. For the purpose of the search we have developed and trained a neural network to distinguish between the proton-induced and photon-induced air showers. The network have been trained using Monte-Carlo event set simulated under TA SD conditions. Both reconstructed composition-sensitive parameters and raw signals registered by the Surface Detectors are used as input data for the neural network. The classification threshold have been optimized to provide the strongest possible constraint on the photons' flux. We report the 95% CL photon flux upper limit of 1.3×10^{-3} km^{-2} sr^{-1} yr^{-1} for E>10 EeV.

We have analyzed the UHECR arrival direction data from both the Pierre Auger Observatory and the Telescope Array experiment by a working group with members from both collaborations. Combining the two datasets requires a cross-calibration procedure due to the different systematic

uncertainties on energy measurements but allows us to perform analyses that are less model-dependent than what can be done with partial sky coverage. We report a significant dipole pointing away from the Galactic Center and a $\sim 4.6\sigma$ anisotropy found when comparing the directions of UHECRs with a catalog of starburst galaxies.

We have applied the same anisotropy analyses that have been performed on the Pierre Auger Observatory and the Telescope Array UHECR data to a variety of Monte Carlo simulations generated according to many different combinations of hypotheses about the sources, composition and magnetic deflections of UHECRs. We have found that only some of these models can yield results similar to those obtained with the real data, including models with the starburst galaxies as the source and models with the sources following the mass distribution of galaxies in the large-scale structure of the local Universe.

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