【Grant-in-Aid for Scientific Research (S)】

Investigation of the rapid loss of planetary radiation belts and the active control method

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Project Information	Project Number : 23H05429 Project Period (FY) : 2023-2027 Keywords: Space plasma, Planetary magnetosphere, Space weather, Aurora

Purpose and Background of the Research

●Outline of the Research

The Earth's outer radiation belt varies dynamically during geomagnetically disturbed periods; once disappears in a few hours and appears again. The physics controlling the rapid loss and reformation processes has not been fully understood yet.
We investigate the rapid loss process of radiation belt electrons by plasma waves by (1) developing a radiation belt model fully incorporating rapid loss, (2) measuring the radiation belt loss process by originally developed instruments onboard a CubeSat, and (3) analyzing spacecraft data measured in terrestrial and Jovian magnetospheres. We focus on the role of the plasma duct, concentrating plasma waves along a specific field line, and on the rapid loss process of radiation belt electrons.

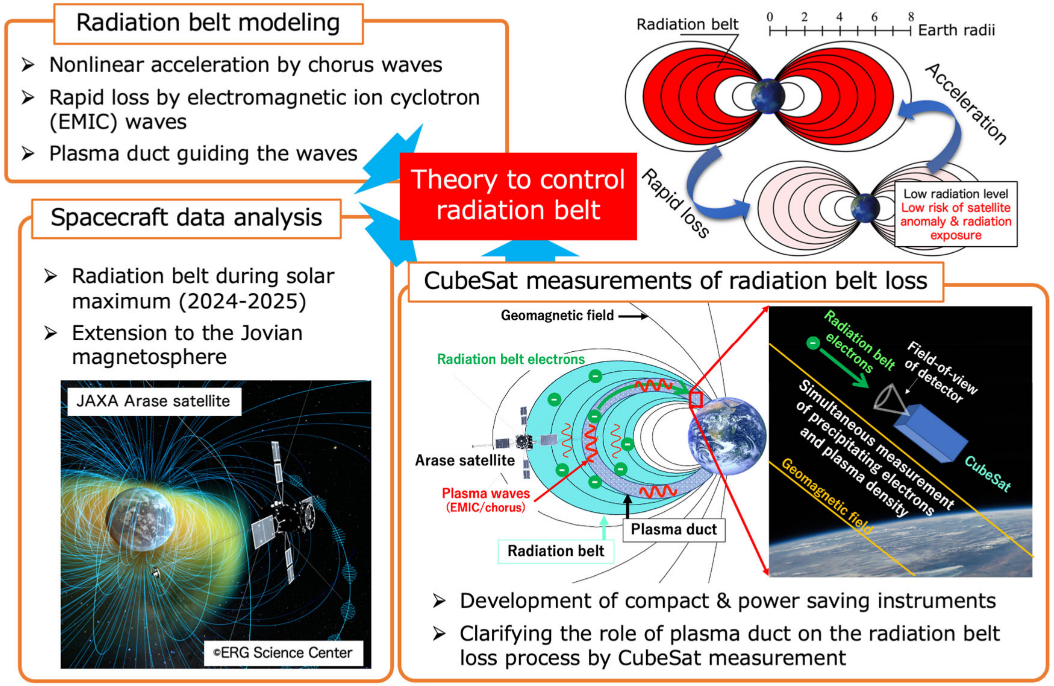

Figure 1. Schematic of probing, controlling, and understanding of radiation belt environments

●Investigation of radiation belt control method

Because radiation belt electrons cause satellite anomalies and radiation exposure in space, the method controlling radiation belt has been investigated for decades. The mutual understanding of the rapid loss process of radiation belt electrons contributes to developing the theoretical basis of the radiation belt control method.

Expected Research Achievements

●Radiation belt modeling

Recent studies clarified that the radiation belt varies more dynamically than conventionally expected due to the rapid loss process by electromagnetic plasma waves. We proposed the numerical Green's function method, which enables us to reproduce the variation of the radiation belt for several hours, considering the rapid loss process occurring in the time scale of less than 1 second. We further develop the proposed method for electromagnetic ion cyclotron waves and the effect of the plasma duct, which concentrates plasma waves along a specific field line where the plasma density is enhanced from those of the surroundings (Figure 2). Our project tries to confirm a hypothesis that the efficient loss of radiation belt electrons occurs along the plasma duct.

●CubeSat measurements of radiation belt loss

To investigate the relationship between the plasma duct and the rapid loss process of radiation belt electrons, we need to observe the relativistic electron precipitation and the plasma density structure simultaneously in the Earth's upper atmosphere. We develop a high-energy electron detector and a plasma density probe.
The electron detector makes use of the avalanche photo-diode we employed in the energetic electron detector onboard the Arase satellite (Figure 3). The developed detector covers a wide energy range from tens to millions of electron volts. By measuring the energy dependence of precipitating electrons into the Earth, we clarify the roles of electromagnetic waves in the radiation belt loss process. We also develop the plasma density probe by miniaturizing the 1-m length plasma probe used in conventional sounding rocket experiments.
We will install the originally developed probes into a CubeSat to measure the loss of radiation belt electrons inside the plasma duct.

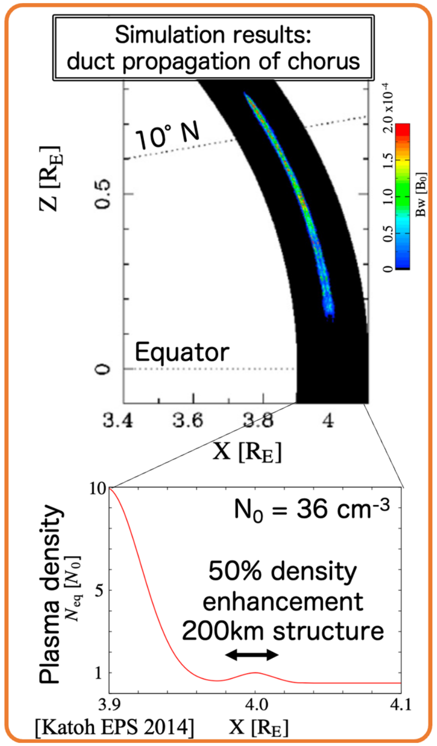

Figure 2. Plasma duct and wave propagation

●Spacecraft data analysis on the radiation belt

We investigate the rapid loss and acceleration processes of the radiation belt electrons by analyzing in situ observation data of spacecraft. Since the period of our project corresponds to the interval of enhanced/maximum solar activity, we can analyze the dynamical behavior of the radiation belt. We also analyze the observation data in Jupiter's magnetosphere, the largest in our solar system. We investigate the rapid ion acceleration process that is possible to occur around Jupiter based on data analysis and simulation studies.
Our project reveals the fundamental physics of the rapid loss of radiation belts, developing the theoretical basis to control the radiation belts.

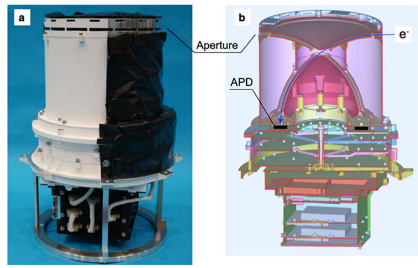

Figure 3. Electron detector onboard the Arase satellite [Kasahara et al., EPS 2018]

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