GRAINE Project: Status of Analysis for the 2023 Balloon Experiment and Future Prospects

Ikuya Usuda[1], Yudai Isayama[1], Toshiyuki Nakano[1], Yuya Nakamura[1], Hideyuki Minami[1], Saya Yamamoto[1], Shogo Nagahara[1], Shigeki Aoki[2], Atsushi Iyono[3], Yuki Sugi[3], Kazuma Nakazawa[4]
for GRAINE collaboration[1,2,3,4,5,6]
[1]Nagoya University, [2]Kobe University, [3]Okayama University of Science,
[4]Gifu University, [5]Aichi University of Education and [6]ISAS/JAXA
usuda@flab.phys.nagoya-u.ac.jp

Introduction

Gamma-Ray Astro Imager with Nuclear Emulsion (GRAINE) aims to archive precise observation of cosmic gamma rays in the sub-GeV/GeV energy range using balloon-borne emulsion telescope. Nuclear emulsion can record three dimensional tracks of charged particles with high angular resolution. The emulsion telescope allows to reconstruct gamma rays from electron–positron pairs produced via pair creation. It provides superior angular resolution compared to other detectors (1° at 100 MeV, 0.1° at 1 GeV)

We conducted balloon experiments in 2011, 2015, 2018, and 2023. In the 2018 experiment, we achieved the first detection of a cosmic gamma-ray source and imaged the Vela pulsar with the world's highest angular resolution in the sub-GeV range [1]. In April 2023, we constructed 2.5m^2 aperture emulsion telescope, 6.5 times larger than the previous experiment and successfully conducted a 27-hour balloon flight during which the Vela pulsar and the region around the Galactic Center were observed. The target for the 2023 experiment is imaging the Vela pulsar in the GeV range and analysing the Galactic Center region.

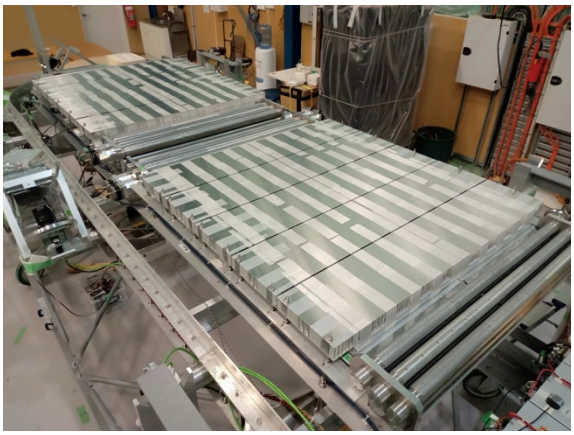

Figure 1 Emulsion telescope of 2.5 m^2 aperture for GRAINE2023. 20 converters mounted on multi-stage shifter.

Analysis of the 2023 flight data

The emulsion telescope consists of three main components: a converter, a time stamper, and an attitude monitor. The converter is a stacked structure of nuclear emulsion films that detects gamma rays and determines their incident angles and energies. The time stamper is a roller-driven multi-stage emulsion film shifter [2], which assigns time stamps to tracks with a resolution better than 0.1 seconds. By combining selected gamma rays with timing and attitude information, events can be mapped onto the celestial sphere.

Analysis of the 2023 flight data is in progress. The converter has detected more than 70 million gamma-ray events in total. Figure 2 shows a background-subtracted gamma-ray count map around the Galactic Center. The observed gamma-ray flux, including contributions from diffuse emission and nearby sources, is consistent with expectations. Gamma rays from the Galactic plane were detected with a significance of 3.2σ. We obtained the first results around the Galactic Center in sub-GeV range.

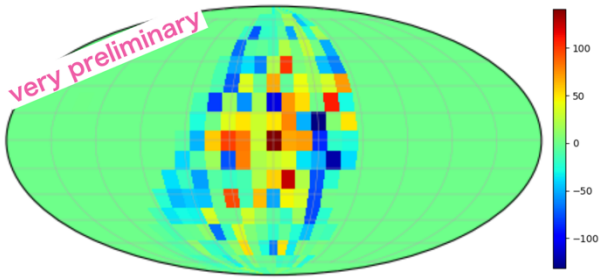

Figure 2 Gamma-ray count map around the Galactic Center (galactic coordinates)

Outlook

We obtained initial result in the 2023 experiment. We will improve the angular resolution of GeV gamma rays through precision measurements. We aim to archive imaging of the Vela pulsar int the GeV range and more detailed analysis of the Galactic Centre region.

References

[1] S. Takahashi, et al., ApJ 960, 47 (2023)
[2] M. Oda et al., Prog. Theor. Exp. Phys. 2022, 113H03 (2022)