（別紙様式２）

フォトンサイエンス国際卓越大学院プログラム（XPS）
光科学特別実習　報告書

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1. **Research topic**

Energy-Resolved Detection of Precipitating Electrons of 30–100 keV by a Sounding Rocket Associated with Dayside Chorus Waves

2. **Background**

Energetic particles are trapped near the Earth by the magnetic field, a zone called the radiation belt. The energetic particles flux rapidly decreases and increases during the geomagnetic storm period. The dynamics of the radiation belts are not comprehensively understood yet despite its discovery 60 years ago. Predicting the dynamics of the radiation belts is of great scientific and practical interest in order to improve space weather forecasting and reduce the effects of hazardous space weather on spacecraft operations [1]. Generally, it is understood that the radiation belt is controlled by a delicate balance between acceleration, transport, and loss processes [2]. Radiation belt models require accurate knowledge of each mechanism, such as wave-particle interactions in the radiation belts and inner magnetosphere.

Electron precipitations into the Earth's atmosphere is one of the most important loss mechanisms of the radiation belt. Electron precipitations have been observed by various methods to investigate the radiation belt dynamics [3]. Whistler mode chorus waves are believed to play an important role in precipitating electrons on the nightside [4]. Chorus waves are also observed on the dayside and dayside chorus waves have different characteristics from nightside chorus waves [5]. Nightside chorus waves are confined to less than 15° in MLAT, while dayside chorus waves were observed up to 30° in MLAT. And dayside chorus waves are also observed during quiet geomagnetic condition compared with nightside. Despite such differences, dayside chorus waves are also expected to contribute to electron precipitation. However, the link between dayside chorus waves and precipitating electrons has not been identified in detail compared to night side due to the lack of energy resolution of observations. Conventional low altitude satellites do not well resolve the energy range of 10-100 keV, hampering verification on resonance condition with chorus waves.

3. **Our study**

Therefore, we developed an energetic electron detector and conducted a rocket experiment to investigate precipitating electrons with typical resonance energy with chorus waves [6]. Our instrument can measure the electron velocity distribution functions in the energy range of 30–100 keV, typical resonance energy with chorus waves, by using APDs (Avalanche PhotoDiode). APDs provide higher signal-to-noise ratio than conventional solid-state detectors because of its internal gain and have advantage of high quantum efficiency for a few tens of keV electrons. Our instrument was installed on the NASA's sounding rocket, RockSat-XN. It was successfully launched from the Andøya Space Center on the dayside at the L-value of 7 on 13 January 2019. The transient electron precipitation was observed at ~50 keV with the duration of ~50s. The VLF receiver of a ground station at Kola peninsula in Russia near the rocket's footprint observed intermittent emissions of whistler mode waves at the VLF frequency range simultaneously with the rocket observations. The energy of precipitating electrons is consistent with those derived from the quasilinear theory of pitch angle scattering by chorus waves through cyclotron resonance, assuming a typical dayside magnetospheric electron density. Thus, we concluded the dayside chorus waves cause electron precipitation as well as nightside.

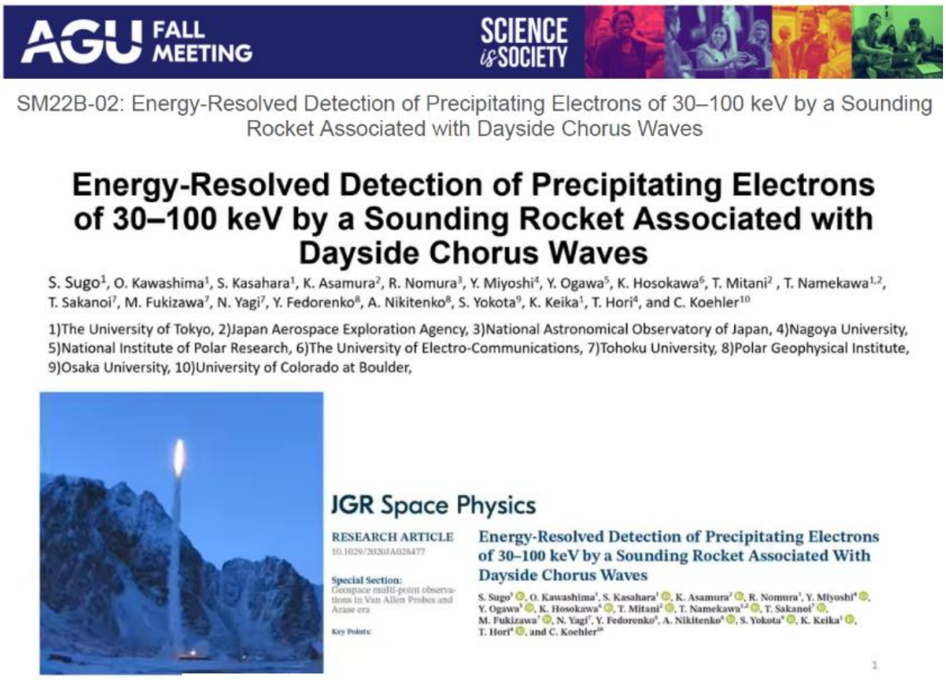

Figure 1. A snapshot of pre-recorded talk

4. Presentation at the AGU fall meeting 2021

I joined the AGU fall meeting 2021 online, presented the result of our rocket experiment in oral and discussed. The AGU fall meeting is one of the largest international conferences on the geophysics and space science, and more than 10,000 attendees in-person were in New Orleans and over 12,000 attendees were online from >100 countries. I was able to learn about the latest research from leading researchers in the field through the meeting.

Before the meeting, I prepared and uploaded a pre-record 15 minutes presentation to AGU website so that discussion points are clear (Figure 1). In the meeting, I attended the session, “Radiation Belt Dynamics: Wave-Particle Interactions and Radiation Belt Modeling” and presented a 5-minute overview talk and discussed talks of the session. Although I could not attend in-person due to COVID-19 pandemic and the presentations from most attendees were short, I had a better understanding of the latest status of radiation belt studies through the discussion.

5. References

[1] Baker, D., Erickson, P., Fennell, J., Foster, J., Jaynes, A., & Verronen, P. (2018). Space weather effects in the Earth's radiation belts. *Space Science Reviews*, **214**(1), 17.
[2] Reeves, G. D., K. L. McAdams, R. H. W. Friedel, and T. P. O'Brien (2003), Acceleration and loss of relativistic electrons during geomagnetic storms, *Geophys. Res. Lett.*, **30**(10), 1529.
[3] Millan, R. M., & Thorne, R. M. (2007). Review of radiation belt relativistic electron losses. *Journal of Atmospheric and Solar-Terrestrial Physics*, *69*(3), 362–377.
[4] Nishimura, Y., Bortnik, J., Li, W., Thorne, R. M., Lyons, L. R., Angelopoulos, V., et al. (2010). Identifying the driver of pulsating aurora. *Science*, *330*(6000), 81–84.
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[6] Sugo, S., Kawashima, O., Kasahara, S., Asamura, K., Nomura, R., Miyoshi, Y., et al. (2021). Energy-resolved detection of precipitating electrons of 30–100 keV by a sounding rocket associated with dayside chorus waves. *Journal of Geophysical Research: Space Physics*, *126*, e2020JA028477.