Extreme Natural Phenomena RIKEN Hakubi Research Team（2021）

RIKEN Hakubi Team Leader: Teruaki Enoto (Ph.D. Physics)

(0) Research field

CPR Subcommittee: Physics

Keywords: High-energy atmospheric physics, X-ray astronomy,
Lunar exploration for water resources, radiation measurements, citizen science

(1) Long-term goal of laboratory and research background

Extreme high-energy natural phenomena in space and on Earth are frontiers that have not yet been explored. Our team challenges cutting-edge research on natural radiation by applying X-ray astronomy techniques. One of them is the study of radiation produced by lightning and thunderclouds. The team is constructing a multi-point observation network for winter thunderstorms along the Japan Sea coast and developing a new field of high-energy atmospheric physics, including photonuclear reactions in lightning. The philosophy of this project is "Collective Power of Science. The idea is not to use a single giant detector but to organically link many devices to produce scientific outcomes. This phrase expresses our desire to redefine science as a culture in collaboration with society rather than confining it to researchers. We will apply this philosophy to space science with scalable CubeSats. We are working for NinjaSat; a 6U-sized CubeSat X-ray observatory. In addition, as a future project, we will explore lunar water resources and measure the lifetime of neutrons by observing neutrons produced by cosmic rays impacting the lunar surface.

(1) Current research activities (FY2020) and plan (until Mar. 2025)

(A) Pioneering high-energy atmospheric physics of thunderclouds and lightning

A radiation monitor, "Cogamo" (Compact Gamma-ray Monitor), which measures gamma rays emitted from thunderclouds in a fully automatic manner, was distributed to citizen supporters in Kanazawa, and observation at Citizen Science was successfully started. Data from radiation and environmental sensors (temperature, humidity, illuminance, etc.) were automatically transmitted remotely and automatically analyzed on a server, and a system was also established to distribute the data on Twitter when thundercloud gamma rays were detected. By operating this system, the team succeeded in automatically detecting multiple thundercloud gamma rays. In addition, joint research with Kanazawa University, Waseda University, and a broadcasting company was initiated, and an optical camera was also installed for observation. The data measured so far have been published (Wada et al., PRR 2021, Wada et al., GRL 2021), and theoretical model building using particle simulators is also in progress (Diniz et al., JGR Atmosphere, 2021). A trainee (student) from Aoyama Gakuin University wrote her thesis on the analysis of observation data from this Citizen Science, which was selected as the top prize at the Aoyama Gakuin University Physics Department's graduation research presentation. We plan to continue and expand this Citizen Science observation network.

(B) X-ray astronomy via the NICER telescope on the ISS and the NinjaSat project

The world's first detection of X-ray enhancement associated with giant radio pulses generated by the Crab pulsar was achieved in a collaborative observation between the NICER X-ray telescope operating on the International Space Station and radio telescopes in Japan (Enoto et al., Science 2021). The discovery paper of the new magnetar Swift J1555.2-5402 was also reported for the first time in the world (Enoto et al., ApJL 2021). We developed the 6U-sized CubeSat NinjaSat with the Tamagawa High Energy Astrophysics Laboratory at RIKEN. We performed vibration tests and thermal vacuum tests of the science payloads, and the development of the Radiation Belt Monitor (RBM) hardware has been completed, which can detect an increase in the radiation environment and issue an alert. This NinjaSat will be launched in FY2023.

(C) Exploration of lunar water resources using neutrons

The lunar surface is constantly bombarded with cosmic rays, and nuclear reactions on the lunar surface produce neutrons. When these neutrons react with water on the lunar surface, they leak out from the surface as thermal neutrons. The Moon Moisture Targeting Observatory (MoMoTarO), which aims to detect and measure these neutrons, has been developed in collaboration with the RIKEN RANS team, Ritsumeikan University, St. Marianna Medical University, and several institutes. In addition, we have studied the use of the MoMoTarO for gamma-ray burst observations and neutron lifetime measurement using a lunar orbiter. We will continue to study this in the next fiscal year.

(3) Members

(RIKEN Hakubi Team Leader)
Teruaki Enoto
(Research Scientist)
Yo Kato, Hiroshi Nagaoka
(Special Postdoctoral Researcher)
Mariko Kimura, Taiki Kawamuro

(Postdoctral Researcher)
Gabriel Sousa Diniz
(Researcher Part-time Worker II)
Miwa Tsurumi,
Kentaro Taniguchi

(4) Representative research achievements

1. "Enhanced x-ray emission coinciding with giant radio pulses from the Crab Pulsar", T. Enoto, T. Terasawa, S. Kisaka, C.-P. Hu, et al., **Science**, 372, 6538, 187-190 (2021).

2. "A Month of Monitoring the New Magnetar Swift J1555.2-5402 during an X-Ray Outburst", T. Enoto, M. Ng, C.-P. Hu, T. Guver et al., **The Astrophysical Journal Letters**, 920, 1, L4 (2021).

3. "Catalog of gamma-ray glows during four winter seasons in Japan", Y. Wada, T. Matsumoto, T. Enoto, K. Nakazawa, et al., **Physical Review Research**, 3, 4, 043117 (2021).

4. "Generation Possibility of Gamma Ray Glows Induced by Photonuclear Reactions", G. S. Diniz, I. S. Ferreira, Y. Wada, T. Enoto, **Journal of Geophysical Research: Atmospheres**, 126, 3, e34101 (2021).

5. " Meteorological Aspects of Gamma Ray Glows in Winter Thunderstorms", Y. Wada, T. Enoto, M. Kubo, K. Nakazawa, et al., **Geophysical Research Letters**, 48, 7, e91910 (2021).

Supplementary

Group photo of Extreme Natural Phenomena RIKEN Hakubi Research Team

Laboratory Homepage
https://www.riken.jp/research/labs/hakubi/e_extr_nat_phenom/
http://enotolab.com