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# Geospace exploration project: Arase (ERG)

**Y Miyoshi[1], Y Kasaba[2], I Shinohara[3], T Takashima[3], K Asamura[3], H Matsumoto[3], N Higashio[3], T Mitani[3], S Kasahara[3], S Yokota[3], S Wang[4], Y Kazama[4], Y Kasahara[5], S Yagitani[5], A Matsuoka[3], H Kojima[6], Y Katoh[2], K Shiokawa[1], K Seki[7], M Fujimoto[3], T Ono[2] and ERG project group**

[1] Nagoya University, Nagoya, Aichi, Japan
[2] Tohoku University, Sendai, Miyagi, Japan
[3] Japan Aerospace Exploration Agency (JAXA), Japan
[4] Academia Sinica Institute of Astronomy and Astrophysics (ASIAA), Taipei, Taiwan
[5] Kanazawa University, Kanazawa, Ishikawa, Japan
[6] Kyoto University, Kyoto, Japan
[7] University of Tokyo, Tokyo, Japan,

E-mail: miyoshi@isee.nagoya-u.ac.jp

**Abstract**. The ERG (Exploration of energization and Radiation in Geospace) is Japanese geospace exploration project. The project focuses on relativistic electron acceleration mechanism of the outer belt and dynamics of space storms in the context of the cross-energy coupling via wave-particle interactions. The project consists of the satellite observation team, the ground-based network observation team, and integrated-data analysis/simulation team. The satellite was launched on December 20 2016 and has been nicknamed, "Arase". This paper describes overview of the project and future plan for observations.

## 1. The ERG project

The ERG (Exploration of energization and Radiation in Geospace) is Japanese geospace exploration project. The project focuses on relativistic electron acceleration mechanism of the outer belt and dynamics of space storms in the context of the cross-energy coupling via wave-particle interactions. The project consists of the satellite observation team, the ground-based network observation team, and integrated-data analysis/simulation team. Details of the mission concept and information have been described in Miyoshi et al. [2012].

## 2. The Arase (ERG) satellite

The comprehensive observations for plasma/particles, fields and waves near the magnetic equator are important for understanding the cross energy coupling for relativistic electron accelerations and dynamics of space storms. The Arase (ERG) satellite has comprehensive instruments for plasma/particles, and field/waves are installed as shown in figure 1.

The satellite was launched on December 20 2016 and has been nicknamed, "Arase". The Arase satellite is sun-aligned spin stabilized with 7.5rpm. The apogee altitude is about 6 Re and the perigee altitude is higher than ~300 km. The inclination angle will be 31deg. After the commissioning operations for a few months after the launch, the Arase satellite will start normal operations to explore the Geospace.

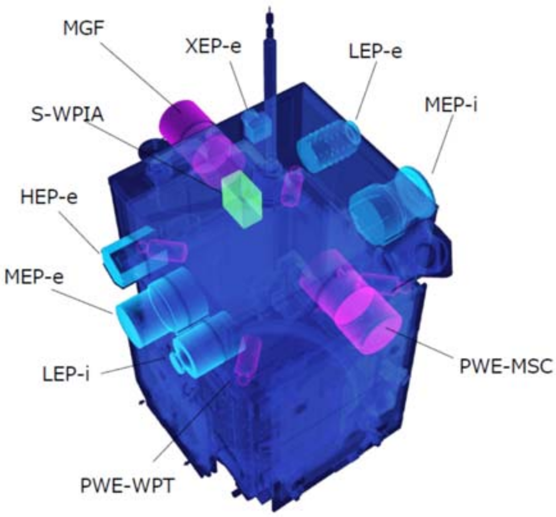


**Figure 1.** Appearance and Science Instruments of the Arase satellite.

*2.1 Plasma/Particle Instruments*

Four electron sensors (LEP-e, MEP-e, HEP-e, and XEP-e) and two ion sensors (LEP-i, and MEP-i). Electron sensors can measure electrons from 10 eV to 20 MeV, while ion sensors can measure ions from 12 eV/q to 180 keV/q with mass discrimination. The energy ranges of each detector are designed to overlap each other, which can provide seamless energy spectrum. About electron observations, both HEP-e and XEP-e instruments mainly observe relativistic electrons of the radiation belts, and these instruments are essential to derive the phase space density profile. On the other hand, LEP and MEP instruments observe hot electrons that are free energy source for plasma waves. Since anisotropies of the distribution function should be a free energy of plasma waves, observations of the distribution function is important to clarify how plasma waves generate inside the radiation belts. Measurements of particles at the energy range of tens keV is very difficult in the radiation belts. Newly developed technologies to remove background contamination can be applied in the instruments, and detail observations of tens keV electrons will be possible.

About ion observations, LEP-i and MEP-i instruments observe several ion species in the inner magnetosphere. Although there are same contamination problems as electron observations, especially, at tens keV energies, the new technology is realize to observe ions up to 180 keV/q in the radiation belts. These ion observation data will be used for study of evolution of ring current ions, and ion observations with mass discrimination are essential to study the composition of ring current particles that come from both solar wind and the ionosphere.

*2.2 Electric Fields and Plasma Wave Observations*

Plasma Wave and Electric Field (PWE) instrument observes electric fields at the frequency range from DC to 10 MHz as wells as the magnetic field at the frequency range from a few Hz to 20 kHz. The electric field is measured by two pairs of wire dipole antennas, and its length is about 30 m tip-to-tip. The high-frequency magnetic field is measured by the two orthogonal search coils.

There are various kinds of plasma waves in the inner magnetosphere. Whistler mode chorus waves [2] and the ion Bernstein mode waves will be important for non-adiabatic acceleration to generate relativistic electrons. Electromagnetic ion cyclotron (EMIC) waves that are generated from ring current ions will work for rapid pitch angle scattering of relativistic electrons. Whistler mode hiss waves inside plasmapause work for the pitch angle scattering of electrons. The PWE instrument can observe the frequency spectrum and wave-form of these plasma waves. The MHD pulsations with ~5 min periods are a driver for adiabatic acceleration by radial diffusion, which can be observed by the PWE instrument as well as the MGF instrument. Thermal plasma density that is important information for wave-particle interactions is determined from cutoff-frequency of the upper-hybrid resonance waves.

### *2.3 Magnetic Field Observations*
Magnetic Field Experiment (MGF) instrument observes the ambient magnetic field as well as the MHD pulsations. The fluxgate sensor with the boom is used for measurements. Observations of ambient magnetic field are a key to know ambient plasma environment around the Arase satellite. The plasma distribution function and pitch angle distribution is obtained using the ambient magnetic field. The local cyclotron frequency is also determined from the MGF measurement. The MGF instrument observes MHD pulsations and EMIC waves as well as the PWE instrument. Since the ring current evolution produces distortions of the ambient magnetic field, and its distortion affects the particle distribution and trajectories in the inner magnetosphere, the accurate measurements of magnetic field deviation from the intrinsic magnetic field is important to evaluate the ring urrent effect. The MGF instrument can measure such deviations of magnetic fields during space storms.

### *2.4 Wave-particle Interaction Analyzers*
In order to measure the wave-particle interactions, that is energy conversion process between plasma/particles and waves, the newly developed S-WPIA system will be installed in the Arase satellite. The vector cross-product of the particle velocity and the electric field velocity should be equal to the time derivative of the kinetic energy of particles; the positive means the acceleration of particles by waves, while the negative means the growth of waves. Therefore, the relative phase between the electric field and the velocity of particles determines the direction of the energy flow. Using the particle data from MEP-e/HEP and the wave form data from the PPE, the S-WPIA system can calculate the relative phase between the waves and the particles for each particle. This will be the first observation to identify directly the wave-particle interaction process in space, and we can observe the cross-energy coupling process via wave-particle interaction [3]. The images for observations of wave-particle interactions is shown in figure 2.

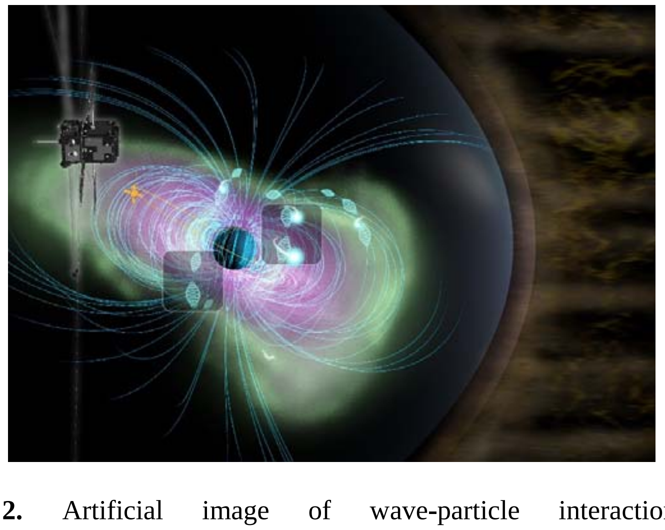

**Figure 2.** Artificial image of wave-particle interactions in the inner magnetosphere by the Arase satellite.

## 3. Ground-based network observations and integrated analysis

Observations from the ground will play a role to complement the Arase satellite observations. SuperDARN worldwide HF radar networks, magnetometer networks, optical image networks, riometer/VLF observation groups join the ERG project. These ground network observations provide global variation of electric field, magnetic field, current system, the plasma/particle distribution. Moreover, the riometer/aurora observations will show when and where the precipitation of energetic particles takes place by the wave-particle interactions. In this way, these ground observations are the remote-sensing tool to observe the global dynamics of the geospace.

In order to understand various kinds of data from satellite and ground observations, the integrated analysis using many data sets is essential to gain science output. Both global simulation and micro-process simulation such as wave-particle interactions are important to understand the physical process through quantitative comparisons with observations.

## 4. Science Data and Space Weather Data

The science data after Level-2 have been archived with NASA/CDF format in the ERG science center (http://ergsc.isee.nagoya-u.ac.jp). The science center will develop the integrated data analysis tool as a plug-in of the IDL/SPEDAS tool.

The Arase satellite provides not only the science data but also the space weather data (http://seesproxy.tksc.jaxa.jp/fw_e/dfw/SEES/English/Top/top_e.shtml). The Arase space weather data includes quasi-real time data for HEP-e, XEP-e and MGF. These data are not calibrated for the scientific purpose, but the data should be useful for monitoring the current space environment as well as inputs to drive the space weather forecast model.

## 5. International collaborations

Currently, a number of satellites have operated in geospace and there are many network observations at the ground. In fact, Van Allen Probes, THEMIS, MMS are operated to investigate inner magnetosphere and geospace. Russia has a plan to launch Resonance. And, several ground-based network observations provide a global-view of geospace from the ground. Simultaneous observations at different radial distance from the Earth and different local times are possible by the international fleet of satellites, which are highly desirable for the ERG project.

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