

Research Result Report

ICRR Inter-University Research Program 2023

Research Subject: Bayesian analysis on the origin of ultra-high energy cosmic ray events collected by the telescope array experiment

Principal Investigator:

Dr. Anatoli Fedynitch

Participating Researchers:

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Summary of Research Result:

This research project aims to determine the fraction of Ultra-High Energy Cosmic Rays (UHECRs) originating from nearby sources by analyzing data obtained with the Telescope Array (TA). Building upon the initial work by Dr. Francesca Capel (arXiv:1811.06464), Keito Watanabe, a master's student during FY2023 at the University of Bonn (Germany), now PhD student at KIT, has extended the Bayesian Hierarchical Model to incorporate more realistic factors such as magnetic fields and heavier arrival compositions.

Due to heavy commitments in my growing research group, I could not visit ICRR extensively. However, I used the FY2023 grant to support Keito Watanabe's stay at ICRR during the summer of 2023 after the ICRC in Nagoya. He shared our recent results with the TA group and delivered a seminar.

The Bayesian analysis project is nearing its publication. In regular, weekly meetings over the past year, Keito, Francesca, I, and occasionally Prof. Sagawa have evolved an initially thought to be straightforward project into a full-scale 30-page paper draft. Most complications stem from the Hamiltonian-Markov-Chain-Monte-Carlo sampling scheme, which turned out to be very sensitive to small numerical oscillations and some choices of computational methods. It required Keito to switch from our CRPropa3-based simulations to numerical solutions using the PriNCe code. In addition, we invested about 3-4 months in roundtrip tests on simulation to resolve

the remaining biases in the reconstruction of probability densities. We decided to write a publication on simulated data and focus on the achievable precision once mass measurements in Telescope Array and the Pierre Auger Observatory are available.

However, the current research project has much more significant implications for my collaboration with the ICRR. Prof. Hiroyuki Sagawa has visited my group in Taiwan twice, and we are establishing closer cooperation between the two institutes, such as an updated MoU to exchange people and goods. We have also applied for relevant TA data analysis grants and have successfully obtained financial support – the Taiwanese Grant allows me to dedicate two postdocs full-time. These projects aim to establish a Deep-Neural-Network event reconstruction scheme for the Telescope Array, which is necessary to measure the mass of the highest-energy cosmic rays. Ultimately, both projects, the DNN reconstruction, and this Bayesian Framework, are coming together at the right time since neither method can leverage a breakthrough result independent from the other.

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