

Project Title:

Generation of cosmic ray air showers at large statistics

Name: Kenji Shinozaki

Laboratory at RIKEN: EUSO Team

1. JEM-EUSO, Extreme Universe Space Observatory on Japanese Experiment Module, is the International Space Station (ISS)-based space mission for ultra-high cosmic rays (UHECRs) observation. RIKEN's EUSO Team coordinates the international collaboration, ~370 scientists from 16 nations (<http://jemeuso.riken.jp>).

The JEM-EUSO detector is designed to measure air shower phenomenon initiated by UHECRs. The phenomenon is formed by a huge amount of secondary particles that are initiated by the single incident primary UHECR. In the end, air showers consists of trillions of particles, predominately electrons and muons. These particles ionize nitrogen molecules in the atmosphere, resulting in emitting of ultra-violet (UV) photons, called fluorescence photons. The observation principle of UHECRs by JEM-EUSO is based on detection of such photons. In this scheme, it is important not only to increase the detection efficiency of fluorescence photons but also to understand the nature of the existing background UV photons seen from the ISS.

So far, the UHECR observations from space have been never made and various types of uncertainties should be studied by the delegated Monte Carlo simulations. Considerable complexity of air shower phenomenon requires a huge amount of CPU power such as offered by the HOKUSAI system.

In this fiscal year, we investigate the JEM-EUSO detector design option using the Space-X Dragon launcher by Hokusai. To understand the nature of background, we also analyzed the data from the EUSO-Balloon pathfinder mission carried out in 2014.

2. We have used about 15,000 hours of CPU time, mainly for simulations by CORSIKA and CONEX (<https://www.ikp.kit.edu/corsika/79.php>). The study was mainly made for the Dragon option of the JEM-EUSO mission. The detector simulations for JEM-EUSO and its pathfinders were carried out using the GEANT4 (<https://cern.ch/geant4>) together with ESAF code developed by the collaboration (C. Berat et al. 2010, *Astroparticle Physics*, 33, 221).

In collaboration with the JEM-EUSO research groups of University of Tübingen (Germany), Integral Science Data Centre (Switzerland), Institute of Experimental Physics (Slovakia), we also analyze the EUSO-balloon data (The JEM-EUSO Collaboration 2015, *Proceedings of the 34th International Cosmic Ray Conference, The Hague, Pos 322*).

3. We achieved three main results. They were presented in the 34th International Cosmic Ray Conference. In the following, the summary of each article found in the proceedings is given.

- “Evaluation of scientific performance of JEM-EUSO mission with Space-X Dragon option” (Pos 648)

We instigated the possibility of use of Space-X Falcon 9 rocket and the Dragon spacecraft

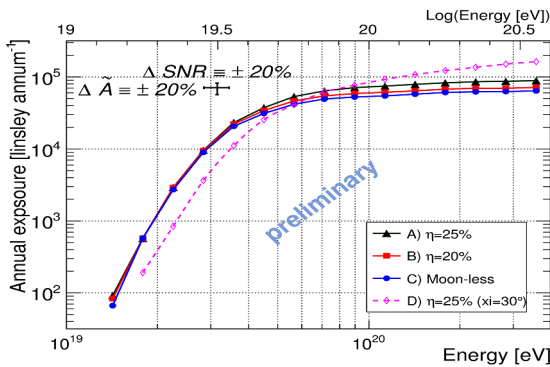
for transport to the ISS Space-X Dragon rocket to realize the full-scale JEM-EUSO mission. We made simulations to find the optimal design of detector and operation scheme based on this scenario. We found the basic performance that we had claimed for the HTV option (J.H. Adams, Jr. et al. 2013, *Astroparticle Physics* 44, 76).

The following figure shows the expected background image for the JEM-EUSO the Space-X Dragon option. This demonstrates the observation area as large as about three times of Sicily and is conserved from that of the



original HTV option.

The next figure shows the expected annual exposure, in practice directly scaling to the UHECR observation efficiency, as a function of energy of UHECR.

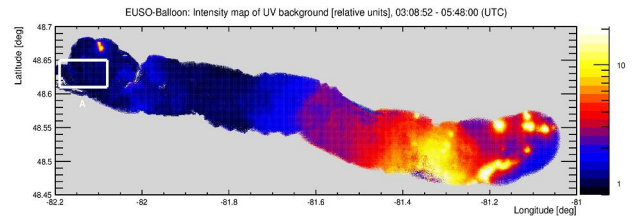


The result was obtained from the large number of air shower simulations made with ESAF package. Several options to improve exposures were investigated as shown in the legend. Such cases allows enhancement of scientific output from the JEM-EUSO mission. Follow-up study is also made with CONEX code.

- Night Time Measurement of the UV Background by EUSO-Balloon (Pos 685)

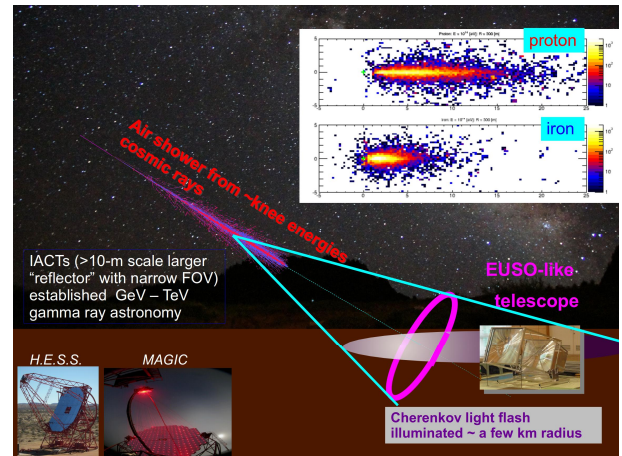
The EUSO-Balloon is a pathfinder mission of the full-scale JEM-EUSO. The first flight was carried out in Timmins, Canada in 2014. The data analysis was made in part using

Hokusai.



The figure shows the analyzed data of UV background along the trajectory of the EUSO-balloon. This marked the first imaging in UV band from stratosphere altitude (~38 km). Hokusai was also used to simulate the detector response. Further analysis is ongoing, aiming at publication in referred journal.

- New concept very high energy cosmic ray observation



using ultra-wide field-of-view telescope (Pos 685)

The conceptual study for new type of cosmic ray observation was made by CORSIKA. The motivation is spin-off use of EUSO-type telescope for lower energy cosmic rays. The result showed the validity of proposed concept, such as discrimination of UHECR types, i.e. proton vs iron.

4. Utilization of Hokusai has been essential for JEM-EUSO and its pathfinder mission that outputs three proceedings papers.

5. For JEM-EUSO and related tasks, we will utilize Hokusai on quick use in the next fiscal year.

Usage Report for Fiscal Year 2015

Fiscal Year 2015 List of Publications Resulting from the Use of the supercomputer
[Publication]

N/A

[Proceedings, etc.]

- K. Shinozaki, A. Santangelo, M. Bertaina, P. Bobík, M.J. Christl, F. Fenu, P. Gorodetzky, A. Guzmán, E. Iwotschkin, G. Medina-Tanco, T. Mernik, A. Neronov, A.V. Olinto, B. Pastirčák, M. Putiš and L. Wiencke for the JEM-EUSO Collaboration

“Evaluation of scientific performance of JEM-EUSO mission with Space-X Dragon option”

Proceedings of the 34th International Cosmic Ray Conference (The Hague), Pos 617.

- Š. Mackovjak, A. Neronov, P. Bobík, L. Del Peral, M.D. Rodríguez Frías, K. Shinozaki, C. Catalano, J.F. Soriano, G. Sáez-Gano, C. Moretto, S. Bacholle for the JEM-EUSO Collaboration

“Night Time Measurement of the UV Background by EUSO-Balloon”

Proceedings of the 34th International Cosmic Ray Conference (The Hague), Pos 685.

- K. Shinozaki, A. Neronov, A. Santangelo and S. Toscano

“New concept very high energy observations by wide field-of-view telescope”

Proceedings of the 34th International Cosmic Ray Conference (The Hague), Pos 617.

[Oral presentation at an international symposium]

N/A

[Others]

N/A