**S001-01** **会場: A** **時間: 10月16日 11:15-11:30**

# Arase : mission overview and initial results

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Geospace Exploration Project; ERG addresses what mechanisms cause acceleration, transport and loss of MeV electrons of the radiation belts and evolutions of space storms. Cross-energy and cross-regional coupling is a key concept for the project. In order to address the above questions, the project has been organized as three research teams; satellite observations, ground-based observations, and modeling/data-analysis studies, and interdisciplinary research are realized truly comprehensive research is realized for total understanding of geospace. The Arase (ERG) satellite was developed with nine science instruments which were developed and provided by JAXA, universities and d institutes in Japan and Taiwan. The Arase satellite was successfully launched on December 20, 2016. After the initial operation including maneuvers, Arase has started its normal observations since March, 2017. Since then, Arase has observed several geomagnetic storms driven by coronal hole streams and CMEs, and many interesting features are observed in association with the geomagnetic disturbances. The six particle instruments (LEP-e/LEP-i/MEP-e/MEP-i/HEP/XEP) have shown large enhancement as well as loss of electrons and ions of wide energy ranges and variations /changes of pitch angle and energy spectrum. The two field/wave instruments (PWE and MGF) observed several kinds of plasma waves such as chorus, hiss, EMIC as well as large scale electric and magnetic field variations. And newly developed S-WPIA has been operated to identify micro-scale processes of wave-particle interactions. Since conjugate observations between Arase and ground-based observations are essential for comprehensive understanding of geospace, we have conducted several campaign observations involving both the satellite and ground-based observations. The project has collaborated with the other domestic/international projects such as EISCAT, SuperDARN and other ground-based observations, and various data are obtained from such inter-project efforts. Moreover, multi-point satellite observations enaged by the international satellite fleet (Arase, Van Allen Probes, THEMIS, MMS, and more) are realized at present. In this presentation, we report the overview and initial highlights for the first year of the Arase exploration and discuss the importance of the synergy of multi-satellites and ground-based observations that are realized by international collaborations.

# Overview of the plasma wave experiment (PWE) on board the Arase (ERG) Satellite -Data evaluation and initial results-

# Yoshiya Kasahara[1]; Shoya Matsuda[2]; Yasumasa Kasaba[3]; Hirotsugu Kojima[4]; Fuminori Tsuchiya[5]; Atsushi Kumamoto[6]; Mitsunori Ozaki[7]; Satoshi Yagitani[1]; Keigo Ishisaka[8]; Yoshizumi Miyoshi[2]; Mitsuru Hikishima[9]; Masahiro Kitahara[10]; Yuto Katoh[10]; Mamoru Ota[1]; Satoshi Kurita[2]; Masafumi Shoji[2]; Tomohiko Imachi[1]; Mariko Teramoto[11]; Ayako Matsuoka[12]; Iku Shinohara[13]; Keisuke Hosokawa[14]; Yasunobu Ogawa[15]; Kazuo Shiokawa[16]; Akira Kadokura[15]

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The ERG (Exploration of energization and Radiation in Geospace) project is a mission to study acceleration and loss mechanisms of relativistic electrons around the Earth. To achieve comprehensive observations of plasma/particles, fields, and waves, the Arase satellite was launched on December 20, 2016. The Plasma Wave Experiment (PWE) is one of scientific instruments on board Arase. It measures electric field from DC to 10 MHz by the wire-probe antennas (WPT), and magnetic field from a few Hz to 100 kHz by the magnetic search coils (MSC). Three kinds of receivers are implemented in the PWE; EFD (Electric Field Detector), OFA/WFC (Onboard Frequency Analyzer and Waveform Capture), and HFA (High Frequency Analyzer). Several kinds of operational modes are implemented in the PWE, and the telemetry data consists of several kinds of data such as power spectrum, waveform, spectral matrix and DC E-field.

The Arase has started nominal scientific operation in March 2017. Varieties of wave phenomena such as chorus, EMIC, and lightning whistlers have been successfully observed by the PWE. Furthermore, we sometimes identified drastic variation of electron density derived from UHR frequency and corresponding wave activity along the trajectory. We have conducted cooperative observations with the ground-based stations and the other satellites in the magnetosphere. During the campaign observation period, we intensively conducted the PWE burst mode operations, by which waveforms were continuously captured and once stored in the mission data recorder (MDR). The data stored in the MDP were selected and downloaded to the tracking stations according to the decision of the stakeholders of the campaign observation.

In the presentation, we introduce the results of data evaluation as well as initial observation results obtained from the PWE.

Acknowledgements: We are greatly indebted to Mitsubishi Heavy Industries Ltd. for their fabrication and total arrangement of the PWE, to Meisei Electric Co. Ltd. for their fabrication of the HFA, and to NIPPI Co. Ltd. for their fabrication of the WPT, MSC and mast.

# Wire Probe Antenna and Electric Field Detector of Plasma Wave Experiment aboard ARASE: Specifications and Evaluation results

# Yasumasa Kasaba[1]; Keigo Ishisaka[2]; Yoshiya Kasahara[3]; Tomohiko Imachi[3]; Satoshi Yagitani[3]; Hirotsugu Kojima[4]; Shoya Matsuda[5]; Masafumi Shoji[5]; Satoshi Kurita[5]; Tomoaki Hori[5]; Atsuki Shinbori[6]; Mariko Teramoto[7]; Yoshizumi Miyoshi[5]; Tomoko Nakagawa[8]; Naoko Takahashi[9]; Yukitoshi Nishimura[10]; Ayako Matsuoka[11]; Atsushi Kumamoto[12]; Fuminori Tsuchiya[13]; Reiko Nomura[14]
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This paper summarizes the specifications and the evaluation results of Wire Probe Antenna (WPT) and Electric Field Detector (EFD), which are the key parts of Plasma Wave Experiment (PWE) aboard the ARASE (ERG) Satellite, in their initial operations and the beginning phase of the full observations.

WPT consists of the two sets of dipole antennas as electric field sensors with 32m tip-to-tip length, with a sphere probe (6cm diameter) attached at each end of wires (length: 15-m). They are extended orthogonally in the spin plane of the spacecraft which is roughly perpendicular to the Sun. WPT enables the PWE to measure the E-field in the frequency range from DC to 10 MHz. This system is almost compatible to the WPT of the Plasma Wave Investigation (PWI) aboard BepiColombo Mercury Magnetospheric Orbiter, except the material of the spherical probe (ERG: Aluminium alloy, MMO: Titanium-alloy). For the ISAS and JAXA spacecraft, there was a long time gap in the history of the development of wire antenna systems after the Geotail mission launched in 1992 (WPT aboard the Nozomi Mars orbiter was not extended in space.), its physical, mechanical, electrical, and operational establishments were critically important not only for this mission but also for the preparation of BepiColombo. Thanks to the engineers of the NIPPI cooporation and JAXA, its full deployment operation on 14-16 January 2017 was succeeded. This paper shows the length of the deployed antenna independently evaluated by the Lorentz force (spacecraft velocity x B-field), the antenna impedance in low frequency (˜0.1-10Hz, registive) and high frequency (several 10s-100s Hz, capacitive), as the basic information of the E-field measurement capability of the PWE E-field receivers, EWO-E (EFD, WFC-E, OFA-E) and HFA. We also discuss the evaluation results for the possible degradation of the spherical probe surface coated by TiAlN as the BepiColombo WPT.

EFD is the 2-channel low frequency electric receiver as a part of EWO (EFD/WFC/OFA), for the measurement of 2ch electric field in the spin-plane with the sampling rate of 512 Hz (dynamic range: +-200 mV/m, +-3 V/m) and the 4ch spacecraft potential with the sampling rate of 128 Hz (dynamic range: +-100 V), respectively, with the the bias control capability for the WPT probes. The electric field in DC - 232Hz provides the capability to detect (1) the fundamental information of the plasma dynamics and accelerations and (2) the characteristics of MHD and ion waves with their Poynting vectors with the data measured by MGF and PWE/WFC-B connected to PWE/SCM (Search Coil Magnetometer) in stable and active magnetosopheric status. The spacecraft potential provides the basic electron density information with the upper hybrid resonance (UHR) frequency provided by PWE-HFA.

The EFD has two data modes: The normal (Medium-mode) data are provided continuously with OFA-E/B data sets, as (1) 2-ch waveforms with 64 Hz (in Apoapsis mode, in L less than 4) or 256 Hz (in Periapsis mode, in L larger than 4), (2) 1-ch spectrum in 1-232 Hz with 1-sec resolution, and (3) 4-ch spacecraft potential with 8 Hz. The burst (High-mode) data are intermittently obtained, and downloaded with WFC-E/B data sets after the selection, as (4) 2-ch waveforms with 512 Hz and (5) 4-ch spacecraft potential with 128 Hz. This paper will show the status of their calibrations after the subtraction of spacecraft Velocity x B field. We also discuss some potential problems for data analyses caused by the effects of surrounding electron plasma characteristics on the spacecraft potential, wake effect by the spacecraft motions, and possible artificial contaminations. They are common problems in the electric field measurements by the biased-probe method.

# Initial results of HFA onboard the ARASE satellite: Observations of plasmasphere evolution and AKR from the both hemisphere

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High Frequency Analyzer (HFA) is a subcomponent of the Plasma Wave Experiment (PWE) onboard the ARASE (ERG) satellite for observation of radio and plasma waves in a frequency range from 0.01 to 10 MHz. In ERG mission, HFA is expected to perform the following observations: (1) Observation of upper hybrid resonance (UHR) waves in order to determine the electron number density around the spacecraft. (2) Observation of magnetic field component of the chorus waves in a frequency range from 20 kHz to 100 kHz. (3) Observation of radio and plasma waves excited via wave particle interactions and mode conversion processes in storm-time magnetosphere.

HFA is operated in the following three observation modes: EE-mode, EB-mode, and Plasmapause-mode. In far-Earth region, HFA is operated in EE-mode. Spectrogram of two orthogonal or right and left-handed components of electric field in perpendicular directions to the spin axis of the spacecraft are obtained. In the near-Earth region, HFA is operated in EB-mode. Spectrogram of one components of electric field in perpendicular direction to the spin plane, and one component of the magnetic field in parallel direction to the spin axis are obtained. In EE and EB-modes, the frequency range from 0.01 to 10 MHz are covered with 480 frequency steps. The time resolution is 8 sec. We also prepared Plasmapause mode to measure the locations and structures of the plasmapause at higher resolution. In Plasmapause-mode, spectrogram of one electric field component in a frequency range from 0.01-0.4 MHz or 0.1-1 MHz can be obtained at time resolution of 1 sec.

In initial check after the successful deployment of the wire antenna and search coils mast, we could start routine observations and detect various radio and plasma wave phenomena such as upper hybrid resonance (UHR) waves, electrostatic electron cyclotron harmonic (ESCH) waves, auroral kilometric radiation (AKR), kilometric continuum (KC) and Type-III solar radio bursts. In the presentation, we will report the initial results based on the datasets obtained since January 2017 focusing on the analyses of plasmasphere evolution by semi-automatic identification of UHR frequency, and AKR from the both hemisphere based on polarization measurement.

# 斜め伝搬コーラス波とのランダウ共鳴による相対論的電子のサイクロトロン加速

# 大村 善治 [1]; HSIEH YIKAI[2]
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# Cyclotron acceleration of relativistic electrons through Landau resonance with oblique chorus emissions

# Yoshiharu Omura[1]; Yikai Hsieh[2]
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A recent test particle simulation of obliquely propagating whistler mode wav-particle interaction [Hsieh and Omura, 2017] shows that the perpendicular wave electric field can play a significant role in trapping and accelerating relativistic electrons through Landau resonance. A further theoretical and numerical investigation verifies that there occurs nonlinear wave trapping of relativistic electrons by the nonlinear Lorentz force of the perpendicular wave magnetic field. An electron moving with a parallel velocity equal to the parallel phase velocity of an obliquely propagating wave basically see a stationary wave phase. Since the electron position is displaced from its gyrocenter by a distance r$*$sin(phi), where r is the gyroradius and phi is the gyrophase, the wave phase is modulated with the gyromotion, and the stationary wave fields as seen by the electron are expanded as series of Bessel functions J_n with phase variations n$*$phi. The J_1 components of the wave electric and magnetic fields rotate in the right-hand direction with the gyrofrequency, and they can be in resonance with the electron undergoing the gyromotion, resulting in effective electron acceleration and pitch angle scattering.

Reference:

Hsieh, Y.-K, and Y. Omura, Nonlinear dynamics of electrons interacting with oblique whistler-mode chorus in the magnetosphere, J. Geophys. Res. Space Physics,122, 675-694, 2017.

ホイッスラーモード・コーラス波による相対論的電子加速メカニズムは外部磁場に平行に伝搬する波動とのサイクロトロン共鳴が重要であると考えられてきた。しかし、磁気赤道から離れた場所では伝搬角が斜めとなり、ホイッスラーモード・コーラス波動と電子は波の平行電界を介してランダウ共鳴する。相対論的電子においては平行電界ではなく垂直電界によるサイクロトロン加速が大きな寄与をすることを理論的に示す。このランダウ共鳴によるサイクロトロン加速は、あらせ衛星で観測されるコーラス波動と相対論的電子との波動粒子相互作用を理解する上で重要な物理過程である。

# Numerical calculations for flux enhancement of radiation belt electrons observed by ARASE: GEMSIS-RBW simulations

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ARASE satellite, launched in December 2016, has observed several magnetic storms with large flux enhancement of MeV electrons so far. During some magnetic storms, the ARASE detected intense whistler-mode chorus emissions in the heart of the outer radiation belt. The whistler-mode chorus may be responsible for the flux enhancement of relativistic electrons, but there is no direct evidence from observations how whistler-mode chorus waves participate in the rapid flux enhancement.

By using the GEMSIS-RBW simulation, we demonstrate development of flux distributions of radiation belt electrons, such as pitch angle distributions and energy spectra, in order to study roles of whistler-mode chorus waves for the rapid flux enhancement during magnetic storms. The RBW simulation calculates wave-particle interactions between radiation belt electrons bouncing along a field line and whistler-mode chorus waves propagating parallel to the field. Several input parameters for the RBW simulations, such as the background plasma density, magnetic field, and dynamic spectra of whistler waves, are obtained from the ARASE satellite during magnetic storms. The simulations are carried out in a field line at which the ARASE is located during the storm.

By comparing the electron flux in energy larger than a few hundred keV observed by the ARASE with the RBW simulation results demonstrating development of electron distributions for a few hours, we study how the electrons are accelerated to relativistic energy range. We will also discuss roles of nonlinear scattering processes for the flux enhancement during the magnetic storms observed by the ARASE.

# Recent Science Highlights of the Van Allen Probes Mission

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The morning of 30 August 2012 saw an Atlas 5 rocket launch NASA's second Living With a Star spacecraft mission, the twin Radiation Belt Storm Probes, into an elliptic orbit cutting through Earth's radiation belts. Renamed the Van Allen Probes soon after launch, the Probes are designed to determine how the highly variable populations of high-energy charged particles within the radiation belts, dangerous to astronauts and satellites, are created, respond to solar variations, and evolve in space environments. The Van Allen Probes mission extends beyond the practical considerations of the hazard's of Earth's space environment. Twentieth century observations of space and astrophysical systems throughout the solar system and out into the observable universe have shown that the processes that generate intense particle radiation within magnetized environments such as Earth's are universal. During its mission the Van Allen Probes verified and quantified previously suggested energization processes, discovered new energization mechanisms, revealed the critical importance of dynamic plasma injections into the innermost magnetosphere, and used uniquely capable instruments to reveal inner radiation belt features that were all but invisible to previous sensors. This paper gives a brief overview of the mission, presents some recent science highlights, and discusses coordination with other magnetospheric missions and observational assets including the recently launched JAXA Arase mission.

# Observation of relativistic electron loss induced by EMIC waves: Arase and PWING induction magnetometer array collaboration

# Satoshi Kurita[1]; Yoshizumi Miyoshi[1]; Kazuo Shiokawa[2]; Nana Higashio[3]; Takefumi Mitani[4]; Takeshi Takashima[5]; Ayako Matsuoka[6]; Mariko Teramoto[7]; Iku Shinohara[8]
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EMIC waves are generated by temperature anisotropy of energetic ions near the magnetic equator and satellite observations show that the waves tend to be observed on the dusk side and noon side magnetosphere. EMIC waves can propagate from the magnetosphere to the ground and they are observed by ground-based magnetometers as Pc1 pulsation. It has been pointed out that EMIC waves can resonate with relativistic electrons through anomalous cyclotron resonance, and cause strong pitch angle scattering of radiation belt electrons. It has been considered that precipitation loss of relativistic electrons by pitch angle scattering induced by EMIC waves is an important loss mechanism of radiation belt electrons. We report on the observation of relativistic electron loss observed by the Arase satellite on the dawn side magnetosphere during a geomagnetic disturbance, which is likely to be related to an EMIC wave activity. During the event, the EMIC wave activity in conjunction with the relativistic electron loss is identified from observation by the ground-based induction magnetometer array deployed by the PWING project. The magnetometer array observation reveals that EMIC waves are distributed in the wide magnetic local time range from the dusk to midnight sector. It is suggested that drifting relativistic electrons are scattered into the loss cone by the EMIC waves on the dusk to midnight sector before they arrive at the Arase satellite located on the dawn side. We will discuss the impact of loss caused by EMIC wave-induced precipitations on the overall flux variation of radiation belt electrons during the geomagnetic disturbance.

# Instantaneous Frequency Analysis on Nonlinear EMIC Emissions: Arase Observation

# Masafumi Shoji[1]; Yoshizumi Miyoshi[1]; Yoshiharu Omura[2]; Yasumasa Kasaba[3]; Keigo Ishisaka[4]; Shoya Matsuda[1]; Yoshiya Kasahara[5]; Satoshi Yagitani[5]; Ayako Matsuoka[6]; Mariko Teramoto[7]; Takeshi Takashima[8]; Iku Shinohara[9]
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In the inner magnetosphere, electromagnetic ion cyclotron (EMIC) waves cause nonlinear interactions with energetic protons. The waves drastically modify the proton distribution function, resulting in the particle loss in the radiation belt. Arase spacecraft, launched in late 2016, observed a nonlinear EMIC falling tone emission in the high magnetic latitude (MLAT) region of the inner magnetosphere. The wave growth with sub-packet structures of the falling tone emission is found by waveform data from PWE/EFD instrument. The evolution of the instantaneous frequency of the electric field of the EMIC falling tone emission is analyzed by Hilbert-Huang transform (HHT). We find several sub-packets with rising frequency in the falling tone wave. A self-consistent hybrid simulation suggested the complicate frequency evolution of the EMIC sub-packet emissions in the generation region. The intrinsic mode functions of Arase data derived from HHT are compared with the simulation data. The origin of the falling tone emission in the high MLAT region is also discussed.

# Simultaneous observations of pulsating aurora with multi-point high-speed optical measurements and ARASE/ERG satellite

# Keisuke Hosokawa[1]; Yoshizumi Miyoshi[2]; Shin-ichiro Oyama[2]; Yasunobu Ogawa[3]; Satoshi Kurita[2]; Yoshiya Kasahara[4]; Yasumasa Kasaba[5]; Satoshi Yagitani[4]; Shoya Matsuda[2]; Mitsunori Ozaki[6]; Fuminori Tsuchiya[7]; Atsushi Kumamoto[8]; Ryuho Kataoka[3]; Kazuo Shiokawa[9]; Hiroshi Miyaoka[3]; Yoshimasa Tanaka[10]; Satonori Nozawa[11]; Mariko Teramoto[12]; Takeshi Takashima[13]; Iku Shinohara[14]
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Pulsating aurora (PsA) is one of the major types of aurora often seen in the lower latitude part of the auroral region in the morning side. The period of the main optical pulsation ranges from a few to a few tens of seconds, and PsA is almost always observed during the recovery phase of substorm. Recent coordinated satellite-ground observations of PsA indicated that the temporal variation of the main optical pulsation is closely associated with the intensity modulation of whistler mode chorus waves in the morning side magnetosphere because the intensities of the chorus waves and optical pulsation show similar temporal variation [e.g., Nishimura et al., 2010]. However, it is still under debate what process causes the precipitation of PsA electrons and what factor controls the period of optical pulsation.

To further associate the chorus intensity variation in the magnetosphere and optical pulsation in the ionosphere, we need to conduct simultaneous ground/satellite observations of PsA. For this purpose, we have installed 3 identical all-sky cameras (ASI) in the northern Scandinavia to observe PsA in a wide area. The cameras were installed into Tromso in Norway, Sodankyla and Kevo in Finland. By employing highly-sensitive EMCCD cameras (Hamamatsu C9100-23B), we succeeded in capturing PsA with a temporal resolution of 100 Hz. The temporal resolution of the camera is sufficient for resolving the temporal variation of both the main pulsation (a few to a few tens of second) and internal modulation (~3 Hz).

During the first coordinated campaign observations of PsA with the ARASE/ERG satellite in March 2017, we obtained several case examples of simultaneous observations of PsA and chorus by the ASIs and ARASE. In particular, on the night of March 28/29, intense PsA appeared for almost 2 hours when the footprint of ARASE was located within the field-of-view of one of the ASIs in Sodankyla. During this 2-h interval, we identified a good agreement between the overall characteristics of the main pulsation of PsA and the chorus burst. For example, when the ASI observed PsA with a constant pulsating frequency, the satellite detected very periodic bursts of chorus. When the satellite observed irregular occurrence of chorus bursts, the main pulsation seen on the ground was rather sporadic.

Most of the past studies [e.g., Nishimura et al., 2010] investigated the relationship between PsA and chorus in relatively short time period, for instance a few minutes. In contrast, an overall good agreement was obtained for 2 hours during the current interval. This again proves the causal relationship between the activities of chorus and PsA. In the presentation, we focus on the event on March 28/29, 2017 and introduce on-going analysis on the fine-scale correlation between the main modulation of PsA and chorus bursts.

Acknowledgement: The operation of the EMCCD camera at Sodankyla has been supported by Sodankyla Geophysical Observatory (SGO).

# Atmospheric impacts of auroral electrons as observed by Arase satellite and ground-based observations at Syowa station

# Ryuho Kataoka[1]; Herbert Akihito Uchida[2]; Yoshimasa Tanaka[3]; Takanori Nishiyama[1]; Masaki Tsutsumi[1]; Yasunobu Ogawa[1]; Akira Kadokura[1]; Yusuke Ebihara[4]; Yoshizumi Miyoshi[5]; Kazuo Shiokawa[6]; Keisuke Hosokawa[7]; Mitsunori Ozaki[8]; Takeshi Takashima[9]; Iku Shinohara[10]; Ayako Matsuoka[11]; Kazushi Asamura[12]; Shoichiro Yokota[13]; Yoshiya Kasahara[14]; Satoshi Kasahara[15]; Nana Higashio[16]; Takefumi Mitani[12]; Yoichi Kazama[17]; Shiang-Yu Wang[18]; Sunny W. Y. Tam[19]; Kaoru Sato[20]

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We introduce the Arase-Syowa conjunction events occurred on 2017 May 28 0000-0200 UT and 2017 June 30 2200-2400 UT. The May 28 event occurred during the main phase of an intense magnetic storm as driven by a slow coronal mass ejection. Arase satellite passed across pulsating auroras and then entered into north-south aligned discrete arcs. The June 30 event occurred during a recovery phase of an isolated moderate substorm at a quiet solar wind condition. Arase satellite passed across pulsating auroras. The atmospheric response to these different types of auroras are compared and evaluated using ground-based observations at Syowa station.

**S001-12** **会場: A** **時間: 10月16日 15:25-15:45**

# Software-type Wave-Particle Interaction Analyzer on board the ARASE satellite

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Wave-Particle Interaction Analyzer (WPIA) is a new type of instrumentation recently proposed by Fukuhara et al. (2009) for direct and quantitative measurements of wave-particle interactions. WPIA computes an inner product $\mathrm{W}(\mathrm{t}_i) = \mathrm{q}\mathbf{E}(\mathrm{t}_i)$ dot $\mathbf{v}_i$, where $\mathrm{t}_i$ is the detection timing of the i-th particle, $\mathbf{E}(\mathrm{t}_i)$ is the wave electric field vector at $\mathrm{t}_i$, and q and $\mathbf{v}_i$ is the charge and the velocity vector of the i-th particle, respectively. Since $\mathrm{W}(\mathrm{t}_i)$ is the gain or the loss of the kinetic energy of the i-th particle, by accumulating W for detected particles, we obtain the net amount of the energy exchange in the region of interest.

Software-type WPIA (S-WPIA) is installed in the ARASE satellite as a software function running on the mission data processor. S-WPIA on board the ARASE satellite uses electromagnetic field waveform measured by Waveform Capture (WFC) of Plasma Wave Experiment (PWE) and velocity vectors detected by Medium-Energy Particle Experiments - Electron Analyzer (MEP-e), High-Energy Electron Experiments (HEP), and Extremely High-Energy Electron Experiment (XEP). The prime target of S-WPIA is the measurement of the energy exchange between whistler-mode chorus emissions and energetic electrons in the inner magnetosphere. It is essential for S-WPIA to synchronize instruments in the time resolution better than the time scale of wave-particle interactions. Since the typical frequency of chorus emissions is a few kHz in the inner magnetosphere, the time resolution better than 10 micro-sec should be realized so as to measure the relative phase angle between wave and velocity vectors with the accuracy enough to detect the sign of W correctly. In the ARASE satellite, a dedicated system has been developed in order to realize the required time resolution for the inter-instruments communications; for the synchronization of instruments, we use both the time index distributed to all instruments with the time resolution of 15.6 msec and a SWPIA counter, which is a counter accumulating pulses distributed from PWE every 1.9 micro-sec to particle instruments through a direct line. In this presentation, we show the principle of the WPIA and its significance as well as the implementation of S-WPIA on the ARASE satellite.

**S001-13** **会場: A** **時間: 10月16日 16:00-16:15**

# Medium-Energy Particle experiments - electron analyzer (MEP-e) for the ERG satellite mission

# Satoshi Kasahara[1]; Shoichiro Yokota[2]; Takefumi Mitani[3]; Kazushi Asamura[3]; Masafumi Hirahara[4]; Takeshi Takashima[5]
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Medium-Energy Particle experiments - electron analyzer (MEP-e) onboard Exploration of energization and Radiation in Geospace (ERG) spacecraft measures the energy and the direction of each incoming electron in the range of ˜7 to 87 keV. The sensor covers 2-pi radian disk-like field-of-view with 16 detectors, and the solid angle coverage is achieved by using spacecraft spin motion. The electron energy is independently measured by an electrostatic analyzer and avalanche photodiodes, enabling the significant background reduction. We describe the technical approaches, data output, and examples of initial observations.

# Coordinated Arase (ERG) satellite and EISCAT radar observations

# Yasunobu Ogawa[1]; Yoshizumi Miyoshi[2]; Kazuo Shiokawa[3]; Keisuke Hosokawa[4]; Shin-ichiro Oyama[2]; Antti Kero[5]; Satonori Nozawa[6]; Kanako Seki[7]; Yoshimasa Tanaka[8]; Takeshi Sakanoi[9]; Iku Shinohara[10]; Yukinaga Miyashita[11]; Ryoichi Fujii[12]; Hiroshi Miyaoka[1]; Akira Kadokura[1]; Kazushi Asamura[13]; Yuto Katoh[14]; Yoshiya Kasahara[15]; Hirotsugu Kojima[16]; Ayako Matsuoka[17]; Satoshi Kurita[2]; Shoya Matsuda[2]
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We report collaborative study of the Magnetosphere-Ionosphere coupling based on coordinated observations of the Arase (ERG) satellite and EISCAT radars. The coordinated observations have been discussed and summarized as a white paper which includes study targets of (1) characteristics and generation mechanisms of chorus waves and pulsating aurora in the morning sector, (2) oxygen ion outflow from polar ionosphere and energetic particle injection by substorm dipolarization in the nightside sector, and (3) EMIC waves and their relation to proton precipitation in the evening sector.

After Arase satellite started normal observations in March, 2017, eighteen simultaneous observations in the morning and nightside sectors have been carried out with the EISCAT Tromsoe UHF/VHF radars and Arase satellite so far. Eight conjunction events in the simultaneous observations show enhanced ionization in the E/D region ionosphere due to hard energy particle precipitation from the magnetosphere. The EISCAT observations for the collaborative study have been conducted as a combination of Japanese and Finnish special programs (SP), peer-review program (PP), and special programs of all EISCAT associations (AA). These data have been processed to make CDF format files, and integrated with other related dataset.

In this paper, we will introduce overview of the Arase-EISCAT observations based on the white paper, and discuss further international collaboration plans between Arase and EISCAT radar projects.

**S001-15　会場: A　時間: 10月16日 16:30-16:50**

# Coordinated Arase satellite and ground-based observations of pulsating electron and proton auroras

# Mitsunori Ozaki[1]; Kazuo Shiokawa[2]; Yoshizumi Miyoshi[3]; Ryuho Kataoka[4]; Yusuke Ebihara[5]; Shin-ichiro Oyama[3]; Yoshimasa Tanaka[6]; Yuichi Otsuka[2]; Masahito Nose[7]; Tsutomu Nagatsuma[8]; Satoshi Kurita[3]; Martin Connors[9]; Reiko Nomura[10]; Kaori Sakaguchi[11]; Satoshi Yagitani[12]; Yoshiya Kasahara[12]; Hirotsugu Kojima[13]; Yasumasa Kasaba[14]; Atsushi Kumamoto[15]; Fuminori Tsuchiya[16]; Yuto Katoh[17]; Mitsuru Hikishima[18]; Shoya Matsuda[3]; Ayako Matsuoka[19]; Masafumi Shoji[3]; Keisuke Hosokawa[20]; Yasunobu Ogawa[4]; Akira Kadokura[4]; Yuka Sato[4]; Masaki Okada[4]; Takanori Nishiyama[4]
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Hot particle temperature anisotropies can excite chorus and electromagnetic ion cyclotron (EMIC) waves near the magnetic equator. The chorus and EMIC waves are candidate of drivers for generating pulsating electron and proton auroras by pitch angle scattering of high energy particles via wave-particle interactions. Both pulsating electron and proton auroras exhibit various kinds of temporal characteristics related with the wave activities. In fact, many previous reports showed that pulsating electron and proton auroras have the luminous variations related with the bundle of chorus and EMIC waves, and with the intervals of successive discrete elements of chorus and EMIC waves. Recently, high-speed (about 100 Hz) EMCCD images revealed fast luminous modulations of pulsating proton aurora related with the subpacket structures of Pc1 geomagnetic pulsations observed on the ground, which are equivalent to the EMIC waves in the magnetosphere. However, simultaneous observations of fast modulations of pulsating electron aurora and related subpacket structures of discrete chorus element have not been reported yet. Since pulsating auroras are faint, direct detection of fast luminous modulations is not easy, even with the most advanced EMCCD cameras. Going beyond correlating overall packet structures in luminosity and wave variations requires advanced temporal and spatial analysis techniques together with advanced EMCCD camera data.

In this study, we show temporal and spatial characteristics of pulsating electron and proton auroras at sub-auroral and auroral latitudes during coordinated Arase satellite and ground-based observations. For detecting the temporal characteristics, we used S transform, which is a signal processing technique for a time-frequency distribution. The S transform has an advantage that the frequency resolution is dependent with the time resolution. Such frequency dependent resolution is important for identifying the fast modulations of auroral luminosity. We identified electron and proton auroral patches having similar temporal characteristics of chorus and EMIC wave activities similarly in the previous reports. The similar temporal characteristics of the luminous and wave activities strongly supports the basic generation mechanism by pitch angle scattering via wave-particle interactions. Additionally, for detecting the spatial variations of auroral patches in the auroral images, we used Level Set Method (LSM), which is one of techniques to extract dynamic objects. An advantage of LSM is exact extraction of complex time-varying objects such as split and combination problems. The spatial variations between pulsating electron and proton auroras were quite different. The proton auroral patch was quite localized, so this localized patch can indicate a localized wave-particle interaction region in the magnetosphere. On the other hand, the electron auroral patch frequently showed split into a few patches and combination with surrounding patches. Such spatial split and combination of auroral patches may indicate more complex wave-particle interaction region for chorus waves.

In this presentation, we will discuss the difference between pulsation electron and proton auroras in details.

# How O+ Becomes a Significant Fraction of the Storm-Time Ring Current

# Lynn M. Kistler[1]; A. M. Menz[2]; C. G. Mouikis[2]
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During storm times, the pressure that creates the storm-time ring current in the inner magnetosphere can be predominantly O+. This is surprising, as the immediate source for the ring current is the nightside plasma sheet, and O+ is usually not the dominant species in the plasma sheet. In this talk we use Van Allen Probes and Cluster data to examine the processes that lead to this heavy ion dominance. The factors that contribute include the different transport paths of O+ and H+ from the cusp region, which brings more energetic O+ than H+ into the near earth plasma sheet, the source spectrum in the near-earth plasma sheet, which tends to be harder for O+ than for H+, and the time dependence of the O+ in the plasma sheet. The plasma sheet O+ tends to be high towards the beginning of the storm, when the convection is largest, bringing it into the inner magnetosphere. All of these processes play a role, and which is most important is a topic which can be addressed by the multi-spacecraft combination of Van Allen Probes and ARASE.

# O+ ionospheric outflow off the beaten path directly into the Inner Magnetosphere as observed by the Van Allen Probes

# Matina Gkioulidou[1]; Donald Mitchell[1]; Aleksandir Ukhorskiy[1]; Shinichi Ohtani[2]; Kazue Takahashi[3]
[1] JHU/APL; [2] The Johns Hopkins University Applied Physics Laboratory; [3] JHUAPL

The low-energy (eV to hundreds of eV) ion population in the inner magnetosphere, the warm plasma cloak, and in particular its heavy ion component, the O+ torus, is crucial to magnetospheric dynamics. Yet, although the effects of high latitude and cusp ionospheric O+ outflow and its subsequent transport and acceleration within the magnetotail and plasma sheet have been extensively studied, the source of low-energy O+ within the inner magnetosphere (already observed by the DE1 spacecraft in the 80s) remains a compelling open question. The HOPE instrument aboard each of the Van Allen Probes, moving in highly elliptical, equatorial orbits with apogee of 5.8 RE, has repeatedly detected low-energy O+ fieldaligned enhancements. We present a comprehensive study of one such event, where low energy O+ field-aligned intensity enhancements were observed, both at small and large pitch angles, during a geomagnetic storm. The energy spectrogram exhibited a dispersive signature and a banded structure, features that our simple particle tracing simulation demonstrated are due to O+ ions outflowing from both hemispheres of the night-side ionosphere directly into the magnetosphere within L = 4, and subsequently bouncing from one hemisphere to the other. These outflows are associated with field-aligned Poynting flux enhancements and field-aligned electron beams, as observed at the Van Allen Probes location, revealing energy transport from the magnetosphere to ionosphere as well as simultaneous fieldaligned electron heating. We also incorporate ionospheric measurements, such as field-aligned currents, as those are inferred by AMPERE data. The combination of unprecedented simultaneous magnetospheric and ionospheric observations allow us to investigate the processes that lead to an O+ outflow event from the lowlatitude, night-side ionosphere directly into the inner magnetosphere. The ubiquity of such events in the Van Allen Probes data might reveal one of the sources for the O+ torus.

# Multi-Scale Observational Views of Subauroral Magnetosphere-Ionosphere Coupling

# Philip J. Erickson[1]; John C. Foster[1]; Anthea J. Coster[1]; Yoshizumi Miyoshi[2]; Iku Shinohara[3]; Kazuo Shiokawa[4]
[1] Haystack Observatory, MIT; [2] ISEE, Nagoya Univ.; [3] ISAS/JAXA; [4] ISEE, Nagoya Univ.

Processes in the ionosphere, plasmasphere, and inner magnetosphere are inherently coupled due to strong electrodynamic forces and the presence of dynamic changes in the cold plasma environment around Earth. The complexity, time variation, and non-local nature of these coupling processes require coordinated, multi-scale observations to advance knowledge on the dominant energy and momentum pathways that cause intense structuring and mass transfer. Understanding of the inner magnetosphere is particularly important for such fundamental processes as heavy, cold O+ ion outflow into the plasma sheet and ring current, and feedback mechanisms that regulate the amount of energy input to the magnetosphere from the solar wind through cold plasma mass loading of the magnetopause.

The recent launch of the Arase satellite provides an excellent opportunity to conduct conjunctive measurements of the inner magnetosphere and subauroral ionosphere. In particular, the Millstone Hill incoherent scatter radar provides wide field views of the E region, F region and topside ionosphere over more than 3 hours in MLT and 25 degrees in magnetic latitude in the American longitude sector. Combining this diagnostic with inner magnetospheric transits of Arase and NASA's Van Allen Probes satellites provides a powerful way to examine dynamic electric field coupling and mass flows in regions affected by the sub auroral polarization stream (SAPS) and storm enhanced density (SED) plumes. We will present early results from dusk sector conjunction measurements that are planned using Millstone Hill, Arase, and Van Allen Probes in late summer and early fall 2017. The in-situ satellite data and ground-based ionospheric radar measurements are complemented by global GPS based total electron content maps, calculated by MIT Haystack Observatory on a routine cadence from more than 5,000 worldwide receivers. GPS TEC measurements provide mesoscale context and interpretation to the localized, precise conjunctive observations, along with large scale imaging of the plasmapause and enhanced density structuring in the dusk MLT sector.

# あらせ衛星搭載中間エネルギーイオン分析器

# 横田 勝一郎 [1]; 笠原 慧 [2]; 三谷 烈史 [3]; 浅村 和史 [3]; 平原 聖文 [4]; 高島 健 [5]; 山本 和弘 [6]
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# Medium-Energy Particle experiments on ERG: ion mass spectrometer (MEP-i)

# Shoichiro Yokota[1]; Satoshi Kasahara[2]; Takefumi Mitani[3]; Kazushi Asamura[3]; Masafumi Hirahara[4]; Takeshi Takashima[5]; Kazuhiro Yamamoto[6]
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Medium-Energy Particle experiments - ion mass analyzer (MEP-i) was developed for the Energization and Radiation in Geospace (ERG) mission in order to obtain the three dimensional distribution function of inner-magnetospheric ions in the medium-energy range between 10 and 180 keV/q. Energy, mass and charge state of each ion are measured by a electrostatic energy analyzer, time-of-flight mass analyzer and solid state detectors. We will show the instrumentation of MEPi, its data products and its observation results in a magnetic storm.

# あらせ衛星搭載LEPiによる低エネルギーイオン観測

# 浅村 和史 [1]; 三好 由純 [2]; 風間 洋一 [3]; 横田 勝一郎 [4]; 笠原 慧 [5]
[1] 宇宙研; [2] 名大 ISEE; [3] ASIAA; [4] 宇宙研; [5] 東京大学

# Observations of low-energy ions with Arase/LEPi

# Kazushi Asamura[1]; Yoshizumi Miyoshi[2]; Yoichi Kazama[3]; Shoichiro Yokota[4]; Satoshi Kasahara[5]
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LEPi is one of the instruments onboard Arase, which is an energy-mass spectrometer designed to measure ions with energies from ˜0.01keV/q up to 25keV/q. In order to discriminate species of incoming ions, LEPi uses a TOF (Time-Of-Flight) technique. TOF also works as a noise rejector, which is useful for rejection of background noise due to high energy particles in the inner magnetosphere. LEPi has passed the initial checkout phase after launch, and now under regular observations. Since the regular observation started (end of March, 2017), Arase encountered several magnetic storms driven by CIR and CMEs. LEPi observed sudden flux enhancement and subsequent gradual decay of low-energy (˜10eV/q) ions around L=4 associated with the magnetic storms. In some cases, these flux modulations coinside with eclipse (absent of Sun light on the spacecraft), but others do not. Spacecraft potential decreases when the spacecraft gets eclipse. Therefore, a part of ions whose enegies are lower than energy range of LEPi are accelerated and appeared inside the range. These fluxes might reflect transportation / energization of cold component in the inner magnetosphere. We will present current LEPi operations and initial scientific results.

**S001-21** **会場: A** **時間: 10月17日 9:45-10:00**

# Characteristics of molecular ions in the ring current observed by the Arase (ERG) satellite

# Kanako Seki[1]; Kunihiro Keika[2]; Satoshi Kasahara[3]; Shoichiro Yokota[4]; Ayako Matsuoka[5]; Yasunobu Ogawa[6]; Kazushi Asamura[7]; Yoshizumi Miyoshi[8]; Iku Shinohara[9]
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There are two plasma sources for the terrestrial magnetosphere, i.e., the ionosphere and the solar wind. It is observationally known that the terrestrial plasma contribution, especially that of heavy ions increases with increasing geomagnetic activities, while the mechanisms of the enhanced ionospheric supply are far from understood. While the O+ ions are the main species of terrestrial heavy ions, the heavier molecular ions such as NO+ and O2+ have been observed in the various regions of the magnetosphere [e.g., Klecker et al, 1986; Peterson et al., 1994; Christon et al, 1994; Poppe et al., 2016]. Previous studies indicated that molecular ions tend to be observed during geomagnetically active periods. In order to get the molecular ion outflows from the deep ionosphere with altitudes of 250-500 km, they need to be energized at least up to the escape energy of ˜10 eV within a short time scale (˜order of minutes) to overcome the dissociative recombination lifetime at the source altitudes. The observations of the high-energy (˜100keV) molecular ions in the ring current and outer magnetosphere suggest an effective acceleration mechanism is in operation during geomagnetically active periods.

In this paper, we report on observations of molecular ions in the ring current by the Arase satellite and their relations to the solar wind and magnetospheric/ionospheric conditions. The ion composition data of the MEPi instrument onboard the Arase satellite, which detects the ions in the energy range from ˜10 to 180 keV/q was analyzed in details. The molecular ions with energized above several tens of keV are detected during early recovery phases of geomagnetic storms. The appearance of the molecular ions does not have a clear dependence of the substorm activities. It suggests indirect supply from the polar ionosphere to the inner magnetosphere and additional acceleration mechanisms such as the circulation of the molecular ions in the magnetosphere. During quiet periods, the molecular ions stayed less than the detection threshold of the MEPi instrument. In the presentation, preliminary comparison with low energy ions will be also reported.

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Poppe et al., J. Geophys. Re. Lett., vol.43, 6749-6758, doi:10.1002/2016GL069715, 2016.

**S001-22** **会場: A** **時間: 10月17日 10:00-10:15**

# 磁気嵐中の内部磁気圏プラズマ圧に対するエネルギー帯および粒子種ごとの寄与について：あらせ衛星搭載MEP-i粒子検出器の観測

# 桂華 邦裕 [1]; 笠原 慧 [2]; 横田 勝一郎 [3]; 星野 真弘 [1]; 関 華奈子 [4]; 能勢 正仁 [5]; 天野 孝伸 [1]; 三好 由純 [6]; 篠原 育 [7]
[1] 東大・理; [2] 東京大学; [3] 宇宙研; [4] 東大理・地球惑星科学専攻; [5] 京大・理 地磁気センター; [6] 名大 ISEE; [7] 宇宙研／宇宙機構

# Energy and mass dependence of the contribution to storm-time plasma pressure in the inner magnetosphere: Arase/MEP-i observations

# Kunihiro Keika[1]; Satoshi Kasahara[2]; Shoichiro Yokota[3]; Masahiro Hoshino[1]; Kanako Seki[4]; Masahito Nose[5]; Takanobu Amano[1]; Yoshizumi Miyoshi[6]; Iku Shinohara[7]
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The ring current is mainly controlled by the ion pressure and its spatial gradient. The ion pressure is dominated by ions with energies of a few to a few 100s keV. Oxygen ions of ionospheric origin can be energized in the plasma sheet and/or the inner magnetosphere up to a few tens to a few hundreds of keV. The ionospheric oxygen ions make a significant contribution to the ion pressure during geomagnetically active periods. This paper examines spatial variations and energy-spectral evolution of energetic (˜10 to ˜200 keV/q) ions during the main phase of a CIR-driven storm on 17 March 2017 (Storm 1) and a CME-driven storm on 27-28 May 2017 (Storm 2). We use ion data from the MEP-i instrument on board the Arase satellite. The instrument measured energetic ions with energies of 5-120 keV/q during Storm 1 and 9-180 keV/q during Storm 2; ion mass/charge was derived from energy and velocity measurements by an electrostatic analyzer and the time-of-flight system, respectively.

During Storm 1, MEP-i observed sudden flux increases of ˜10 keV/q protons on the dawn side (˜5h MLT) at the beginning of the main phase. After Arase passed through its perigee into an out-bound path around midnight, MEP-i saw high fluxes of greater-than-10 keV/q protons and oxygen ions (and possibly other minor ions) at Lm ˜3.5. MEP-i continued to observe high-flux ions until the end of the main phase. Both proton and oxygen ion pressures increased; the O-to-H ratio increased by about an order of magnitude, from ˜0.02 to 0.2-0.3. The high-flux greater-than-10 keV/q ions consisted of clearly different two populations: one dominated by 5-20 keV/q ions, likely originating from pre-existing cold plasma sheet population; and the other with structured dispersion signatures at 30-90 keV/q, likely due to the penetration of ions accelerated in the near-Earth plasma sheet. We found that both populations contributed to the total pressure almost equally. It is noticeable that energy ranges that made the dominant contribution (called contributing energies) were extremely narrow, dE = 10-20 keV/q (corresponding to one or two MEP-i's energy bins), for both populations.

During Storm 2, Arase completed a full orbit during the main phase. MEP-i observed enhanced ion fluxes at Lm ˜4 at the storm beginning, when Arase was located around midnight. As Arase moved toward post-midnight in an inbound path, MEP continued to observe proton and oxygen high fluxes in a wide energy range (10-120 keV/q). The pressure increased for both protons and oxygen ions; the O-to-H ratio increased from 0.01 to 0.3 during the early main phase (SYM-H greater than -50 nT), and remained at a level of 0.2-1.0 until the storm minimum (SYM-H ˜-140 nT). The pressure was contributed by protons and oxygen ions with energies fully covered by MEP-i. The contributing energies are much wider than during Storm 1 and slightly mass dependent: ˜20-˜100 keV/q for protons and ˜30-˜120 keV/q for oxygen ions. We also found energy dependence of the O-to-H pressure ratio. It increased with increasing energies, and was higher than 1.0 for greater-than-100 keV/q. The wide contributing energies and the mass dependence of pressure ratio implies the penetration of high-temperature plasma sheet and more effective acceleration of oxygen ions compared to protons.

# High energy Electron exPeriment (HEP) onboard the ERG satellite

# Takefumi Mitani[1]; Takeshi Takashima[2]; Satoshi Kasahara[3]; Wataru Miyake[4]; Masafumi Hirahara[5]
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The Exploration of energization and Radiation in Geospace (ERG) satellite was successfully launched on December 20, 2016, and now explores how relativistic electrons in the radiation belts are generated during space storms. ”High energy Electron exPeriment (HEP)” onboard the ERG satellite observes 70 keV - 2 MeV electrons

and provides three-dimensional velocity distribution of electrons every spacecraft spin period. Electrons are observed by two types of camera designs, HEP-L and HEP-H, with regard to geometrical factor and energy range. HEP-L observes 0.1 - 1 MeV electrons and its geometrical factor is $10^{-3}$ cm$^2$ str, and HEP-H observes 0.7 - 2 MeV and G-factor is $10^{-2}$ cm$^2$ str.

HEP-L and HEP-H each consist of three pin-hole type cameras, and each camera consist of mechanical collimator, stacked silicon semi- conductor detectors and readout ASICs. HEP-H has larger opening angle of the collimator and more silicon detectors to observe higher energy electrons than HEP-L.

The initial checkout in orbit was carried out in February 2017 and it was confirmed that there was no performance degradation by comparing the results of the initial checkout in orbit and the prelaunch function tests. Since late March, HEP has carried out normal observation.

In this presentation we introduce the HEP instrument design, prelaunch tests results and report the initial results in orbit.

# Initial results of the extremely high-energy electron experiment (XEP) onboard theArase satellite

# Nana Higashio[1]; Haruhisa Matsumoto[2]
[1] JAXA; [2] JAXA

The extremely high-energy electron experiment (XEP) is one of the instruments onboard the Arase satellite (JAXA). Equipped with five solid-state silicon detectors (SSDs), one GSO single crystal scintillator, and an anti-scintillator, the XEP has one-way conic sight. Its energy range is from 400 keV to 20 MeV electrons. The Arase satellite was launched in December 2016. After the launch, the XEP began to measure relativistic electrons and successfully observed dynamical evolution of relativistic electrons of the outer belt during magnetic storms. During initial 3 months, Arase observed five magnetic storms driven by CIRs and CMEs. Relativistic electrons of the outer belt sharply decreased after the storm commencement, and then recovered to the pre-storm level. During some storms, Arase observed large flux enhancement during the recovery phase. In this presentation, we report overview of the XEP instrument and initial observation results.

# あらせ衛星の準リアルタイムデータを利用した放射線帯変動予測

# 坂口 歌織 [1]; 長妻 努 [2]; 東尾 奈々[3]; 高島 健 [4]; 三谷 烈史 [5]; 松岡 彩子 [6]; 三好 由純 [7]; 篠原 育 [8]; 能勢 正仁 [9]
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# Prediction of the outer radiation belt variation using quasi-realtime data of the Arase satellite

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The Van Allen radiation belts exist in the outer space surrounding the Earth. When the radiation belt electrons increase associated with a geomagnetic storm, a large amount of electrons in the MeV energy range penetrate the shield of the satellite’s body and may cause deep dielectric charge/discharge inside the satellite. In order to know the risk of satellite anomalies in advance, prediction of the radiation flux electron flux is necessary.

In this presentation, we introduce a prediction model of MeV electron flux of the outer radiation belt using quasi realtime data of the Arase satellite. Multivariate autoregressive model and Kalman filter are used to predict variation of electronic flux as a function of L values up to several days ahead. Logarithm daily averages of MeV electron fluxes observed by Arase/XEP instrument are set as prediction targets. The daily average fluxes are classified by L values every 0.2 in the range of 3 to 6. Daily average of realtime Dst index, which is a preceding indicator, is set as an explanatory parameter. Training of the model was carried out with two patterns of observation data by (1) Van Allen Probes/REPT in past two years, (2) Arase/XEP in 20 days of initial observation. Several geomagnetic storms have occurred since the quasi-realtime of Arase becomes available to use . We present the verification result of prediction accuracy by the difference of geomagnetic storm, energy, training data, and lead time.

地球近傍の宇宙空間には、地球の周囲を取り囲む様にヴァンアレン放射線帯が存在する。放射線帯の高エネルギー電子は磁気嵐の発生に伴い大きくフラックスが変動する。放射線帯電子が増加すると、大量の MeV エネルギー帯の電子が人工衛星の機体外壁を貫通し、衛星内部で深部帯電・放電を引き起こすことがある。情報通信研究機構では深部帯電による衛星障害リスク予測のため、放射線帯電子フラックスの予測モデルの開発を進めている。

本発表では、衛星「あらせ」の準リアルタイムデータを用いた放射線帯 MeV 電子フラックスの予測モデルについて紹介する。本モデルでは、電子フラックスの変動を数日先まで予測する手法として、多変量自己回帰モデルとカルマンフィルタを利用した。予測のターゲットは、「あらせ」の XEP 計測器が観測する MeV 電子フラックスの L 値毎の 1 日の標本対数平均とした。L 値は 3 から 6 の範囲において 0.2 毎に分類した。電子フラックスの変動を予測するための説明変数として、先行現象である地磁気嵐の発達を示す Dst 指数速報値の一日平均を用いた。モデルの学習は、Van Allen Probes による過去２年分の観測データと、「あらせ」の初期観測 20 日分のデータの２パターンで行った。「あらせ」の準リアルタイムデータが取得可能になってから、現在まで数回の地磁気嵐が発生している。これらの地磁気嵐に伴う電子フラックスの変動について、地磁気嵐毎にエネルギー・学習データ・リードタイムなどの違いによる予測精度の検証結果と、今後の精度向上に向けた取り組みについて発表する。

**S001-26 会場: A 時間: 10月17日 11:15-11:30**

# ERG衛星の高エネルギー電子観測器に観測される準周期的なフラックス変動について

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# Quasiperiodic modulations of energetic electron fluxes in the ULF range observed by the ERG satellite.

# Mariko Teramoto[1]; Tomoaki Hori[2]; Yoshizumi Miyoshi[2]; Satoshi Kurita[2]; Shinji Saito[3]; Nana Higashio[4]; Takefumi Mitani[5]; Ayako Matsuoka[6]; Inchun Park[7]; Takeshi Takashima[8]; Reiko Nomura[9]; Masahito Nose[10]; Akiko Fujimoto[11]; Manabu Shinohara[12]; Yoshimasa Tanaka[13]; Iku Shinohara[14]
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Exploration of energization and Radiation in Geospace (ERG) satellite was successfully launched on December 20, 2016. The Extremely High-Energy Electron Experiment (XEP) and High-Energy Electron Experiments (HEP-L and HEP-H) are carried by the ERG satellite to observe energetic electrons. These instruments frequently observed quasiperiodic modulations of energetic electron fluxes with period of ˜100-600 sec. Continuous flux modulations with the period of ˜600 s appeared in the 700keV-3.6MeV energy range during the period 0920UT-1120UT on March 31, 2017 when the ERG satellite was located at L˜5.5-6.1 and MLT˜3-4 h. We compare these flux modulations with the magnetic field observed by the Magnetic Field Experiment (MGF) on the ERG satellite. It is found that these flux modulations are not accompanied by corresponding magnetic signatures. It indicates that these quasiperiodic flux modulations are not caused by drift-resonant interactions between ULF waves and energetic electrons, at least locally. In this study, we will show several events and discuss possible mechanism for quasiperiodic flux modulations of energetic electrons on XEP and HEP.

**S001-27** **会場: A** **時間: 10月17日 11:30-11:45**

# Low-energy particle experiments - electron analyzer (LEPe) for the Arase mission

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Academia Sinica Institute of Astronomy and Astrophysics (ASIAA) and Institute of Space and Plasma Sciences (ISAPS) at National Cheng Kung University in Taiwan developed a low-energy electron instrument (LEPe) for the Exploration of Energization and Radiation in Geospace (ERG) mission, in collaboration with Institute of Space and Astronautical Science (ISAS), Japan. The LEPe instrument employs a toroidal tophat-type electrostatic analyzer with multi-channel plates, and measures electrons with energies of ˜20 eV to 19 keV. The analyzer was designed toward relatively large sensitivity for statistically better signals. Against background radiations, the analyzer has 6mm thick aluminum shields and one background anode for reduction and subtraction of radiation signals. The instrument measures three dimensional electron fluxes in approximately 8 seconds of one spin, with angular resolutions of 22.5 degrees. For the purpose of resolving loss cones, specific 45 degrees are divided into 12 channels, 3.75 degrees for each. The ERG spacecraft was successfully launched late in 2016, and science operations phase has started since late March, 2017. The LEPe instrument is functioning well and is measuring low-energy electrons that dominate in the inner magnetosphere and also control wave activities. In this presentation, we will explain the LEPe instrument onboard the ERG spacecraft and will introduce initial results of the measurements.

# Relationship between high-L energetic electrons and the Earth’s high-latitude disturbances

# Chih-Yu Chiang[1]; Tzu-Fang Chang[2]; Sunny W. Y. Tam[1]; Wun-Jheng Syugu[1]; Yoichi Kazama[3]; B.-J. Wang[4]; Shiang-Yu Wang[5]; Satoshi Kasahara[6]; Shoichiro Yokota[7]; Tomoaki Hori[8]; Yoshizumi Miyoshi[8]; Iku Shinohara[9]
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The Exploration of energization and Radiation in Geospace (ERG) satellite has been successfully launched from the Uchinoura Space Center in December 2016. The main goal of the ERG project is to elucidate acceleration and loss mechanisms of relativistic electrons in the radiation belts. In addition, the apogee of the ERG satellite’s orbit often exceeds the edge of outer radiation belt in radial distance. Thus the data measured from the higher-L region may be associated with the activities observed in the Earth’s high-latitude region. We statistically compare the Auroral Electrojet (AE) index with the data measured by the Low-Energy Particle Experiments - Electron Analyzer (LEP-e) and Medium-Energy Particle Experiments - Electron Analyzer (MEP-e) onboard the ERG satellite in the past months. With the selected data for L $>$7, we statistically investigate the contributions of the different electron energies observed in various magnetic local time (MLT) sectors to the Earth’s high-latitude disturbances.

# Comparison of events with prominent fluctuations common to particle and wave observations by the ERG/Arase satellite

# Sunny W. Y. Tam[1]; Chih-Yu Chiang[1]; Tzu-Fang Chang[2]; Wun-Jheng Syugu[1]; Yoichi Kazama[3]; B.-J. Wang[4]; Shiang-Yu Wang[5]; Kazushi Asamura[6]; Nana Higashio[7]; Satoshi Kasahara[8]; Yoshiya Kasahara[9]; Ayako Matsuoka[10]; Takefumi Mitani[6]; Shoichiro Yokota[11]; Yoshizumi Miyoshi[12]; Iku Shinohara[13]
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The Energization and Radiation in Geospace (ERG) satellite, launched in December 2016 and also known as Arase since then, began its regular observations of the inner magnetosphere in March 2017. On board the satellite are various instruments for the measurements of electrons and ions of various energy ranges, and electric and magnetic fields at various frequencies. The electron instruments include the Low-Energy Particle Experiments - Electron Analyzer (LEP-e), which performs measurements of electrons in the energy range between ˜20 eV and 19 keV, and three other experiments, Medium-Energy Particle Experiments - Electron Analyzer (MEP-e), High-Energy Electron Experiments (HEP) and Extremely High-Energy Electron Experiments (XEP), respectively covering the medium, high, and extremely high energy ranges up to 20 MeV. Ion measurements are performed by Low-Energy Particle Experiments - Ion Mass Analyzer (LEP-i) and Medium-Energy Particle Experiments - Ion Mass Analyzer (MEP-i) together for energies between 10 eV and 180 keV per unit charge, while the electric and magnetic fields are observed by Plasma Wave Experiment (PWE) and Magnetic Field Experiment (MGF).

As LEP-e focuses on the lowest energy range among the electron sensors, it is expected to cover the largest electron population in the observations. Hence, significant variations in the LEP-e measurements are indicators of physical processes that affect a majority of electrons. Over several months, LEP-e has observed a number of events in which the measured electron counts exhibit prominent fluctuations at regular time scales. These events are examined also using measurements of the other aforementioned experiments, and it is found that similar prominent fluctuations are also observed by all of those instruments in quite a few events. In this presentation, we focus on such events and discuss the similarities and differences among them.

**S001-30** **会場: A** **時間: 10月17日 12:15-12:30**

# Survey of radiation belt low-energy electron fluxes based on the ERG LEP-e measurements

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The Exploration of energization and Radiation in Geospace (ERG) satellite, which is led by Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA), has observed the Earth's radiation belts for several months. Through years of efforts, Taiwan team successfully delivered the low-energy particle experiments - electron analyzer (LEP-e) for deployment on the ERG satellite. In Taiwan, the project is led by Academia Sinica Institute of Astronomy and Astrophysics (ASIAA) in partnership with National Cheng Kung University (NCKU). The LEP-e instrument measures a 3-D velocity distribution function of low energy electrons ranging from ˜20 eV to 19 keV. We provide an overview of electron fluxes within the radiation belts using the LEP-e instrument data obtained in the past months. The L-shell plots are made upon 100 eV, 1 keV and 10 keV, respectively, to display the electron flux in various L-shells measured by the ERG satellite. The enhancement of the electron fluxes is found to show correspondence with the increase of ring current intensity. These electrons are found to migrate inwards as the ring current increases. We also investigate the 3-D distribution of the electron fluxes and discuss the contribution of the energetic electrons to the ring current.

**S001-31** **会場: A** **時間: 10月17日 12:30-12:45**

# あらせ衛星－地上連携観測で観測された孤立型サブストームの総合解析

# 田中 良昌 [1]; 西山 尚典 [2]; 門倉 昭 [2]; 尾崎 光紀 [3]; 塩川 和夫 [4]; 大山 伸一郎 [5]; 能勢 正仁 [6]; 長妻 努 [7]; 堤 雅基 [2]; 西村 耕司 [2]; 佐藤 薫 [8]; 三好 由純 [5]; 笠原 禎也 [9]; 熊本 篤志 [10]; 土屋 史紀 [11]; 疋島 充 [12]; 松田 昇也 [5]; 松岡 彩子 [13]; 篠原 学 [14]; 藤本 晶子 [15]; 寺本 万里子 [16]; 野村 麗子 [17]; 片岡 龍峰 [2]; 行松 彰 [1]
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# A comprehensive analysis of an isolated substorm observed during the first coordinated Arase and ground-based observations

# Yoshimasa Tanaka[1]; Takanori Nishiyama[2]; Akira Kadokura[2]; Mitsunori Ozaki[3]; Kazuo Shiokawa[4]; Shin-ichiro Oyama[5]; Masahito Nose[6]; Tsutomu Nagatsuma[7]; Masaki Tsutsumi[2]; Koji Nishimura[2]; Kaoru Sato[8]; Yoshizumi Miyoshi[5]; Yoshiya Kasahara[9]; Atsushi Kumamoto[10]; Fuminori Tsuchiya[11]; Mitsuru Hikishima[12]; Shoya Matsuda[5]; Ayako Matsuoka[13]; Manabu Shinohara[14]; Akiko Fujimoto[15]; Mariko Teramoto[16]; Reiko Nomura[17]; Ryuho Kataoka[2]; Akira Sessai Yukimatu[1]
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We present results of a comprehensive analysis of an isolated substorm observed at 4-6 UT on March 21, 2017, during the first campaign of Arase (ERG) satellite and ground-based coordinated observations. This is a rare case study of the coupling between the solar wind, magnetosphere, ionosphere, and mesosphere using the satellite and ground-based observational data during the substorm. The isolated substorm occurred around 4:00 UT associated with a southward Bz excursion during the arrival of a corotating interaction region (CIR) and diffuse/pulsating auroras were observed from 04:30 UT to the sunrise at Husafell (HUS; 65.5-degree MLAT and UT ˜MLT at HUS), Iceland. At the same time, cosmic noise absorption (CNA), which is caused by the energetic electron precipitation (E >several tens of keV), was detected with the riometers at HUS and its geomagnetic conjugate station, Syowa (SYO), Antarctica. In addition, polar mesosphere winter echoes (PMWEs) was simultaneously observed around 75 km altitude with the PANSY radar at SYO. Pc 1 magnetic pulsations were also observed by the world-wide induction magnetometer network before and after the substorm onset. The Arase satellite, which was located at the geomagnetic conjugate to HUS and SYO but near the magnetic equator in the magnetosphere, observed whistler-mode chorus waves at 04:45-06:45 UT in the frequency range of 0.3 - 3 kHz. The measurement was made coinciding with diffuse/pulsating auroras, CNA, and PMWEs.

We suggest a possible scenario for the sequence of the substorm, shown as follows. The substorm occurred during the arrival of the CIR and the energetic ions/electrons were injected into the inner magnetosphere, resulting in generation of the chorus waves on the morning side and the electromagnetic ion cyclotron (EMIC) waves mainly on the evening side, that are associated with Pc 1 pulsations on the ground. The energetic electrons were precipitated to the polar ionosphere in the morning sector by the pitch angle scattering due to the chorus wave - particle interaction then caused the diffuse/pulsating auroras and CNAs in the ionosphere and PMWEs in the mesosphere. In the presentation, we discuss whether this scenario can explain the observed data quantitatively.

# Propagation of Dipolarization Signatures Observed by the Van Allen Probes in the Inner Magnetosphere

# Shinichi Ohtani[1]; Tetsuo Motoba[2]; Kazue Takahashi[3]
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Dipolarization, the change of the local magnetic field from a stretched to a more dipolar configuration, is one of the most fundamental processes of magnetospheric physics. It is especially critical for the dynamics of the inner magnetosphere. The associated electric field accelerates ions and electrons and transports them closer to Earth. Such injected ions intensify the ring current, and electrons constitute the seed population of the radiation belt. Those ions and electrons may also excite various waves that play important roles in the enhancement and loss of the radiation belt electrons. Despite such critical consequences, the general characteristics of dipolarization in the inner magnetosphere still remain to be understood. The Van Allen Probes mission, which consists of two probes that orbit through the equatorial region of the inner magnetosphere, provides an ideal opportunity to examine dipolarization signatures in the core of the ring current. In the present study we investigate the spatial expansion of the dipolarization region by examining the correlation and time delay of dipolarization signatures observed by the two probes. Whereas in general it requires three-point measurements to deduce the propagation of a signal on a certain plane, we statically examined the observed time delays and found that dipolarization signatures tend to propagate radially inward as well as away from midnight. In this paper we address the propagation of dipolarization signatures quantitatively and compare with the propagation velocities reported previously based on observations made farther away from Earth. We also discuss how often and under what conditions the dipolarization region expands.

# The magnetic field investigation on the ARASE (ERG) mission: Data characteristics and initial scientific results

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The ARASE (ERG) satellite was successfully launched on December 20 2016. A fluxgate magnetometer (MGF) was built for the ARASE satellite to measure DC and low-frequency magnetic field.

The requirements to the magnetic field measurements by ARASE was defined as (1) accuracy of the absolute field intensity is within 5 nT (2) angular accuracy of the field direction is within 1 degree (3) measurement frequency range is from DC to 60Hz or wider. MGF measures the vector magnetic field with the original sampling frequency of 256 Hz. The dynamic range is switched between +/-8000nT and +/- 60000nT according to the background field intensity.

The MGF initial checkout was carried on January 10th 2017, when the MGF normal performance and downlinked data were confirmed. The 5-m length MAST for the sensor was deployed on 17th January. The nominal operation of MGF started in March 2017.

The MGF data are calibrated based on the results from the ground experiments and in-orbit data analysis. The MGF CDF files are distributed by the ARASE Science Center and available by Space Physics Environment Data Analysis Software (SPEDAS).

The acceleration process of the charged particles in the inner magnetosphere is considered to be closely related to the deformation and perturbation of the magnetic field. Accurate measurement of the magnetic field is required to understand the acceleration mechanism of the charged particles, which is one of the major scientific objectives of the ARASE mission. We designed a fluxgate magnetometer which is optimized to investigate following topics;

(1) accurate measurement of the background magnetic field - the deformation of the magnetic field and its relationship with the particle acceleration.

(2) MHD waves - measurement of the ULF electromagnetic waves of frequencies about 1mHz (Pc4-5), and investigation of the radiation-belt electrons radially diffused by the resonance with the ULF waves.

(3) EMIC waves - measurement of the electromagnetic ion-cyclotron waves of frequencies about 1Hz, and investigation of the ring-current ions and radiation-belt electrons dissipated by the interaction with the EMIC waves.

These scientific subjects are now investigated by the ARASE working team colleagues.

# Evolution of ionospheric convection and ULFs during the 27 March 2017 storm: ERG-SuperDARN campaign

# Tomoaki Hori[1]; Nozomu Nishitani[1]; Simon G. Shepherd[2]; John M. Ruohoniemi[3]; Martin Connors[4]; Mariko Teramoto[5]; Shin'ya Nakano[6]; Kanako Seki[7]; Naoko Takahashi[8]; Satoshi Kasahara[9]; Shoichiro Yokota[10]; Takefumi Mitani[11]; Takeshi Takashima[12]; Nana Higashio[13]; Ayako Matsuoka[14]; Kazushi Asamura[11]; Yoichi Kazama[15]; Shiang-Yu Wang[16]; Sunny W. Y. Tam[17]; Yoshizumi Miyoshi[1]; Iku Shinohara[18]
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The Exploration of energization and Radiation in Geospace (ERG) satellite, which was nicknamed &quot;Arase&quot; after its launch on late December, 2016, has successfully started the regular observation recently. In concert with in situ measurement made by Arase in the inner magnetosphere, the campaign observation of SuperDARN radars has been conducted with a special scan mode &quot;interleaved_normalscan&quot; since March, 2017. Some of the radars being operated in the special mode observed dynamic evolution of ionospheric convection and superimposed ULF-like convection fluctuations with frequencies of ˜mHz over North America and Canada during a moderate magnetic storm on March 27, 2017. Large-scale evolution provided by the radar observations made at mid-latitudes in the early morning sector show that ionospheric convection changed its direction between westward and eastward several times in the course of the storm main phase. It is also seen that some meso-scale patchy structures seen on the 2-D profile of line-of-sight (LOS) velocity propagated both westward and eastward just after a major intensification of substorm. Interestingly, those velocity fluctuations were accompanied by a drifting energetic electron population as observed by particle instruments onboard Arase. A simulation of the inner magnetosphere coupled with a global MHD simulation for this event reproduces intense particle injections in the premidnight sector, consistent with the energy dispersion of the observed drifting population. A detailed interpretation of the observations including those captured by Arase will be discussed considering the simulation results.

# Study of plasmaspheric refilling using data from the ERG-MFG, the VAPs-EMFISIS, the ground-based magnetometers and the IPE model

# Yuki Obana[1]; Naomi Maruyama[2]; Masahito Nose[3]; Ayako Matsuoka[4]; Mariko Teramoto[5]; Reiko Nomura[6]; Akiko Fujimoto[7]; Yoshimasa Tanaka[8]; Manabu Shinohara[9]; Yoshizumi Miyoshi[10]; Iku Shinohara[11]
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The Earth's inner magnetosphere is a complex dynamical region comprising plasma populations with wide energy ranges, the plasmasphere, the ring currents, and the radiation belts. The plasmasphere is the lowest energy population in the inner magnetosphere, but the accurate prediction of the evolution of the plasmasphere is critical in understanding the dynamics of the inner magnetosphere, because the cross-energy coupling is important concepts for the understanding of the inner magnetosphere. In this study, we study plasmaspheric refilling following geomagnetic storms, using data from ERG-MFG, VAPs-EMFISIS and the ground-based magnetometers. Furthermore, using Ionosphere Plasmasphere Electrodynamics Model (IPE), we calculate the plasmaspheric refilling rates and evaluate the relative contribution of various mechanisms (heating, neutral particle density, composition and wings, etc.) to the refilling rate.

内部磁気圏には、プラズマ圏、環電流、放射線帯と呼ばれる幅広いエネルギー階層に属すプラズマ群が存在しており、互いに結合し、影響し合って複雑な系を形成している。プラズマ圏はその中で最も低エネルギーのプラズマ群であるが、その組成がEMIC波の励起を制御するため、環電流や放射線帯粒子の拡散に影響を及ぼすと言われている。このように、プラズマ圏の形成メカニズムを正確に理解・把握することは、内部磁気圏ダイナミクスを理解する上で欠かせない要素である。

本研究では、磁気嵐に伴うプラズマ圏の再充填過程について、地上・衛星同時多点観測データを解析し、再充填率と再充填中の各段階における電子、軽イオン、重イオンの振る舞いを詳細に調査する。

磁力線共鳴振動の共鳴周波数を観測データから同定し、適当な磁場モデルと磁力線沿いの密度分布モデルを仮定してMHD波動方程式を解くことで、磁気圏赤道面におけるプラズマ質量密度を推定することができる。本研究では磁力線共鳴周波数を地磁気観測データのほか、the Exploration of energization and Radiation in Geospace (ERG/ARASE) 衛星搭載のMagnetic field experiment (MGF) による磁場観測データ、the Van Allen Probes (VAPs) 搭載のElectric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) によるDC磁場観測データから算出する。

またEMFISISによる電場・磁場波動観測データによりプラズマ波動のUpper Hybrid Resonance周波数を同定することで、電子密度を算出することができる。本研究ではこの電子密度と前述の質量密度を比較することで、プラズマ中の平均イオン質量を算出し、再充填中の軽イオンと重イオンの振る舞いを推定する。

さらにこれらの観測結果を、Ionosphere-Plasmasphere Electrodynamics (IPE) modelによる数値計算結果と比較することにより、環電流加熱、中性粒子の密度や組成などの各要因が再充填率へどのように影響しているのかを考察する。

現在、2017年7月の磁気嵐イベントについて解析を進めており、講演ではその初期解析結果について報告する予定である。

**S001-36** **会場: A** **時間: 10月17日 15:00-15:15**

# アイスランド～昭和基地共役点観測の現状

# 門倉 昭 [1]; 田中 良昌 [2]; 片岡 龍峰 [1]; 内田 ヘルベルト陽仁 [3]; 岡田 雅樹 [1]; 小川 泰信 [1]; 佐藤 由佳 [1]; 田口 真 [4]; 尾崎 光紀 [5]; 塩川 和夫 [6]; 細川 敬祐 [7]; 三好 由純 [8]; 元場 哲郎 [9]; 行松 彰 [2]; 山岸 久雄 [10]; 佐藤 夏雄 [1]
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# Current status of Iceland-Syowa conjugate observation

# Akira Kadokura[1]; Yoshimasa Tanaka[2]; Ryuho Kataoka[1]; Herbert Akihito Uchida[3]; Masaki Okada[1]; Yasunobu Ogawa[1]; Yuka Sato[1]; Makoto Taguchi[4]; Mitsunori Ozaki[5]; Kazuo Shiokawa[6]; Keisuke Hosokawa[7]; Yoshizumi Miyoshi[8]; Tetsuo Motoba[9]; Akira Sessai Yukimatu[2]; Hisao Yamagishi[10]; Natsuo Sato[1]
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Current status of the upper atmosphere physics observation between Iceland and Syowa Station, Antarctica (geomagnetic conjugate observation) will be explained. As for the observations in Iceland, re-construction of observations has been carried out since 2015, based on the JSPS funding whose title is &quot;Study on the auroral conjugacy with high temporal resolution observation&quot;. In collaboration with other JSPS funding &quot;Study of dynamical variation of particles and waves in the inner magnetosphere using ground-based network observations&quot; leaded by Prof. Shiokawa, in 2016, a new VLF instrument and the OMTI (Optical Mesosphere Thermosphere Imager ) have been installed at Husafell, and a new high-speed all-sky imager and a proton auroral spectrograph at Tjornes. As for the observations around Syowa Station, re-construction of observations at Syowa Station and West Ongul island, and a new deployment of unmanned observation network have been carried out under the 9th-term Japanese Antarctic Research Expedition (JARE) project since 2016. In 2017, a new high-speed all-sky imager has been installed at Syowa Station, and an unmanned auroral observation system at Amudsen Bay area. With the ground-based conjugate observation network using those new instruments, simultaneous observations with the Arase satellite have been carried out since March, 2017.

アイスランドと南極昭和基地との間の超高層現象の地磁気共役点観測の現状について紹介する。アイスランドについては、科学研究費補助金（基盤研究（A）: 海外学術調査）課題「高時間分解能観測によるオーロラ現象の南北共役性の研究」（代表：門倉、平成 27～31 年度）を中心に、科学研究費補助金（特別推進研究）課題「地上多点ネットワーク観測による内部磁気圏の粒子・波動の変動メカニズムの研究」（代表：塩川、平成 28～32 年度）とも協力して、観測機器の整備を進めていて、平成 28 年度には、フッサフェル観測点に VLF 観測装置と OMTI（超高層大気イメージングシステム）を、チョルネス観測点に高速全天イメージャとプロトンオーロラスペクトログラフを、それぞれ新規設置した。昭和基地については、平成 28 年度からの第⊠期南極観測計画の下、昭和基地と西オングル島観測機器の整備、無人観測ネットワークの展開などを進めていて、平成 28 年度末には、昭和基地に高速全天イメージャを、アムンゼン湾に無人オーロラ観測装置を、それぞれ新規設置した。これらの新しい観測機器も加えた共役点地上観測ネットワークとあらせ衛星との同時キャンベーン観測が 2017 年 3 月より実施されてきているが、その観測経過の紹介も行う。

# 原子大気オーロラ輝線 777.4 nm への分子大気オーロラ輝線の影響評価

# 大山 伸一郎 [1]; 細川 敬祐 [2]; 小川 泰信 [3]; 三好 由純 [1]; 津田 卓雄 [2]; 栗田 怜 [1]; Kero Antti[4]; 藤井 良一 [5]; 野澤 悟徳 [6]; 宮岡 宏 [3]; 田中 良昌 [7]; 水野 亮 [6]; 川端 哲也 [6]
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# Evaluation of the auroral molecular-emission effects on the atomic line at 777.4 nm

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http://www.soyama.org/

Auroral electron precipitation and corresponding ionospheric features have been studied using the emission-intensity ratio among various combinations of the auroral wavelengths. Relatively high energetic electron precipitations (a few to a few tens of keV), which mainly ionize neutral particles at the E-region heights, can be represented by the molecular lines, and auroral electrons with lower energies than about 1 keV can be represented by the atomic lines. For example, one of the representative molecular lines at E-region altitudes is 427.8 nm, which is emitted from the molecular nitrogen ion. This line has the advantage of measuring spatiotemporally ununiformed aurora because of the short life time (about 70 ns) and relatively bright emission intensity reaching up to a few kR. It is known that there are many lines from the molecular nitrogen first positive bands (N2 1P). Another bright line at E-region altitudes is the atomic oxygen line at the wavelength of 557.7 nm. While this line has been widely used for measuring aurorae, we may need careful treatments in the analysis because of relatively long life time (1s) and unknown excitation/emission mechanisms. Some representative emission lines at the F-region heights are 777.4 and 844.6 nm from the atomic oxygen. While the emission intensity of 777.4 nm is moderately high, emissions from the N2 1P (2,0) line and the dissociative excitation of atomic oxygen at the E-region heights contaminate the 777.4-nm line. Such contamination problem is not significant at the 844.6-nm line, but it tends to be darker than the 777.4-nm line. An atomic oxygen line at wavelength of 630.0 nm, which is the brightest line at the F-region heights, is not suitable for measuring spatiotemporally changing aurora because of considerably long life time (about 100s). These emission lines and many other lines have been studied, for example, in evaluation of the precipitating electron energy flux and the ionospheric conductivity.

We began all-sky EMCCD camera observations at several locations in the northern Europe since October 2016 in order to improve our understanding of the precipitating electron energy during the pulsating aurora. One of the stations is the Tromsoe EISCAT radar site in Norway, and multiple all-sky EMCCD cameras were deployed in order to select the best combination of the wavelengths for estimating the precipitating electron energy. In this study, a collocated auroral spectrograph is applied for evaluating effects of the N2 1P (2,0) line and the dissociative excitation of atomic oxygen on the atomic oxygen 777.4 nm line. The simultaneous EISCAT-measured electron density will be compared with the spectrograph results including the emission intensity at wavelength of 844.6 nm. Results from the comparison study can be applied for assessing the validity of the energy flux estimation process from the optical data.

光学的オーロラ測定値を用いた降下電子や電離圏特性の研究では様々な波長輝線を組み合わせた強度比が計算されてきた．E 領域をストッピングハイトに持つ比較的高いエネルギー（数〜数十 keV）を持った降下電子の特性は分子大気発光輝線が代表的であり，比較的低いエネルギー（1 keV 以下）の電子降下を反映する F 領域発光の輝線としては原子大気発光が知られている．例えば分子大気発光としては窒素分子イオンの 427.8nm があり，発光時定数が 70 ナノ秒と非常に短く，数 kR に達することもあり比較的明るいなど，時空間的に変化が激しいオーロラ現象を捕捉する上で有利である．他にも数多くの窒素分子 1P バンドが知られている．E 領域発光を代表する輝線に酸素原子発光の 557.7nm もあるが，発光時定数が約 1 秒あり，また励起発光過程に未解明な部分が残っているなど詳細解析をする際には注意が必要となる．一方，F 領域発光を代表する輝線には酸素原子発光の 777.4nm や 844.6nm がある．777.4nm は比較的明るいものの，輝線近くの窒素分子 1P (2,0) と dissociative excitation による E 領域発光があり，これらが高エネルギー降下電子に応答するため，高低両エネルギー帯の降下電子の影響を受けてしまう．844.6nm にはそのような影響は少ないが，777.4nm より相対的に暗い．F 領域で最も明るい 630.0nm 線は約 100 秒ある発光時定数によって時空間的にスムージングされた測定値となり変動の激しいオーロラ現象解析には向かない．他にも多数の波長が測定・研究されてきたが，E 領域と F 領域で発光する二つの線の強度比を計算することによって，降下電子エネルギーフラックスや電気伝導度の推定が行われてきた．

2016 年 10 月から我々は脈動オーロラを起こす降下電子エネルギーの特性を理解するために EMCCD 全天カメラを北欧多地点に設置し観測を開始した．中でもノルウェーのトロムソにある EISCAT 観測所には光学フィルターを搭載したカメラを複数台設置し，発光強度比から降下電子特性を推定するために効果的な波長の組み合わせを選択する観測実験を実施した．本研究では併設されたオーロラスペクトログラフを利用し，777.4nm 発光強度から窒素分子 1P (2,0) と酸素原子 dissociative excitation の E 領域発光強度を除去する．その結果および一緒に取得される 844.6nm 発光強度について，EISCAT レーダーが同時測定した F 領域電子密度の時間変動と比較し，低エネルギー電子降下を代表するのにより

適切な波長を選択する．さらに分子輝線強度との比を計算し，EISCAT 電子密度から計算した降下電子エネルギーフラックスとの比較を行うことで，強度比の応用の妥当性を評価する．

# PWINGプロジェクトによるサブオーロラ帯における内部磁気圏プラズマ・波動計測の現状

# 塩川 和夫 [1]; 堀 智昭 [2]; 片岡 龍峰 [3]; 栗田 怜 [2]; 三好 由純 [2]; 長妻 努 [4]; 西谷 望 [2]; 能勢 正仁 [5]; 尾花 由紀 [6]; 大塚 雄一 [1]; 大山 伸一郎 [2]; 尾崎 光紀 [7]; 坂野井 健 [8]; 関 華奈子 [9]; 新堀 淳樹 [10]; 篠原 育 [11]; 鈴木 臣 [12]; 高木 佑基 [10]; 高橋 直子 [13]; 竹下 祐平 [10]; 田中 良昌 [14]; 土屋 史紀 [15]
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# Current status of the ground-based network observation of the inner magnetosphere by the PWING project at subauroral latitudes

# Kazuo Shiokawa[1]; Tomoaki Hori[2]; Ryuho Kataoka[3]; Satoshi Kurita[2]; Yoshizumi Miyoshi[2]; Tsutomu Nagatsuma[4]; Nozomu Nishitani[2]; Masahito Nose[5]; Yuki Obana[6]; Yuichi Otsuka[1]; Shin-ichiro Oyama[2]; Mitsunori Ozaki[7]; Takeshi Sakanoi[8]; Kanako Seki[9]; Atsuki Shinbori[10]; Iku Shinohara[11]; Shin Suzuki[12]; Yuki Takagi[10]; Naoko Takahashi[13]; Yuhei Takeshita[10]; Yoshimasa Tanaka[14]; Fuminori Tsuchiya[15]
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http://www.isee.nagoya-u.ac.jp/dimr/PWING/

The plasmas in the inner magnetosphere have wide energy ranges from electron volts to Mega-electron volts. These plasmas (electrons and ions) rotate around the earth longitudinally due to gradient and curvature of geomagnetic field and interact with ULF/ELF/VLF waves at frequencies of mHz to kHz to cause their energization in the equatorial plane of the magnetosphere and loss into the ionosphere. The PWING Project (study of dynamical variation of Particles and Waves in the INner magnetosphere using Ground-based network observations, http://www.isee.nagoya-u.ac.jp/dimr/PWING/) started in April 2016, supported by a Grant-in-Aid for Specially Promoted Research of the Japan Society for the Promotion of Science (JSPS), in order to provide global distribution and quantitative evaluation of the dynamical variation of plasmas and waves in the inner magnetosphere. We have been operating all-sky cooled-CCD imagers, 64-Hz sampling induction magnetometers, 40-kHz sampling ELF/VLF receivers, and 64-Hz sampling riometers at 8 stations at subauroral latitudes (˜60 MLAT) around the geomagnetic north pole, as well as two 100-Hz sampling EMCCD cameras at two stations. The stations are distributed in Canada, Iceland, Finland, Russia, and Alaska. We combine these longitudinal network observations with the ERG (Arase) satellite, which was launched on December 20, 2016, and our global modeling studies. Using these comprehensive dataset, we investigate dynamical variation of particles and waves in the inner magnetosphere, which is one of the most important research topics in recent space physics. The first campaign observation of PWING project with the newly-launched ERG satellite was conducted in March 21-April 2017. In this presentation, we show current status of these instruments of the PWING project and preliminary results obtained from the first ERG-ground campaign.

# あらせ衛星搭載のプラズマ波動観測器によって計測された波形データの精密較正

# 北原 理弘 [1]; 加藤 雄人 [1]; 疋島 充 [2]; 笠原 禎也 [3]; 松田 昇也 [4]; 小嶋 浩嗣 [5]; 尾崎 光紀 [6]; 八木谷 聡 [3]
[1] 東北大・理・地球物理; [2] 宇宙研; [3] 金沢大; [4] 名大 ISEE; [5] 京大・生存圏; [6] 金沢大・理工・電情

# Accurate calibration of waveform data measured by the Plasma Wave Experiment on board the ARASE satellite

# Masahiro Kitahara[1]; Yuto Katoh[1]; Mitsuru Hikishima[2]; Yoshiya Kasahara[3]; Shoya Matsuda[4]; Hirotsugu Kojima[5]; Mitsunori Ozaki[6]; Satoshi Yagitani[3]
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The Plasma Wave Experiment (PWE) is installed on board the ARASE satellite to measure the electric field in the frequency range from DC to 10 MHz, and the magnetic field in the frequency range from a few Hz to 100 kHz using two dipole wire-probe antennas (WPT) and three magnetic search coils (MSC), respectively. In particular, the Waveform Capture (WFC), one of the receivers of the PWE, can detect electromagnetic field waveform in the frequency range from a few Hz to 20 kHz. Whistler mode chorus emissions, electrostatic electron cyclotron harmonic waves, and other plasma waves related to acceleration and scattering of energetic electrons are expected to be detected in the frequency range covered by WFC. A new type of instruments named Software-type Wave Particle Interaction Analyzer (S-WPIA) is installed on the ARASE satellite to measure the energy exchange between plasma waves and particles directly and quantitatively. Since S-WPIA uses the waveform data measured by WFC to calculate the relative phase angle between the wave magnetic field vector and velocity vectors of energetic electrons, the high-accuracy is required to calibration of both amplitude and phase of the waveform data.

Generally, the calibration procedure of the signal passed through a linear time invariant system consists of three steps; the transformation into spectra in the frequency domain, the calibration by the transfer function reflecting in the characteristics of the system, and the inverse transformation of the calibrated spectra into the time domain. Practically, in order to reduce the side robe effect, a raw data is filtered by a window function such as a Hamming window in the time domain before applying short time Fourier transform. However, for the case that a first order differential coefficient of the phase transfer function of the system is not negligible, the phase of the window function convoluted into the calibrated spectra is shifted differently at each frequency, resulting in a discontinuity in the time domain of the calibrated waveform data. To eliminate the effect of the phase shift of a window function, we suggest several methods to calibrate a waveform data accurately and carry out simulations assuming simple sinusoidal waves as an input signal and using transfer functions of WPT, MSC, and WFC obtained in pre-flight tests. In consequence, we conclude that the following two methods can reduce an error contaminated through the calibration to less than 0.1 % of amplitude of input waves; (1) a Turkey-type window function with a flat top region of one-third of the window length and (2) modification of the window function for each frequency by referring the estimation of the phase shift due to the first order differential coefficient from the transfer functions.

**S001-P02** **会場: Poster** **時間: 10月18日**

# Polarization Analyses and Direction Finding of Plasma Waves via the Continuous Cross-Spectrum Measurement by Arase/PWE

# Shoya Matsuda[1]; Yoshiya Kasahara[2]; Hirotsugu Kojima[3]; Yasumasa Kasaba[4]; Satoshi Yagitani[2]; Mitsunori Ozaki[5]; Tomohiko Imachi[2]; Keigo Ishisaka[6]; Satoshi Kurita[1]; Mamoru Ota[2]; Yoshizumi Miyoshi[1]; Ayako Matsuoka[7]; Mariko Teramoto[8]; Iku Shinohara[9]
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Exploration of energization and Radiation in Geospace (ERG) is a mission for understanding particle acceleration, loss mechanisms, and the dynamic evolution of space storms in the context of cross-energy and cross-regional coupling [Miyoshi et al., 2012]. The Plasma Wave Experiment (PWE) is one of the science instruments on board the ERG (Arase) satellite to measure electric field and magnetic field in the inner magnetosphere. OFA/WFC (Onboard Frequency Analyzer and Waveform Capture), which is a sub-system of PWE, measures electric and magnetic field spectrum and waveform from a few Hz to 20 kHz. The PWE/OFA subsystem calculates and produces three kind of data; OFA-SPEC (power spectrum), OFA-MATRIX (spectrum matrix), and OFA-COMPLEX (complex spectrum). They are continuously processed 24 hours per day and all data are sent to the ground. OFA-MATRIX measures ensemble averaged complex cross-spectra of each two components (ExEx∗, ExEy∗, and EyEy∗for the electric field, and BxBx∗, BxBy∗, BxBz∗, ByBy∗, ByBz∗, and BzBz∗for the magnetic field) in every 8 seconds in the nominal mode. OFA-COMPLEX measures instantaneous complex spectra of electric and magnetic fields in every 8 seconds in the nominal mode. We can derive polarization and wave propagation direction of observed plasma waves for 24 consecutive hours by applying cross-spectrum analyses method (e.g., Means' method [Means, 1972], wave distribution function method [Storey and Lefeuvre, 1980] and SVD method [Santolik and Lefeuvre, 2003]) to these products measured by PWE/OFA. After we finished the initial check-out process and appropriate signal calibration, we successfully obtained clear polarization characteristics and wave propagation direction of observed plasma waves (e.g., whistler-mode chorus waves, magnetosonic waves, and plasmaspheric-hiss). We have been used the continuous cross-spectra obtained by PWE/OFA for the selective downlink of the observed raw waveforms. In this presentation, we introduce onboard processing techniques for continuous cross-spectrum calculation and its initial results.

# Data processing in the Software-type wave-particle interaction analyzer on board the ARASE satellite

# Mitsuru Hikishima[1]; Hirotsugu Kojima[2]; Yuto Katoh[3]; Yoshiya Kasahara[4]; Satoshi Kasahara[5]; Takefumi Mitani[6]; Nana Higashio[7]; Ayako Matsuoka[8]; Yoshizumi Miyoshi[9]; Kazushi Asamura[6]; Takeshi Takashima[10]; Shoichiro Yokota[1]; Masahiro Kitahara[3]; Shoya Matsuda[9]
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The software-type wave-particle interaction analyzer (S-WPIA) is software function on board the ARASE (ERG: Exploration of energization and Radiation in Geospace) satellite, which measures amount of energy transfer involving wave-particle interactions in the magnetosphere. The amount of energy exchange between wave/particle can be represented as inner product of electric wave field vector and velocity vector of particle. The phase difference of the wave and particle determine the accuracy of S-WPIA measurement. In order to obtain the accurate relative phase, whole information of individual particle at every particle detection timing and instant wave fields with high sampling timing are collected. These collected large volume data contain electric and magnetic wave and data set of multiple particle instruments over a wide energy range and the ambient magnetic field. These data are transferred to onboard data storage. The data combination of waves and particles in S-WPIA calculation can be selected flexibly. using the stored data set of waves and particles. The calculation results of S-WPIA as well as raw data of particles and plasma waves are transferred to telemetry. The present paper describes the detailed design of S-WPIA algorithm on board the ARASE satellite.

**S001-P04** **会場: Poster** **時間: 10月18日**

# Ion Flux Oscillations and ULF Waves Observed by ARASE Satellite and Their Origin

# Kazuhiro Yamamoto[1]; Masahito Nose[2]; Satoshi Kasahara[3]; Shoichiro Yokota[4]; Kunihiro Keika[5]; Ayako Matsuoka[6]; Mariko Teramoto[7]; Reiko Nomura[8]; Akiko Fujimoto[9]; Yoshimasa Tanaka[10]; Manabu Shinohara[11]; Iku Shinohara[12]; Yoshizumi Miyoshi[13]
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The ARASE satellite, which was launched on December 20, 2016, is now observing the nightside inner magnetosphere. The inclination of the orbit is larger than those of other recent spacecraft flying in the inner magnetosphere such as THMEIS and Van Allen Probes. This unique orbit provides us new information on ULF waves since ULF waves have latitudinal structure and the antinode of magnetic fluctuations of fundamental mode is at high magnetic latitudes, where the previous satellites did not pass.

Although Pc pulsations are predominantly observed on the dayside, ARASE satellite sometimes observes Pc4-5 pulsations on the nightside. Some of these waves are accompanied with energetic particle flux modulations. We found 6 events of the particle flux modulations accompanying Pc pulsations on the dawnside and nightside. Theoretical studies suggest that ULF waves detected at afternoon are generated by (internal) plasma instabilities like drift-mirror instability [Hasegawa, 1969] and drift-bounce resonance [Southwood et al, 1969]. These instabilities cause plasma pressure disturbances or flux modulation of ions. Non resonant ion clouds injected on the duskside also considered to be one of the candidates of ULF wave driver [Zolotukhina, 1974]. We therefore discuss whether the ULF waves observed by ARASE satellite are generated internally or externally, and the flux modulations are created by plasma instabilities or the other non-resonant effects such as a gradient of phase space density in space and energy, or oscillating plasma flow.

On March 31, 2017, Medium-Energy Particle Experiments - Ion Mass Analyzer (MEPi) onboard ARASE detected ion flux oscillations at 12-70 keV with a period of ˜120 seconds in the normal (NML) mode observation. NML mode observation provides details of the direction of particle movements. The pitch angle distribution of proton flux showed isotropic flux oscillations. At the same time, Pc4 pulsations with the same oscillation period were observed. These ion flux and field perturbations were seen on the dawnside (4.3-5.9 MLT).

ARASE found oscillations of ion count with a period of ˜130 seconds in the time-of-flight (TOF) mode observation at midnight on May 29, 2017. Because the TOF mode degenerates the azimuthal resolution from 16 bins to 4bins, it is difficult to calculate a pitch angle distribution with a sufficient angle resolution. Therefore, we used the list data, that is created for onboard calibrations, to make a pitch angle distribution of ion counts. The pitch angle distribution did not have clear fluctuations, so that the oscillations in ion count may be attributed to non-gyrotropic particle distributions.

# Modulation of electron pitch angle distributions observed by MEPe onboard the Arase satellite

# Satoshi Kurita[1]; Yoshizumi Miyoshi[1]; Satoshi Kasahara[2]; Shoichiro Yokota[3]; Yoshiya Kasahara[4]; Atsushi Kumamoto[5]; Fuminori Tsuchiya[6]; Shoya Matsuda[1]; Ayako Matsuoka[7]; Mariko Teramoto[8]; Iku Shinohara[9]
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We report on the modulation of electron pitch angle distributions observed by Medium Energy Particle experiment - electron analyzer (MEPe) on board the Arase satellite. MEPe has a capability to measure three dimensional distribution functions of electrons in the energy range from 7 keV to 80 keV with a fine angular resolution (˜5 degrees). The pitch angle distributions are characterized by flux enhancement of 10 - 30 keV electrons in a very narrow and oblique pitch angle range. The observed pitch angle distributions are similar to quasiperiodic bursts of energetic electrons in conjunction with upper-band chorus reported by Fennell et al. [2014] based on the Van Allen Probes measurement. The MEPe measurement newly found that decrease in electron flux below 10 keV at low pitch angles is also accompanied with the flux enhancement. We found several events showing that quasi-periodic modulation in electron pitch angle distributions in the MEPe dataset, and plasma wave measurements by Plasma Wave Experiment (PWE) revealed that upper-band chorus is necessarily observed in conjunction with the flux enhancement. We will show characteristics of the flux enhancement observed by MEPe and discuss the generation mechanism of the flux variation based on simultaneous electron and plasma wave measurement by the Arase satellite.

# Energetic electrons observed at higher latitude region of the plasma sheet near the radiation belt

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The Arase satellite was successfully launched on Dec. 20, 2016, and it has started the regular mission observation since the end of March, 2017. The orbital inclination of Arase is about 31 degree, so that Arase can observe higher latitude plasma sheet near the plasma sheet boundary. During this summer, the local time of the apogee is located at near the midnight, and Arase observed the plasma sheet just outside of the outer radiation belt as expected. In these observations, we found that energetic electron bursts up to 500 keV frequently appear at higher L-value plasma sheet. Possible sources of these energetic electron bursts of a few hundreds keV in the region are (1) directly accelerated from magnetotail reconnection sites and (2) dispersion-less injections. It is interesting to distinguish the acceleration source of them and address each contribution of the energy input to the radiation belt for understanding the relation between magnetotail reconnection and the acceleration of MeV electrons in the radiation belts. We will present the initial results on the characteristics of the observed energetic electron bursts by using the wide-range electron distribution measurements from 10 eV to 20 MeV.

# In situ statistical observations of EMIC waves by Arase satellite

# Reiko Nomura[1]; Ayako Matsuoka[2]; Mariko Teramoto[3]; Yoshizumi Miyoshi[4]; Masahito Nose[5]; Akiko Fujimoto[6]; Manabu Shinohara[7]; Yoshimasa Tanaka[8]
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We present in situ statistical survay of Electromagnetic ion cyclotron (EMIC) waves observed by Arase satellite from 3 March to 16 July 2017. We identified 64 events using the fluxgate magnetometer (MGF) on the satellite. The EMIC wave is the key phenomena to understand the loss dynamics of MeV-energy electrons in the radiation belt, yet it is unclear how important in terms of the global scale of the whole radiation belt. Especially the EMIC waves observed at localized weak background magnetic field will be discussed for the wave excitation mechanism in the deep inner magnetopshere.

# 北欧全天カメラとVan Allen Probes衛星を用いた脈動オーロラ同時観測事例の解析

# 川村 豪 [1]; 細川 敬祐 [1]; 栗田 怜 [2]; 大山 伸一郎 [2]; 三好 由純 [2]; 小川 泰信 [3]; 藤井 良一 [4]; Wygant John[5]; Breneman Aaron[5]; Bonnell John[6]; Kletzing Craig A.[7]
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# Simultaneous observation of pulsating aurora with high time resolution all-sky cameras and Van Allen Probes satellites

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Pulsating Aurora (PsA), which consists of diffuse patches/arcs blinking with various periodicities ranging from a few to a few tens of second, is known to occur frequently in a local time sector from the magnetic midnight to dawn. It has been suggested that the luminosity variation of PsA is controlled by the intensity modulation of whistler-mode chorus waves in the magnetosphere. Chorus wave is a kind of whistler-mode wave which often appears near the equatorial plane of the magnetosphere. It is generated through non-linear development of whistler mode waves propagating parallel to the magnetic field line. Chorus waves scatter relatively high-energy electrons (more than a few keV) through wave-particle interaction, and then precipitate them into the atmosphere. There have been several studies which attempted to evaluate the correspondence between PsA and chorus waves quantitatively. To date, however, such a correspondence has not yet been confirmed due to poor temporal resolution of the measurements and the limited number of simultaneous observations.

In this study, we directly compare the optical intensity of PsA and the amplitude of chorus waves which were respectively observed by a high time resolution (100 Hz) EMCCD all-sky camera and the Van Allen Probes satellites(VAP-A,VAP-B). The EMCCD all-sky camera has been operative in Sodankyla, Finland since October 2016 with a temporal resolution of 100 Hz. We make use of the Filter Bank data (FBK data) from EFW/EMFISIS sensors onboard the VAP whose temporal resolution is 8 Hz. By combining these two high time resolution data sets, we could resolve the possible association of the main pulsation of PsA with the bursts of chorus waves. By calculating the footprint of VAP by using Tsyganenko 96 model, we extracted an event of PsA during ˜2 h from 2300 UT on October 4, 2016 to 0100 UT on October 5, 2016, during which the footprint of the VAP-A was located within the field-of-view of the EMCCD camera. We simply calculated the cross correlation coefficient between the optical intensity from each pixel of the EMCCD camera and FBK data from the VAP-A. As a result, it is shown that the correlation between these two parameters (i.e., optical intensity and wave amplitude) is not always high at the estimated footprint of the satellite. This means that we need to calculate more precise footprint. In the presentation, frequency analysis of the optical intensity and wave amplitude will also be presented, and the causal relationship between the bursts of chorus waves and the main pulsation of PsA will be discussed.

脈動オーロラは、数秒から数十秒の周期で準周期的に明滅を繰り返すオーロラであり、真夜中過ぎから明け方までの時間帯に頻繁に発生することが知られている。脈動オーロラを引き起こす準周期的な電子降下は、磁気圏コーラス波動と密接に関係していると考えられている。コーラス波動はプラズマ圏外部の磁気赤道面付近において、磁力線に平行に伝搬するホイッスラーモード波が非線形発展することによって発生する。コーラスは、通常エレメントと呼ばれる数十ミリ秒から数百ミリ秒の間に発生し、そのエレメントが数秒間の群構造をもってコーラスバーストと呼ばれる間欠的な放射を作り出す。近年の衛星観測およびシミュレーション研究では、脈動オーロラの内部変調がエレメントに、主脈動がバースト構造に対応していることが示されている。一方、脈動オーロラとコーラス波動の一対一の対応を同定する試みは、これまでにも幾つかの研究においてなされてきた。しかし、観測機器の時間分解能や、イベント数が少ない等の問題があり、さらに検証を進める必要がある。

本研究では、フィンランドのソダンキラに設置されている100 Hzという高いサンプリング周波数で撮影できるEMCCDカメラによって得られた脈動オーロラの発光強度と、同時刻にVan Allen Probes (VAP) 衛星によって得られた電磁界波動のフィルタバンクデータを比較し、コーラス波動が脈動オーロラを駆動しているという仮説を検証することを目的としている。フィルタバンクデータは、周波数方向の分解能を落とすことによって、波動の電磁界強度を高い時間分解能 (8 Hz) で取得することを可能にしている。高速地上光学観測とフィルタバンクデータを組み合わせることで、これまでの研究で問題となってきた時間分解能の問題を解決することができる。脈動オーロラとコーラス波動の強度を比較するためには、VAP衛星のフットプリントが、EMCCDカメラの視野に入っている必要がある。そのため、VAP衛星のフットプリントをTsyganenkoモデルによって算出し、EMCCDカメラの視野に入っていることを確認した上で、比較解析を行うイベントを選定した。

その結果、2016年10月4日2300 UT - 2016年10月5日0100 UTに、カメラの視野内にVAP-A衛星のフットプリントが位置し、かつ脈動オーロラが出現している事例を抽出することができた。このイベントでは、2016年10月4日

2100 UT 頃に、サブストームのオンセットがあり、2300 UT 頃から脈動オーロラが継続的に観測された。イベントの前半部分では、視野の中央付近にアーク状の脈動オーロラが現れており、特に、2016 年 10 月 4 日 2330 UT 付近では、全天カメラの視野全体で、パッチ状の強い脈動オーロラが確認できた。この時、VAP-A 衛星のフットプリントは、全天カメラの視野の東よりに存在しており、イベントの時間中に、1 時間ほど全天カメラの視野内に入っていた。さらに、同時刻に、VAP-A 衛星がコーラス波動を観測していたことが確認でき、コーラス波動のフィルタバンクデータを確認したところ、脈動オーロラの発光強度が高い時間帯は、コーラス波動も強くなっていることがわかった。次に、このイベントについて、EMCCD カメラの各ピクセルについて、VAP-A 衛星のフィルタバンクデータとの相関係数を計算し、その空間的な分布を視覚化した。その結果、相関係数が高くなる位置は存在するが、計算されたフットプリントの位置とは完全に一致しないことが分かった。但し、このフットプリントは、T96 モデルによって計算されたものであるため、より正確な磁力線のトレーシングを行い、相関係数が高くなる場所がフットプリントの位置とどの程度一致するかを確認する予定である。また、発表では、地上光学データとフィルタバンクデータの双方について周波数解析を行った結果についても報告を行う予定である。

# あらせ衛星観測データに基づくプラズマポーズ外縁の高密度領域で発生するコーラス放射とプラズマ密度変動との対応に関する研究

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# Arase observation of the enhancement of whistler-mode chorus emissions in a dense plasma region in the vicinity of plasmapause

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Whistler-mode chorus emissions play significant roles in the pitch angle scattering of energetic electrons in the kinetic energy range from keV to MeV in the inner magnetosphere. Resonant electrons whose pitch angle becomes smaller than loss cone through the pitch angle scattering precipitate into the high latitude atmosphere, contributing the enhancement of diffuse/pulsating aurora. Previous studies suggested that the periodicity of pulsating aurora is closely related to the repetition period of chorus emissions, but the mechanism controlling the repetition period of chorus emissions has not been fully understood.

In the present study, we discuss the enhancement of chorus emissions in a dense plasma region around the plasmapause, based on the Arase satellite observation. The event was appeared in the spectra measured by Onboard Frequency Analyzer (OFA) of Plasma Wave Experiment (PWE) on board the Arase satellite from 02:05 to 02:45 UT in 5 May 2017. During the event, Arase moved from L = 5.4 to 5.8, MLT from 01:00 to 01:30, and the magnetic latitude from 2.7 to 7.2 degree, respectively. By referring the history of the upper-hybrid resonance (UHR) frequency identified in the spectra measured by High Frequency Analyzer (HFA) of PWE, we found that Arase measured the enhancement soon after the crossing of the plasmapause around 02:03 UT. The enhancement of the spectra was identified from 02:05 UT in the frequency range from 1.3 kHz to 2.3 kHz with a distinct gap at 1.6 kHz. The frequency range of the waves decreased with increasing the radial distance of Arase from the Earth, closely associated with the decrease of the local background magnetic field intensity. These spectral characteristics are similar to those of typical lower-band and upper-band chorus emissions with a gap at half the gyrofrequency in the chorus source region.

The identified event of the chorus enhancement is interesting because (1) the background plasma density was significantly larger than those of chorus events typically observed in the outside of the plasmapause and (2) modulation of the plasma density was measured simultaneously with the variation of the spectral properties of chorus emissions. The number density of the background plasma estimated from the UHR frequency varies from 57 to 100 cm$^{-3}$ during a few minutes. Here, we used 3.2 kHz as the local electron cyclotron frequency fce by assuming that a gap at 1.6 kHz of chorus emissions corresponds to 0.5 f$_{ce}$. The ratio between fce and the plasma frequency f$_{pe}$, f$_{pe}$/f$_{ce}$, varies from 21 to 28, whereas a typical f$_{pe}$/f$_{ce}$ in the chorus generation region is less than 10 in the outside of the plasmapause. Based on the obtained f$_{pe}$/f$_{ce}$, we estimate the resonance energy for whistler-mode waves of frequency of 0.5 f$_{ce}$ to 138 and 80 eV for the plasma density of 57 and 100 cm$^{-3}$, respectively. We present results of the detailed analysis of wave and particle data measured by Arase during the event in order to understand the generation process of the observed chorus.

地球内部磁気圏に存在する keV から MeV に至る高エネルギー電子のピッチ角散乱には、ホイッスラーモード・コーラス放射が重要な役割を果たすと考えられている。磁気赤道面付近で発生するコーラス放射とサイクロトロン型の共鳴条件を満たす高エネルギー電子はピッチ角散乱を受け、ロスコーン角よりも小さいピッチ角を持つに至った一部の高エネルギー電子は極域電離圏高度まで降り込むこととなり、脈動オーロラを含むディフューズオーロラの発光を引き起こすと考えられている。特に脈動オーロラの特徴である周期的な発光については、コーラス放射が周期的に発生することが脈動オーロラの周期性に深く関連していることが過去の研究により指摘されている。しかしながら、コーラス放射発生過程の周期性を何が引き起こしているかは未解明である。

本研究はあらせ衛星による観測結果に基づいて、プラズマポーズ外縁部で観測されたコーラス放射の発生過程と、発生時に同時に観測されたプラズマ密度の変動との関連に着目した解析を行った。解析には、あらせ衛星に搭載されたプラズマ波動・電場観測器 (PWE: Plasma Wave Experiment) の High Frequency Analyzer (HFA) ならびに Onboard Frequency Analyzer (OFA)、磁場観測器 (MGF: Magnetic Field Experiment)、低エネルギー電子分析器 LEP-e のデータを用いる。対象とするイベントは、2017 年 5 月 5 日 UT2:05-2:45、磁気赤道面付近の磁気地方時 01:00 から 01:30、磁気緯度 2.7-7.2、L = 5.4 - 5.8 の地点で観測されたものである。OFA の磁場成分に着目すると、1.3-2.3kHz の周波数帯域にスペクトルの増大がみられ、また、約 1.6kHz で波動強度が極小となる様相が示されている。これは典型的なコーラス放射のスペクトルにみられる特徴である Upper-band chorus と Lower-band chorus に対応しているものと考えられる。次に、HFA により

観測された波動電場成分のスペクトルから解析した広域混成共鳴（UHR）周波数に基づいてプラズマ密度を推定すると、対象とするイベントはあらせ衛星がプラズマポーズを横切ったタイミングで観測されていること、また、コーラス放射の発生が同定された領域でのプラズマ密度は 100/cc 近くまで達することが明らかとなった。なお、電子サイクロトロン周波数 f$_{ce}$ は、コーラス放射の強度の減衰がみられた周波数 1.6 kHz が 0.5 f$_{ce}$ に対応すると仮定して見積もった値を用いた。さらに、コーラス放射が発生している領域では、UHR 周波数の変動、すなわちプラズマ密度の変動が生じていることが示された。プラズマ密度の変動は数分の時間スケールで生じており、その範囲は 57 cm$^{-3}$ から 100 cm$^{-3}$ であることが見積もられた。ここで f$_{ce}$ とプラズマ周波数 f$_{pe}$ との比 f$_{pe}$/f$_{ce}$ を見積もると、プラズマ密度変動に対応する f$_{pe}$/f$_{ce}$ は 21.2 から 28.1 となる。この値は、典型的にコーラス放射が観測される領域での値が 10 以下に対して非常に大きな値となっている。コーラス放射と共鳴条件を満たす電子のエネルギーについて見積もると、0.5 f$_{ce}$ の周波数をもつホイッスラーモード波動との共鳴エネルギーは、プラズマ密度が 57 cm$^{-3}$ の場合は 138eV、100 cm$^{-3}$ の場合は 80 eV となり、LEP-e の観測範囲となる。発表では、観測されたコーラス放射の発生過程とプラズマ密度変動との対応について詳細に解析した結果を報告する。

# Absolute Direction Finding Method for the PWE/OFA Data

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The ERG (Arase) satellite was launched on 20 December 2016 to study acceleration and loss mechanisms of relativistic electrons in the Earth's magnetosphere. The Plasma Wave Experiment (PWE), which is one of the science instruments on board the ERG satellite, measures electric field and magnetic field. The PWE consists of three sub-systems; EFD (Electric Field Detector), OFA/WFC (Onboard Frequency Analyzer and Waveform Capture), and HFA (High Frequency Analyzer).The OFA/WFC measures electromagnetic field spectra and raw waveforms in the frequency range from few Hz to 20 kHz, and the OFA produces three kind of data; OFA-SPEC (power spectrum), OFA-MATRIX (spectral matrix), and OFA-COMPLEX (complex spectrum). The OFA-MATRIX measures ensemble averaged complex cross-spectra of two electric field components, and of three magnetic field components. The OFA-COMPLEX measures instantaneous complex spectra of electric and magnetic fields. These data are produced every 8 seconds in the nominal mode, and it can be used for polarization analysis and wave propagation direction finding.

In general, spectral matrix composed by cross-spectra of observed signals is used for direction finding, and many algorithms have been proposed. For example, Means method and SVD method can be applied on the assumption that the spectral matrix is consists of a single plane wave, while wave distribution function (WDF) method is applicable to the observation data in which are combined by multiple numbers of plane waves. When we cannot obtain cross-spectra between electric field and magnetic field, it is impossible to distinguish the absolute direction of waves by applying those methods. The wave direction estimation only using the OFA-MATRIX data has same problem above mentioned.

We developed a new absolute direction finding method using the OFA-MATRIX and OFA-COMPLEX. In this presentation, we introduce the method for the OFA data and evaluation results of the reliability of the estimation.

# Comparison of ULF waves measured by the ERG satellite and MAGDAS network

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ULF waves in frequency band between 1.67 and 6.67 mHz, Pc 5 magnetic pulsations, are believed to contribute to the acceleration of energetic electrons in the outer radiation belt during magnetic storms. Many researchers suggested that high solar wind velocity and high long-duration Pc 5 power observed on the ground in the storm recovery phase are closely associated with the production of relativistic electrons (Baker et al., 1998; Rostoker et al., 1998; Mathie and Mann, 2000; O'Brien et al., 2001, 2003). The ground-based magnetic observations are expected to be useful tool for monitoring or interpolating globally the ULF wave in the inner magnetosphere. We try to estimate the ULF wave map in the inner magnetosphere by using the global multipoint magnetometers on the ground.

In order to achieve the goal, we examined the ULF wave during 22:00 - 23:00 UT on 21 March, 2017 measured by the Magnetic Field Experiment (MGF) on the Exploration of energization and Radiation in Geospace (ERG) satellite and compared it to the ground-based magnetometer data (MAGDAS network data are mainly used). The solar wind was the high solar wind stream phase (600 km/s). There was no similar magnetic variation at the foot point site (Dikson, Russia) on the ground of ERG satellite. However, we found the synchronous and large amplitude ULF wave on the Tixie (Russia, L=5.89). Tixie was located the east of ERG satellite. The ground magnetic field variations at Kuju, Davao and Canberra (these stations were located along the same longitude of Tixie) were different from the ULF wave at Tixie. In this study, we will examine the generation mechanism and propagation process of the simultaneous ULF wave observed on the ERG and the ground, and discuss the reason why the ULF waves are observed at the different local time.

# ERG satellite observation of large amplitude Pc5 wave and the O+ drift-bounce resonance

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A large amplitude Pc5 wave is observed in the inner magnetosphere (L˜5.5-6.0) on 27 March 2017 by Magnetic Filed Experiment (MGF) onboard the Exploration of energization and Radiation in Geospace ’ARASE’ (ERG) satellite. The $O^+$ flux oscillation in the energy range of 10-70 keV is also observed by Medium-Energy Particle Experiments - Ion Mass Analyzer (MEPi) with almost the same period of the Pc5 wave (about 600 s). Before the Pc5 wave was excited, the magnetic field is oscillating with the shorter period of 60-100 s. The start of the $O^+$ flux oscillation coincides with the period change of the magnetic field oscillation. This Pc5 wave and the sudden variation of the wave period are also observed by MMS1 (Magnetospheric Multiscale satellite), which is located near ERG in this event. We will estimate the azimuthal wave structure of the Pc5 wave, using the magnetic field data from the ERG and MMS satellites. We suppose that the $O^+$ flux oscillation is due to the drift-bounce resonance and is related to the sudden change of the wave period.

# Global distribution of ULF waves during magnetic storms on March 27, 2017 and April 4, 2017

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The relativistic electron population in the Earth's outer radiation belt is drastically variable, especially during the active condition of the magnetosphere such as magnetic storms. One of the candidate mechanisms to cause the increase or decrease of relativistic electrons is the radial diffusion of the electrons driven by ultra-low-frequency (ULF) waves in Pc5 frequency ranges. However, how much ULF Pc5 waves contribute to the evolution of the radiation belt is still an open issue. In particular, previous papers have investigated the radial distribution of ULF Pc5 waves in the inner magnetosphere, but the spatial distribution is not well understood because of the limited number of satellite.

In December 2016, the Arase satellite was launched into the inner magnetosphere, and the campaign observations between Arase and ground-based observations are now operated. During the first campaign observation from the end of March to April 2017, two distinct magnetic storms were occurred. The first storm was occurred on March 27, 2017 (Storm 1), which lasted for about six days. On the other hand, the second storm on April 4, 2017 (Storm 2) lasted for about two days. The temporal variation of the dynamic pressure and density of solar wind during each storm is almost similar. However, the solar wind flow speed data shows that Storm 1 is caused by the CIR, while Storm 2 might be caused by the CME. Therefore, background field variations that excite ULF Pc5 waves in the inner magnetosphere can be different between Storm 1 and 2. In addition, the Extremely High-Energy Electron Experiment (XEP) data onboard Arase clearly show the increase of high-energy electrons (400 keV-20 MeV) during the recovery phase of Storm 1, while they did not recover to the pre-storm level during Storm 2. Remarkable difference between two storms is the substorm activities in the recovery phase. In Storm 1, the AE index continuously increased, while in Storm 2, it stayed in low level. In this study, based on the multiple satellite observations including Arase and the global simulation by Block-Adaptive-Tree Solar -Wind Roe-Type Upwind Scheme (BATS-R-US) with the Comprehensive Ring Current Model (CRCM), we investigate the temporal and spatial distribution of ULF Pc5 waves and their relation to solar wind conditions and substorm injections.

# Energy spectra variations of high energy electrons in magnetic storms observed by ARASE and HIMAWARI

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ARASE observed several magnetic storms caused by CIR or CME form March in 2017. The relativistic electrons in the outer radiation belt were increased and their energy spectra were changed in some storms observed by XEP/HEP onboard the ARASE spacecraft. In the same time, SEDA-e/HIMAWARI8 was observed in different local time on GEO.

We will report on energy spectra variations of high energy electrons including calibrations of differential flux between XEP and HEP and on those comparisons between ARAE and HIMAWARI that observed each storm in different local time.

# Calibration of HEP instrument onboard Arase and investigation of flux drop out of the outer belt during storms

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Since the Arase satellite was launched to orbit in 2016, new observation data has been obtained. In order to precise scientific data, the data should be calibrated and then converted to the physical unit. The HEP instrument onboard Arase is designed to observe 70 keV- 2 MeV high-energy electrons. In this energy range, the background radiation caused by energetic protons interferes with observations. Our research aims to discriminate background radiation events through data calibration. Using the Geant4 simulation tool, we conduct the particle simulation to calculate more realistic G-factor of the HEP instrument by designing the geometry of the HEP detector. The energy dependence of G-factor will be also calculated using the Geant4 simulation. We also investigate the loss processes of the outer belt electrons during March 2017 storms, using HEP and XEP data. During the periods, Arase was on the dawn side, while Van Allen Probes was on the dusk side, so that comparative study between two satellites provides the spatial information on the loss region. In this study, we investigate both Arase and Van Allen Probes MagEIS data and estimate the time differences for commencements of electron losses.

# あらせ衛星で受信されたKilometric Continuum（速報）

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# Kilometric Continuum observed by the ARASE satellite (preliminary report)

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Kilometric continuum (KC) is a wave phenomenon identified by the GEOTAIL satellite [1]. This is a kind of escaping continuum whose upper frequency is close to the maximum frequency of its SFA (sweep frequency receiver). The upper frequency is also 800 kHz in the IMAGE satellite receiver which can observe up to 3 MHz [2]. The most typical feature is the geomagnetic latitude dependence of the reception probability. The probability is highest near the equator. The source of KC is believed to be in the equatorial region. The maximum plasma frequency is the plasmapause is around 200 kHz. The frequencies of KC are higher than the maximum frequency. This point is different from the characteristics of the conventional continuum. The IMAGE satellite found that the source is in notch where the electron density is depleted near the equatorial plasma pause. Many other satellites such as INTERBALL-1 [4], POLAR [5], CRES [6], reported KC observations.

Although we tried to observe KC by the SELENE (Kaguya), KC was not observed since its intensity is lower than the noise level. Since the Arase satellite launched in the last December observes KC, we report the preliminary results on the KC observations. The IMAGE satellite which found the source of KC is in a polar orbit. The Arase satellite's inclination is about 32 degrees. Its apogee and perigee are about 32,000 km and 440 km, respectively. This is convenient for observations near the source region.

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Kilometric continuum (KC）は Geotail 衛星で見つけられた波動 [1] で、SFA 掃引受信器の 800 kHz の観測上限周波数まで受信され周波数範囲は AKR と同様であるが，escaping continuum の一種である。3MHz まで受信可能な IMAGE 衛星においても上限周波数は，800kHz であった [2]。最も特徴的な特性は、その受信確率の磁気緯度依存性である。赤道近傍で受信される確率が高く、緯度が高くなるにつれ低くなる。このことから、KC の源は赤道域であり、通常の continuum と同様にプラズマポーズなどの電子密度分布の勾配が急なところとで、電波の周波数とプラズマ周波数が等しいところ考えられている。しかし、プラズマポーズの最高プラズマ周波数は 200kHz 程度で、KC の周波数は一般にそれよりも高く，通常の continuum とは性格が異なると考えられる点が興味深い。IMAGE [3] では，notch (bite-out) と呼ばれるプラズマポーズ近傍の赤道で電子密度分布の急減する領域が低高度になった（窪んだ）ところが KC の源であることを発見した。その他，INTERBALL-1 [4], POLAR [5], CRRES [6] などの衛星での観測が報告されている。詳しくは review [7] が出ている。

月周回衛星かぐやでの観測を試みたが，KC は雑音レベル以下であったため，AKR しか受からなかった。昨年末に打ち上げられたあらせ衛星では KC が受信されている。KC の源を発見した IMAGE 衛星は極軌道であった。あらせ衛星は近地点 約 440km，遠地点 約 32,000km，軌道傾斜角 約 32 度なので，源近傍での観測も期待される。先ずは受信状況を調べることとした。

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# 昭和基地SuperDARNレーダーによるあらせ同時観測初期結果

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# SENSU Syowa SuperDARN initial results from SD-Arase simultaneous observation

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SuperDARN is recognised as one of the most important ground-based network observations for Arase(ERG) project and hence considerable preparation for conjugate simultaneous observations and researches has been made in collaboration with Arase team (especially with ERG Science Center) and among SD-Japan core group including 3 SuperDARN PIs in Japan.

The 9th phase of Japanese Antarctic Research 6-year project started in 2016, and SENSU Syowa SuperDARN observation (operated since 1995) was approved with a new research project, 'Study on polar upper atmosphere in possible ground minimum period and inner magnetosphere dynamics with SuperDARN radars'. At this timing, current status of SENSU Syowa SuperDARN radars and detailed SENSU initial results from Arase-SENSU Syowa SuperDARN campaign observation are shown and discussed.

SuperDARN短波レーダーネットワーク観測はあらせ衛星の連携地上観測網の中でも最も重要な地上観測網のひとつと位置づけられ、認識されており、衛星打上げ前よりあらせ(ERG)チーム、国内SuperDARNチームとも連携して同時観測研究の為の様々な準備が進められたきた。第IX期南極地域観測6か年計画が2017年より開始され、20年以上観測を行ってきた昭和基地短波レーダーは、本第IX期では「SuperDARNレーダーを中心としたグランドミニマム期における極域超高層大気と内部磁気圏のダイナミクス」の研究課題で観測を実施している。あらせ衛星の本格稼働を機に、南極昭和基地SENSEU SuperDARN短波レーダーの現状および同時キャンペーン観測時の観測初期結果について報告する。

# カナダのサブオーロラ帯における11年間の全天カメラ観測に基づくサブストームに伴うSARアークの統計解析

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# Statistical analysis of substorm-assoisiated SAR arcs based on 11-year all-sky imaging observations at subauroral latitude

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SAR arcs are the optical phenomenon caused by low-energy electron precipitation into the ionospheric F layer from the interaction region between the ring current and the plasmasphere. In the recovery phase of geomagnetic storms, low-energy electrons in the plasmasphere are heated by high-energy plasma in the ring current, and these electrons precipitate into the F layer at subauroral latitude where oxygen atoms are excited at altitudes about 400 km. Thus, SAR arcs have been observed at subauroral latitudes during geomagnetic storms. However, Shiokawa et al. (2009) reported an event of SAR arcs detached from the main oval after substorms, based on observation at Athabasca, Canada (54.7N, 246.7E, magnetic latitude = 61.7N). However, statistical analysis of such substorm-associated SAR arcs have not been done yet. Thus, in this study, we do a statistical analysis of substorm-associated SAR arcs observed at Athabasca.

We analyzed 11-year all-sky images at wavelengths of 630.0 nm obtained at Athabasca form 1 January, 2006 to 31 December, 2016. First of all, we made keogram which is time versus latitude plot created from the image at wavelengths of 630.0 nm, and investigated events that the SAR arcs are often detached from the main oval after substorms at Athabasca. Then we found more than 300 events. These SAR arcs were classified by the pattern. We investigated dependences of these SAR arc appearances and their latitudes and durations on AU/AL indices, SYM-H, X component of magnetic field variation at Yellowknife (YKC), north of Athabasca in the auroral zone, solar wind pressure, and IMF-Bz. In the presentation, we will report this analysis result and discuss characteristics and causes of the detachment of SAR arcs from the main oval associated with substorms.

SARアークは磁気嵐の回復相に収縮したプラズマ圏にリングカレントのエネルギーが入り込む。これによって加熱されたプラズマ圏電子が磁力線に沿って電離圏F層に降り込むことにより、酸素原子が励起し発光する現象と知られている。近年、Shiokawa et al. (2009) によって、磁気嵐ではなくサブストームに関連して発生したSARアークが報告されている。しかし、このサブストームに関連したSARアークに関する統計解析はこれまでなされていなかった。そこで本研究では、磁気緯度62度のサブオーロラ帯に位置するカナダのアサバスカでの高感度全天カメラによる観測に基づき、サブストームに関連して発生したSARアークの統計解析を行った。

アサバスカでは、超高層大気イメージングシステム (OMTIs) により、2005年9月3日からSARアークの観測を行っている。本研究では、2006年1月1日から2016年12月31日までの11年間の観測について解析を行った。まず、波長630.0 nmフィルターを通した画像から南北方向の輪切りを時間方向に並べたケオグラムを作成し、高緯度のオーロラの発達後に低緯度にSARアークが分離して残る例を調べた。その結果、11年間で300例以上が観測された。この観測されたSARアークは全天カメラ画像やケオグラムにおける形状によって、アーク状に見える例、帯状に見える例などに分類した。さらに、サブストーム発生の指標であるAU, AL指数、アサバスカの高緯度側のオーロラ帯に位置するイエローナイフにおける地磁気のX成分、磁気嵐発生の指標であるSYM-H指数、Kp指数、IMFの南向き成分Bz、太陽風動圧Pswを用いて、SARアーク発生の時刻に対して、これらのパラメータの時間変化を統計的に調べた。講演では、これらの統計結果を報告し、サブストームに伴って低緯度側に分離するSARアークの特性とその発生原因を議論する。

**S001-P19 会場: Poster 時間: 10月18日**

# 脈動オーロラ主脈動とコーラスバーストの周期性に関する統計的比較

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# Statistical comparison of periodicity of main pulsation of PsA and chorus burst

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Pulsating aurora (PsA) is a kind of diffuse aurora which switches on and off with a period ranging from a few seconds to a few tens of seconds by quasi-periodic electron precipitation from the magnetosphere. Previous studies have suggested that the temporal variation of PsA is caused by the wave-particle interaction between whistler-mode chorus waves and high energy electrons in the magnetosphere. Especially, it has been indicated that there is one to one correspondence between the amplitude variation of the chorus waves and the luminosity modulation of PsA. In the past, however, statistical studies on the correspondence between the periodicities of the chorus waves and PsA have not yet been conducted due to the lack of high time resolution satellite/ground-based measurements.

To compare the chorus wave amplitude and the luminosity variation of PsA in the statistical fashion and confirm the relationship between these two phenomena, we perform a statistical analysis of the periodicities of PsA and chorus waves by using high time resolution ground-based and satellite observations.

For this purpose, we make use of All-sky WATEC Imager (AWI) which has been operative in Tromso, Norway (69.6N, 19.2E) and EFW/EMFISIS sensors onboard the Van Allen Probes (VAPs) satellites. AWI is composed of small high sensitivity cameras (WAT-910HX), fish-eye lens, and optical filters which have different transparent wavelengths. All-sky auroral images are taken with a temporal resolution of 1-2 Hz. The two wave sensors onboard the VAPs provide so-called filter bank data (FBK data) which has a temporal resolution of 8 Hz. Because of its high time resolution data acquisition, the FBK data enable us to analyze the periodicity of burst of chorus.

In the statistical analysis, we have employed all-sky images taken from November 2010 to March 2013 in Tromso, and the EFW/EMFISIS FBK data obtained from June 2014 to January 2015. We computed the average and mode period of the main pulsation of PsA, and they were estimated to be 15.6 sec and 9.0 sec, respectively. We also derived the distribution of the modulation period which has two peaks at 7.0 - 12.0 s (Peak 1) and 14.0 - 21.0 s (Peak 2). We find that the periodicity of PsA is not dependent on their shape and luminocity. It was also indicated that the period of Peak 2 becomes slightly longer in the later MLT sector. Regarding the statistics of chorus burst, we analyzed a few chorus events by using the FBK data, and found that the periodicity of the chorus bursts shows good agreement with the periodicity of main pulsation derived by the current statistics. We will derive the average and mode period of chorus bursts and identify the distribution of periodicity in the statistical fashion.

In the presentation, we discuss the casual relationship between PsA and chorus burst based on the statistical results.

脈動オーロラは、磁気圏から高エネルギーの電子が準周期的に降り込むことによって、高度 100 km 付近の超高層大気が数秒から数十秒の周期で明滅する現象である。この準周期的変動を主脈動と呼ぶ。脈動オーロラの明滅が、磁気圏に存在するコーラス波動と電子の間の波動粒子相互作用によって作り出されていることが古くから示唆されてきた。特に、近年、脈動オーロラ主脈動とコーラス波動の集団的発生 (コーラスバースト) の間に 1 対 1 対応がある事例が報告されている。しかし、これまで地上観測及び衛星観測の双方において、高時間分解能の観測が定常的に行われていなかったことにより、脈動オーロラ主脈動及びコーラスバースト出現の周期性に関する統計的研究は不十分であった。そこで、本研究では高い時間分解能を有する地上光学観測及び衛星電磁波動観測を統計的に解析することにより、脈動オーロラ主脈動とコーラスバーストの周期性の対応関係を実証することを目的としている。本研究で用いる観測機器は、ノルウェー・トロムソ（緯度:69.6 度 経度:19.2 度 磁気緯度:66.2 度）に設置されている全天 WATEC 並列イメージャ、及び NASA の Van Allen Probe (VAPs) 衛星の電磁界波動センサー (EFW, EMFISIS) である。全天 WATEC 並列イメージャは共通の小型カメラと魚眼レンズ、及び透過波長の異なる複数のフィルターで構成されており、脈動オーロラに伴う発光を 0.5 - 1 秒の時間分解能で撮像している。また、VAPs 衛星の EFW、EMFISIS には、波動観測の周波数分解能を落とすことで容量を削減し、電磁界強度を 8 Hz という高い時間分解能で連続的に記録している Filter Bank と呼ばれるデータ (FBK データ) が存在する。FBK データは 8 Hz の高時間分解能で電磁界の波動成分を観測しているため、数秒から数十秒の周期で再帰的に現れるコーラスバーストの統計解析を大量のデータに基づいて行うことができる。

本研究では、全天 WATEC 並列イメージャによって 2010 年 11 月 - 2013 年 3 月の期間に取得された波長 557.7 nm の撮像データ、及び VAPs 衛星によって 2014 年 6 月 - 2015 年 1 月の期間に取得された Filter Bank データを用いて、脈動オーロラ主脈動の明滅及びコーラスバーストの周期性に関する統計解析を行った。解析ウインドウを 5 分として脈動オーロラの輝度値及びコーラス波動の電磁界強度の時系列データに対して周期解析を行うことで脈動オーロラ主脈動及びコーラスバーストの周期分布を導出した。その結果、脈動オーロラ主脈動の平均周期は 15.6 秒、最頻周期は 9.0 秒であり、その周期分布には 7.0 - 12.0 秒 (ピーク 1 ) と 14.0 - 21.0 秒 (ピーク 2 ) に異なる二つのピークが存在することが分

かった。さらに、脈動オーロラの輝度及び形状 (パッチ状かアーク状か) でイベントを分類したうえで周期分布を導出したところ、周期性は輝度や形状に大きく依存しないことが分かった。但し、暗い PsA　やパッチ状の PsA は少し長めの周期を持つ傾向が見られた。さらに、磁気地方時 (MLT) に対する依存性について調べたところ、ピーク 2 については MLT に対する依存性がみられ、朝側に行くほど明滅周期が長くなることが分かった。これらの結果は、脈動オーロラ主脈動を生み出すコーラス波動には 2 つの異なるモードが存在する可能性を示唆する。また、コーラスバーストの周期性については、数例のコーラスイベントについて FBK データの解析を行った結果、統計解析で導出された脈動オーロラ主脈動の平均周期と良い一致を示す例を同定している。今後は、FBK データを用いて、コーラスバーストの周期性についても脈動オーロラの主脈動に対して行ったものと同様の周期解析を行い、周期分布を統計的に導出することでコーラスの強度や形態、観測された MLT に対する依存性を検証していく予定である。発表では、脈動オーロラ主脈動とコーラスバーストの周期性を統計的に直接比較し、脈動オーロラ主脈動の発生に対してコーラス波動が果たしている役割を議論する。

**S001-P20** **会場: Poster** **時間: 10月18日**

# カナダのサブオーロラ帯における磁気圏起源のELF/VLF帯波動の2地点同時観測データの初期解析

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# Preliminary analysis of magnetospheric ELF/VLF waves simultaneously observed at two stations in Canada at subauroral latitudes.

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ELF/VLF waves are generated by electron temperature anisotropy in the equatorial plane of the magnetosphere, and propagate to the ground along geomagnetic field lines. It is also known that the waves interact with electrons drifting longitudinally in the inner magnetosphere, and help accelerating them to relativistic energies. However the instantaneous longitudinal distribution of these waves has not been well understood. Yonezu et al. (JGR 2017) investigated global extent of magnetospheric ELF/VLF waves by using simultaneous observations at three stations in auroral and subauroral latitudes at Athabasca in Canada, Kannuslehto in Finland and Syowa Station in Antarctica. In the present analysis, we investigate local extent of the waves by using simultaneous observations at two stations with a longitudinal separation of ˜30 degrees at subauroral latitudes at Athabasca (54.7N, 246.4E, MLAT: 61.3) and Kapuskasing (49.4N, 277.8E, MLAT: 58.7N) in Canada. Using the same receiver antennas at these two stations, we could obtain wave spectra of the same quality. The period of investigation is from December 11, 2016 to May 8, 2017 (a total of 180 days). We investigated appearance of magnetospheric ELF/VLF waves every 10 minutes in the wave spectra at 0-10kHz. The available periods for the analysis in Athabasca and Kapuskasing are 3415 h and 3391 h, respectively, and the period for which magnetospheric ELF/VLF waves were observed are 546h (16%) and 283h (8%), respectively. The period of simultaneous wave spectra available at two stations is 3039 h, and the magnetospheric ELF/VLF waves were observed simultaneously only for 120h (4%). This result indicates that the simultaneous occurrence rate is less than half of the occurrence rate at each station for a longitudinal separation of 30 degrees (2-h in local time), suggesting that the magnetospheric ELF/VLF waves are localized in longitude. In the presentation, we report more detailed characteristics of the longitudinal extent of ELF/VLF waves and discuss their implication on the plasma dynamics of the inner magnetosphere.

ELF/VLF 波動は地球磁気圏のプラズマ粒子の温度異方性によって赤道面付近で生成され、磁力線にそって地上に伝播する。この波動は地球の内部磁気圏を経度方向に周回するプラズマ粒子と相互作用し、一部の電子を相対論的エネルギーまで加速することが知られている。しかしこの波動の経度方向の拡がりに関してはまだよくわかっていない。Yonezu et al. (JGR, 2017) では、カナダの Athabasca、フィンランドの Kannuslehto、南極の昭和基地の 3 か所のオーロラ帯・サブオーロラ帯の観測点を用いた ELF/VLF 波動の同時観測により、磁気圏における ELF/VLF 波の大まかな空間的拡がりについての調査が行われている。今回の解析では、同じサブオーロラ帯の緯度で経度がおよそ 30 度離れた 2 地点で同じ波動受信機を用いた同時観測を行って均質なデータを得ることで、より局所的な領域における ELF/VLF 波動の拡がりを調べた。

本研究ではカナダの Athabasca(地理緯度：北緯 54.7 度、東経 246.4 度　磁気緯度：北緯 61.3 度)、Kapuskasing(地理緯度：北緯 49.4 度、東経 277.8 度　磁気緯度：北緯 58.7 度) の 2 地点における ELF/VLF 波動の同時観測データの解析結果を報告する。観測に用いたデータは 2016 年 12 月 11 日-2017 年 6 月 8 日の 180 日間である。観測された 0-10kHz の波動スペクトルについて 10 分間ごとに ELF/VLF 波動の有無を調べた。Athabasca, Kapuskasing でスペクトルが存在し雷ノイズによって汚染されていない利用可能な期間はそれぞれ 3415h と 3391h であり、そのうち磁気圏起源の ELF/VLF 波動が観測された期間はそれぞれ 546h（16%）と 283h(8%) であった。2 地点の同時観測が行われている期間は 3039h であり、そのうち ELF/VLF 波動が同時刻に観測された期間は 120h(4%) であった。このことは、経度が約 30 度離れた 2 地点では同時発生確率がそれぞれの地点の発生確率の半分以下に小さくなることを示しており、磁気圏起源の ELF/VLF 波動が経度方向に極めて局在化していることを示唆している。講演では、より詳細な解析を行うことにより、ELF/VLF 波動の経度方向の拡がりとその考察を報告する。

# 脈動電子オーロラのあらせ衛星および地上観測の初期結果報告：コーラス波動が駆動源と考えられる脈動オーロラパッチの時空間解析

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# Initial report on ARASE/ground observations of pulsating aurora:Spatio-temporal analysis of auroral patches related with chorus

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Pulsating aurora is a kind of aurora blinking at several tens of seconds period and having a patchy structure with several to 100 kilometers. Additionally, pulsating auroras have rapid luminous variations at a few Hz. The basic generation mechanism of pulsating aurora is the pitch angle scattering of high-energy electrons by chorus waves. However, the relationship between pulsating aurora and chorus waves has not been well understood, because adjacent auroral patches occasionally show different spatio-temporal features. In this study, we have studied spatio-temporal variations of pulsating auroral patches related with chorus waves by using coordinated Arase satellite and ground-based observations at sub-auroral and auroral latitudes. We identified a pulsating auroral patch having a high correlation between the luminous variations taken by EMCCD camera and the chorus intensities observed by Arase satellite. We need to exactly extract the outer shape of pulsating auroral patch to analyze the spatial variations. However, it is not easy because the spatial form of pulsating auroral patch is complex. We used Level Set Method (LSM), which is an image processing technique for extracting of moving objects, to exactly detect the outer shape of pulsating auroral patches. We confirmed that pulsating auroral patches frequently merge with adjacent auroral patches and split into a few distinct patches. We also analyzed fast modulations of the pulsating auroral patch by using a fast EMCCD camera (about 100 Hz sampling) images. Similarly to previous reports, the pulsating auroral patch related with chorus waves showed a fast (a few Hz) modulation. These observation results indicate the spatial variations of wave-particle interaction regions and the temporal characteristic of discrete chorus elements.

In this presentation, we will report on the initial results of the spatio-temporal analysis of pulsating auroral patches related with chorus waves observed at sub-auroral and auroral latitudes in detail.

脈動オーロラは数十秒程度の明滅周期をもち、数 km〜100 km の空間スケールのパッチ構造をもつオーロラである。さらに、脈動オーロラの発光強度は数 Hz 程度でも激しく変化している。数十秒程度の明滅を主脈動と呼び、主脈動の中にある数 Hz 程度の発光強度の速い変化を内部変調と呼んでいる。脈動オーロラ発生メカニズムはコーラス波動発生に伴う高エネルギー電子のピッチ角散乱と考えられている。しかし、脈動オーロラパッチのすぐ横には、異なる時空間特徴を示すパッチが存在する場合もあり、脈動オーロラとコーラス波動の関係は十分に理解されていない。本研究では、あらせ衛星と地上観測キャンペーンで得られた脈動オーロラとコーラス波動のデータを用いてコーラス波動発生に伴う脈動オーロラパッチの時空間変動の解析を行った。EMCCD カメラで撮像された脈動オーロラの発光強度の変化とあらせ衛星で観測されたコーラス波動群の強度変化よりコーラス波動発生に伴う脈動オーロラパッチを同定した。同定した脈動オーロラの空間変化の解析には、オーロラ画像において脈動オーロラ領域の抽出を行う必要がある。しかし、脈動オーロラのパッチ形状は複雑であるため、単純な画像処理では抽出が困難である。我々は脈動オーロラ領域の抽出を行うために、分離・結合を伴う動オブジェクトの抽出に用いられている Level Set Method(LSM) を用いた。LSM を用いた解析で、脈動オーロラパッチは、激しく分裂と結合を示している様子が確認された。また、EMCCD カメラで高速撮像 (約 100 Hz) された脈動オーロラパッチから高速変調解析を行った。その結果、コーラス波動の強度変化と高い相関をもつオーロラパッチが、従来報告されているように明滅するパッチの明るい時間にのみ数 Hz の輝度値の変調成分を有していることを確認した。これらの観測結果より、波動粒子相互領域の空間変動及びコーラス波動群を構築するコーラスエレメントとの関連性の解明が期待される。

本発表では、コーラス波動発生に伴う脈動オーロラパッチの時空間変化解析結果について詳細に報告する予定である。

# OFFの間に暗くなりすぎる脈動オーロラの統計解析

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# Statistical analysis of over-darkening pulsating aurora

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Pulsating aurora is a phenomenon during which the upper atmosphere at ˜100 km altitude pulsates with a period ranging from a few to a few tens of second by quasi-periodic precipitation of high energy electrons from the magnetosphere. It has been suggested that the interaction between the chorus waves and energetic electrons near the equatorial plane of the magnetosphere has a potential to cause of luminosity modulation of pulsating aurora. This hypothesis is supported by the existence of one-to-one correspondence between quasi-periodic variations in the luminosity of pulsating aurora and intensity of chorus wave. Recent analyses of high time resolution ground-based optical observations has reported that the brightness of pulsating aurora decreases below the diffuse background level immediately after the switch-off of the main optical pulsation (e.g., Kataoka et al. [2012], Dahlgren et al. [2017]). To date, however, the statistical properties of such ’over-darkening pulsating aurora’ have not been investigated in detail; thus, the origin of this phenomenon is still unclarified.

In this paper, we derive the characteristics of the over-darkening pulsating aurora by performing a statistical analysis using several ground-based/satellite observations, and then try to understand whether this phenomenon is directly associated with the fundamental characteristics of chorus waves. The optical instruments employed in this study are the 5-channel photometer and an EMCCD all-sky camera in Tromso;, Norway (69.6N, 19.2E, 66.7MLAT) which have been operative since last winter season. The field-of-view of the 5-channel photometer is directed along the local magnetic field line and it measures the emission intensity of aurora/airglow at 5 wavelengths (427.8, 557.7, 670, 777.4, 844.6 nm) with a temporal resolution of 20 Hz. The EMCCD all-sky camera captures auroral emission with a temporal resolution of 100 Hz. In addition to these instruments, the wave instruments onboard the THEMIS spacecraft are used for analyzing the chorus wave with a temporal resolution of 1 Hz.

In the analysis, we made simple time-series plots of data from the 5-channel photometer, EMCCD camera, and computed the occurrence frequency of the over-darkening pulsating aurora. The statistical analysis using data from one winter season indicates that ˜15% of all the ON/OFF pairs of pulsating aurora over-darken immediately after their ON phase. Interesting point is that we have identified at least one over-darkening pulsating aurora during all the intervals analyzed so far, which means that over-darkening is a common characteristic of pulsating aurora.

An additional analysis using the THEMIS satellites indicates that similar characteristics are sometimes seen in the time-series of the chorus wave amplitude. However, their occurrence frequency is likely to be smaller than that seen on the ground. In the presentation, we discuss the origin of over-darkening of pulsating aurora based on the statistical results, and suggest a model explaining their generation mechanism.

脈動オーロラは、磁気圏から高エネルギーの電子が準周期的に降り込むことによって、高度100 km付近の励起された熱圏大気粒子が数秒から数十秒の周期で明滅する現象である。脈動オーロラの明滅を作り出す電子の降下は、準周期的に強度が変動する磁気圏コーラス波動と電子との相互作用（ピッチ角散乱）によって生じると考えられている。特に、脈動オーロラの準周期的な輝度変化とコーラス波動の強度変化の間に高い相関関係があることが示されている。近年の高時間分解能光学観測データの解析から、脈動オーロラの主脈動がONからOFF、またはOFFからONに切り替わる時に、発光強度が背景の発光強度のレベルよりも低くなる事例が報告されている（e.g., Kataoka et al. [2012], Dahlgren et al. [2017]）。しかし、コーラス波動と脈動オーロラの対応関係を研究する際に、このような「OFFの間に暗くなりすぎる」傾向に着目して、データが解析されたことは無く、その発生頻度や発生条件、及び原因について未だに明らかにされていない。

本研究は、脈動オーロラの明滅がOFFの間に暗くなりすぎる事例について、地上光学観測の統計解析を行うことで、発生頻度などの性質を明らかにすることを目的とする。また、衛星によるコーラス波動の観測データについても解析を行い、暗くなりすぎる性質がコーラス波動そのものの性質に起因するのかどうかを検討する。本研究で用いる地上観測装置は、ノルウェー・トロムソ（地理緯度:69.6N, 経度:19.2E, 磁気緯度:66.7MLAT）において2017年2月から稼働を開始した5チャンネルフォトメータと電子倍増型CCD (EMCCD) 全天カメラである。5チャンネルフォトメータは磁力線方向を20 Hzの時間分解能で観測しており、測定波長は427.8, 557.7, 670, 777.4, 844.6 nmである。また、EMCCD全天カメラは、オーロラ発光を100 Hzという高い時間分解能で撮像している。これらに加え、NASAのTHEMIS衛星によって1秒の時間分解能で取得された電磁界波動を用いることで、コーラス波動の解析も行う。

まず、5チャンネルフォトメータが稼働を開始したあとに観測された全18晩分 (総観測時間95時間) の脈動オーロラの事例について、OFFの間に減りすぎる事例がどの程度の頻度で発生しているかを調べた。その結果、検出された全てのON/OFFペアのうちの約15%が、OFF時に輝度が背景よりも減りすぎる傾向を示していることが分かった。また、これまでに解析を行った計18晩については、OFF時に輝度が減りすぎる事例が見られない晩は存在しなかった。これらに加える形で、THEMIS衛星によって得られたコーラス波動の強度変動の時系列データを解析したところ、地上光学観測

と類似の OFF 時に電磁界強度が減りすぎる傾向が見られていることが分かった。但し、その頻度は、地上光学観測で見られているものよりも低いことが明らかになりつつある。今後、地上、衛星双方の観測について 1 シーズン分のデータを用いた統計解析を行うことでこの傾向を確認する予定である。また、OFF 時に減りすぎるという性質がどのような条件の下（輝度、MLT など）で発現するのかについても調べる予定である。発表では、脈動オーロラの発光強度が OFF の時に減りすぎるという性質が、コーラス波動そのものの性質によるものなのか、波動粒子相互作用によって散乱を受ける電子のピッチ角分布によるものなのかを議論し、その発現メカニズムに関するモデルを提案する。

# Energetic electron precipitation associated with Pc1/EMIC waves: Six-month LF-wave observations over North America

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Energetic electron losses from the outer radiation belt occur during magnetic storm and substorm. One of the mechanisms is precipitation into the atmosphere, and electromagnetic ion cyclotron (EMIC) wave is one of candidates to cause pitch angle scattering of energetic electron. EMIC waves, which are observed in the Pc1-Pc2 frequency range (0.1-5Hz), are excited by the ion cyclotron instability in the equatorial region of the magnetosphere and propagate along magnetic field lines to the ionosphere. After EMIC waves inject into the ionosphere, their wave mode is converted and part of them propagate horizontally in the ionospheric duct layer. While it has been theoretically studied that EMIC waves play an important role in energetic electron precipitation into the atmosphere, experimental observations have been too limited to support this idea.

Here, we investigated relation between occurrences of EMIC waves and energetic electron precipitation by means of ground-based magnetometers and low frequency (LF) radio wave propagation observation and found several events which occurred simultaneously.

We use induction magnetometers data in North America (PWING and CARISMA stations) to investigate occurrence of EMIC waves. LF radio waves propagate from transmitters to a receiver, reflecting between earth's surface and the lower ionospheric boundary (altitude of 70-90km). Ionization caused by precipitating electrons in the lower ionosphere results in changes in the radio propagation path and attenuation of signal amplitude. Thus, precipitation of energetic electrons (higher than 100keV) causes deviation of the LF wave amplitude from that in undisturbed conditions. In this study, we analyzed LF wave signals received at Athabasca, Canada (latitude=54.7, longitude=246.7, L=4.45) and Poker Flat, Alaska (latitude=65.1, longitude=212.5, L=5.95). LF radio waves received at Athabasca are transmitted from several stations in United States: WWVB (latitude=40.7, longitude=255.0, L=2.28, 60kHz), NAA (latitude=44.7, longitude=292.7, L=2.89, 24.0kHz), NDK (latitude=46.4, longitude=261.5, L=2.98, 25.2kHz) and NLK (latitude=48.2, Longitude=238.1, L=2.85, 24.79kHz). LF radio waves received at Poker Flat are transmitted from NDK and NLK.

We compared occurrences of night time LF wave amplitude variations from the quiet day curve with substorm and Pc1 for six month from 1 January to 30 June 2017. In this study, 55 Pc1 events were identified from the induction magnetometer at Athabasca whose power exceeded $10^4$nT$^2$/Hz. We also identified 107 substorms as the events whose AE indices were larger than 600nT and horizontal component values of the magnetic field at some stations in North America (magnetic latitude higher than $60^0$) were lower than -200nT. We found 76 substorm events accompanied by the LF wave amplitude variation (71.0%) and five Pc1 events accompanied by LF variation (9.1%). While electron precipitation region detected by LF radio waves is localized on the propagation path from a transmitter to a receiver, Pc1 waves propagate in a horizontal direction widely outside the localized ionospheric source. This is one of reasons to explain the low occurrence of Pc1 event which accompanied the LF amplitude variation.

The five Pc1 events which accompanied LF wave amplitude variation occurred on 18 January, 22 February, 8 March, 21 March and 27 April 2017. We will analyze polarization and propagation direction of Pc1 using multiple induction magnetometer data to investigate spatial correspondence between location of Pc1 ionospheric source and that of energetic electron precipitation.

Acknowledgement

The authors thank I.R. Mann, D.K. Milling and the rest of the CARISMA team for data. CARISMA is operated by the University of Alberta, funded by the Canadian Space Agency.

# コーラス波強度変動とアイスランドにおいて観測された脈動オーロラの明滅周期の比較

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# Comparing chorus intensity modulation with time variation of pulsating aurora observed in Iceland

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In this study, we report the relationship between time variation of pulsating auroral emission intensity and whistler-mode chorus waves. Pulsating aurora is a kind of diffuse aurora which is mainly observed during the substorm recovery phase at the post midnight. Pulsating aurora shows two typical time variations. One is the time variation whose period is from a few to a few tens seconds. The other is a few Hz modulation. Pulsating aurora is thought to be generated by precipitating electrons from the magnetosphere into the ionosphere which interact with whistler waves at the magnetic equator. Nishimura et al. [2010] reported that, among whistler waves, especially chorus waves generated by non-linear wave-particle interaction show time variation consistent with that of pulsating aurora by observation with THEMIS satellite and ground-based all-sky imager. However the number of events used for the comparison between modulation of whistler-mode chorus wave and pulsating aurora is limited and thus the cause of pulsating aurora has not been explained completely. Arase (ERG) satellite was successfully launched in December 2016. And ERG is observing the plasma electric and magnetic field at the pulsating aurora source region. We analyze the data obtained during ERG satellite-ground based simultaneous champagne observation.

On 21 March 2017, the footprint of ERG satellite transited through the field of view of the National institute of Polar Research panchromatic all-sky imager which installed at Husafell, Iceland (geographic latitude: 64.67 degrees, geographic longitude: 338.97 degrees, geomagnetic latitude: 69.13 degrees, geomagnetic longitude: 71.67 degrees) during 04:00-06:00 UT (03:40-05:40 MLT). The solar wind data showed that the magnetic field intensity and proton density increased from 5 nT to 18 nT and from 15 /cm$^3$ to 50 /cm$^3$ respectively during 00 UT to 06 UT . The solar wind speed increased during 07 UT on 21 March to 00 UT on 23 March. These data indicate that the Corotating Interaction Region (CIR) reached the Earth. On the other hand, the time resolution of Watec all-sky imager is about 2 Hz. This all-sky imager recorded aurora images in the mpeg format by digital video recorder (DVR) during this time. The effective pixels are 720 x 240 pixels and the frame rate of DVR is 3 fps. So we created 3 fps images from the movie. The pixels of each image are 639 x 449, 8 bit/pixel. Although this imager is not monochromatic, we assumed that 557.7 nm auroral emission was dominant in images and calculated geographic latitude and geographic longitude of each pixel in images and then, mapped images on geographic coordinate at 110 km altitude. As a result, elongated arc in the east-west direction moved from high latitude (magnetic latitude 70.5 degrees, geographic latitude 66.5 degrees) to low latitude (magnetic latitude 69.5 degrees, geographic latitude 65.5 degrees) within the field of view of the all-sky imager. And then, pulsating aurora was observed within the range from magnetic latitude 69-72 degrees during 04:40-05:30 UT. At this time, ERG observed plasma waves and particles at the morning side magnetic equator (3.9-4.8 MLT). The distance from the center of the Earth to ERG was L˜6 $R_E$ . We compared between 0.4-1.2 kHz waves of electric and magnetic field observed by PWE/OFA and time variation of pulsating aurora at the ERG footprint. Although chorus waves were observed during 04:42-04:57 UT, 5:02-05:08 UT, and 5:10-05:18 UT, the time variation of pulsating auroral emission at the ERG footprint did not correspond one-to-one that of chorus waves. We deduced that this discrepancy was caused by inaccurate mapping of aurora images or ERG footprint on geographic coordinate. We will compare the time variation of chorus waves intensity and pulsating auroral emission intensity again by, for example, adding some degrees to or subtracting some degrees from geographic coordinate of ERG footprint.

本研究では地上光学観測で観測された脈動オーロラの発光強度の時間変化とあらせ衛星で観測されたホイッスラーモードのコーラス波の対応関係について報告する。脈動オーロラはディフューズオーロラの１種で、真夜中過ぎのサブストーム回復相で主に観測される。脈動オーロラには２つの特徴的な時間変動があり、１つは主脈動と呼ばれる数秒から数十秒周期で明滅を繰り返すもので、もう１つは内部変調と呼ばれる数 Hz の時間変動である。脈動オーロラは放射線帯に存在するホイッスラーモード波と電子がサイクロトロン共鳴することで電子が加速され、磁力線に沿って電離圏に降り込むことで引き起こされると考えられている。ホイッスラーモード波の中でも、非線形波動粒子相互作用により生成されるコーラス波強度の時間変化と脈動オーロラの明滅周期がよく一致していることが THEMIS 衛星との地上同時光学観測により報告されている [Nishimura et al., 2010]。しかしながら、このような磁気赤道付近のホイッスラーモードのコーラス

波による波動粒子相互作用領域の時間変化と電離圏高度の脈動オーロラとの明滅周期を比較したイベント数はほとんどなく、脈動オーロラを引き起こす因果関係の詳細は明らかになっていない。あらせは2016年12月に打ち上げが成功し、脈動オーロラソース領域のプラズマ・電磁場詳細観測を行っている。今回我々はあらせ衛星の地上同時キャンペーン観測中のデータについて解析を行った。

本研究では2017年3月21日04:00-06:00 UT（03:40-05:40 MLT）にあらせ衛星のfootprintがIcelandのHusafell (地理緯度64.67度N、地理経度338.97度E、磁気緯度69.13度、磁気経度71.67度) の全天視野内を通過したイベントの解析を行った。このとき、太陽風観測は0 UTから6 UTにかけて磁場強度とプロトン密度がそれぞれ5 nTから18 nTへ、15 /$cm^3$から50 /$cm^3$へ増加しており、その後07 UTから3月23日00 UTにかけて太陽風速度が350 km/sから650 km/sに上昇していることから、地球には高速太陽風によって圧縮された低速太陽風領域 (CIR: Corotating Interaction Region) が到達していたと考えられる。一方、Husafellの地上Watecイメージャーは、観測時間分解能約2 Hz、有効画素数720 x 480 pixelsでこの期間連続に全天白色オーロラ画像をデジタルビデオレコーダーによって動画形式で記録していた。Husafellには観測時間分解能30 Hzの全天TVカメラ（ナイトビュア型）も設置されているが、この時間帯は観測を行っていなかった。本研究では、Watecイメージャーで記録された動画ファイルのそれぞれのフレームを画素数639 x 449 pixels、8 bit/pixelでデジタル画像化した。このイメージャーは単色でないが、データはオーロラ557.7 nm発光が支配的と仮定し、高度110 kmで地理座標上に球面三角関数を用いて発光をマッピングして画像中の各ピクセルの地理緯度と地理経度を求めた。この結果、04:00 UTでは東西方向に伸びたアーク状のオーロラが、04:30 UTから04:40 UTにかけて高緯度（磁気緯度70.5度、地理緯度66.5度N）側から低緯度（磁気緯度69.5度、地理緯度65.5度N）側に移動したが、その後ブレイクアップは起きず、04:40-05:30 UTにかけて磁気緯度69-72度の範囲で脈動オーロラが観測された。一方、あらせ衛星は朝側（3.9-4.8 MLT）のL˜6 $R_E$でプラズマ波動と粒子の観測を行っており、04:00-06:30 UTにかけてこのfootprintがHusafell全天視野内にあった。あらせ衛星PWE/OFAで観測された電場と磁場の0.4-1.2 kHz波動データとあらせ衛星footprintの脈動オーロラ発光強度を比較した。この結果、04:42-04:57 UT、5:02-05:08 UT、5:10-05:18 UTの3つの時間帯に顕著なコーラス波が観測されていたが、脈動オーロラの発光強度の時間変化と明瞭な一対一対応は見られなかった。この原因として、全天イメージャーの画像データやあらせ衛星のfootprintの位置が正しく地図上にマッピングされていないという可能性が考えられる。 今後あらせ衛星のfootprintの位置の精度を検証するために、緯度、経度方向にずらした点での対応関係を調べるなどして、あらせ衛星で観測されたコーラス波とあらせ衛星のfootprintの位置での脈動オーロラ発光強度の時間変化を詳細比較していく予定である。

# 複数波長観測による脈動オーロラ降下電子のエネルギー推定とそのMLT依存性

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# MLT dependencies of the electron energy responsible for pulsating auroras based on the multi-wavelength obsevation

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Pulsating aurora (PsA) is a kind of diffuse aurora and shows quasi-periodic intensity modulation with 2 s to 30 s intervals. PsA is mainly observed from the post-midnight to the morning sectors during the recovery phase of substorms. Based on the EISCAT observations, Hosokawa and Ogawa [2015] showed that energy of precipitating electrons responsible for pulsating aurora tends to be higher on the late MLT sector. On the other hand, applying the triangulation method on pulsating auroras, Partamies et al. [2017] reported that there are no significant MLT dependence of the emission height of pulsating auroras. This result suggests that precipitating electron energies for pulsating aurora do not depend on MLT.

In order to investigate MLT dependencies of the characteristic energy of precipitating electrons responsible for pulsating aurora,we apply the method proposed by Ono et al.[1992] to estimate the characteristic energy by choosing the two optical wavelengths of 427.8 nm and 844.6 nm. Auroral images at these emission lines were obtained by monochromatic EMCCD cameras installed in Tromso, Norway, and the emission intensity along the magnetic field line is used for the estimation. We analyzed 13 nights (about 900 minutes) of pulsating aurora events from February 2017 to April 2017. The average of characteristic energy of precipitating electrons are 3.6 keV at pre-midnight and 4.4 keV at post-midnight, so that it is expected that the characteristic energy of precipitating electron at post-midnight tends to be larger than that at pre-midnight. Besides the MLT dependence of precipitating electron energy, we will discuss the spatial distribution of precipitating elelectron energy in the pulsating patches.

脈動オーロラは、2〜30秒の間隔で発光する、準周期的なオーロラであり、主にサブストームの回復相に、深夜から明け方にかけて観測される。脈動オーロラに伴う降下電子エネルギーのMLT依存性について、Hosokawa and Ogawa [2015] によるレーダー観測では、深夜から明け方に向かうにつれて降下電子のエネルギーが高くなる傾向が見られた。一方で、Partamies et al. [2017] では、三角測量による脈動オーロラ発光高度の解析から、降下電子のエネルギーのMLT依存性に関して統計的に調査したが、有意な依存性は認められなかった。

本研究では、Ono et al. [1992] で提案された、複数波長で測定されたオーロラ発光強度の比を用いる手法を応用して降下電子のエネルギー推定を行い、そのMLT依存性を調べた。解析には、ノルウェー・トロムソに設置された427.8 nmと844.6 nmの単色EMCCDカメラ2台で取得された二次元画像を用いた。本発表では2017年2月から2017年4月までの間に取得された13晩分（約900分間）の脈動オーロライベントに対して、磁気天頂方向付近で取得された2波長の強度比から、降下電子エネルギーの推定を行った。初期解析の結果、該当期間においては、pre-midnightの平均エネルギーが3.6 keVに対して、post-midnightの平均エネルギーは4.4 keVという結果が得られ、post-midnightにおける降下電子エネルギーのほうがやや高い傾向が得られた。発表では、MLT依存性に加え、脈動オーロラのパッチの中の降下電子エネルギー分布の推定についても報告を行う。

# Energetic electron precipitations observed by VLF/LF sub-ionospheric propagation: ARASE and ground-based observation campaign

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Sub-ionospheric propagation of narrowband VLF/LF radio waves is a useful probe to observe energetic electron precipitation with energy of 100keV to MeV. Here, we show overview of observational characteristics of energetic electron precipitations at auroral and sub-auroral latitudes observed by a VLF/LF radio receiver network installed at Ny-Alesund(NAL), Athabasca(ATH) and Poker Flat Research Range, Alaska(PKR) during ARASE and ground-based observation campaign in the spring of 2017. The six sub-ionospheric propagation paths in total are available in northern America and three paths are available in Scandinavia; The ATH station is located at sub-auroral latitude (54.7N, 246.7E, L=4.45) and radio signals from mid-latitude transmitters (WWVB: 40.7N, 255.0E, 60kHz, NAA: 44.7N, 292.7E, 24.0kHz, NDK: 46.4N, 261.5E, 25.2kHz and NLK:48.2N, 238.1E, 24.79kHz) were recorded. PKR is located below the auroral latitude (65.1N, 212.5E, L=5.95) and received the signals from NDK and NLK. The NAL station is inside the northern polar cap (78.9N, 11.9E) and radio signals from mid-latitude transmitters (MSF: 54.9N, 256.3E, 60.0kHz, DCF: 50.0N, 9.0E, 77.5kHz, and NRK: 64.0N, 337.4E, 37.5kHz) are recorded. During the observation campaign, three magnetic storms occurred in March and April (Dst minima on Mar. 23, Mar. 27, and Apr. 4) and phase advances (available for WWVB, DCF, and MSF) and amplitude depressions of received radio signals were recorded during these periods. The phase advances are caused by lowering the ionospheric reflection height (70-90km) of radio waves due to energetic electron precipitation and subsequent enhancement of ionization in the lower ionosphere. The amplitude depressions are caused by attenuation of radio waves when they pass through the enhanced ionization region. These observational signature are proxies of energetic electron precipitation on radio propagation paths and the simultaneous multi-path observation enables us to investigate spatial structure of energetic electron precipitation region. Overview of the night time sub-ionospheric propagation of VLF/LF waves observed are summarized as follows: (1) Phase advances and amplitude depressions were observed at all received stations associated with storm time substorms. Substorm induced energetic electron precipitations were detected by the VLF/LF radio receiver network. (2) The energetic electron precipitation signatures sometimes show different start timing and duration depending on transmitter-receiver pairs, implying that spatial structure of energetic electron precipitation region is smaller than longitude separations of radio paths (˜15 degrees in longitude). (3) The phase and amplitude variations with time scale of minutes were embedded inside the substorm induced energetic electron precipitation signatures. In some cases, the variations are corrected with magnetic field fluctuation in the Pc5 range observed by ground magnetometers. (4) The amplitude depressions associated with Pc1 were occasionally observed (Hirai et al. ibid).

# Analysis of spacecraft surface charging events in MEO

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Analysis of spacecraft surface charging in the medium earth orbit (MEO) is important for spacecraft designs and operations, because surface charging sometimes cause spacecraft anomalies due to discharging arcs. However, the plasma environment which induces the spacecraft surface charging in MEO was not so well studied, since it was difficult to measure the ambient plasma accurately due to contamination by high energy particles of the radiation belts. Therefore, we use the data of the Van Allen Probe (VAP) and the ARASE satellite, which are designed for scientific missions to measure wide energy range plasma and radiation environment accurately. Since their almost all surfaces are conductive and electrically tied together with their chassis, their surface charging potential equals their absolute charging potential. We study the surface charging events using the proton flux data of the Helium Oxygen Proton Electron (HOPE) onboard VAP. We find ion flux peaks accelerated by spacecraft potential in the spin averaged differential proton flux data and estimate the spacecraft potential. The results show that most of the surface charging events (spacecraft potential &lt; -50 V) occur in the midnight-to-dawn sectors and intense charging events (spacecraft potential &lt; -1,000 V) occur mainly in the Earth's shadow. We also survey spin averaged differential proton flux data of the Low energy Experiments (LEP) data of the ARASE satellite and find surface charging events. We will discuss the environment which induces these charging events in MEO.

**S001-P28** **会場: Poster** **時間: 10月18日**

# 内部磁気圏における Pc5 波動との共鳴によって形成される相対論的電子のピッチ角分布の特徴

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# Characteristics of pitch angle distributions of relativistic electrons under interaction with Pc5 waves in the inner magnetosphere

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Radial transport of relativistic electrons in the inner magnetosphere has been considered as one of acceleration mechanisms of the outer radiation belt electrons and can be driven by the drift resonance with ULF waves in the Pc5 frequency range. The maximum changes of the electron in the radial distance ($L$) due to the drift resonance depend on the electron energy, pitch angle, and Pc5 wave structure. Those dependences are expected to form the characteristic pitch angle distributions (PADs) as a function of $L$ and electron energy. In this study, we investigate PADs of relativistic electrons due to the drift resonance with a monochromatic Pc5 wave by using two simulation models of the inner magnetosphere: GEMSIS-Ring Current (RC) and GEMSIS-Radiation Belt (RB) models. The GEMSIS-RB simulations calculate guiding center trajectories of relativistic electrons in electric and magnetic fields obtained from the GEMSIS-RC model, which simulates a monochromatic Pc5 wave propagation in the inner magnetosphere.

The results show the characteristic PADs depending on the energy and $L$, which is explicable with the pitch angle dependence of resonance conditions. At a fixed location, those PADs can change from pancake (90 degree peaked) to butterfly (two peaks in oblique PAs) distributions as the transport by the monochromatic Pc5 wave progresses. These butterfly distributions are observed in the $L$ range where electrons with lower PAs satisfy the resonance condition. It is also found that the lower PA electron with a fixed magnetic moment can be transported deeper inside because of the PA changes to larger values through the adiabatic transport, which enables them to satisfy the efficient resonance condition in wider $L$ range compared to the 90 degrees PA electrons.

# Rapid acceleration of relativistic electrons associated with pressure pulse: Simulation and Arase and Van Allen Probe observations

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Relativistic electron fluxes of the outer radiation belt rapidly change in response to solar wind variations. One of the shortest acceleration processes of electrons in the outer radiation belt is wave-particle interactions between drifting electrons and fast-mode waves induced by compression of the dayside magnetopause caused by interplanetary shocks. In order to investigate this process by a solar wind pressure pulse, we perform a code-coupling simulation using the GEMSIS-RB test particle simulation (Saito et al., 2010) and the GEMSIS-GM global MHD magnetosphere simulation (Matsumoto et al., 2010). As a case study, an interplanetary pressure pulse with the enhancement of ˜5 nPa is used as the up-stream condition. In the magnetosphere, the fast mode waves with the azimuthal electric field ( negative $E_{phi}$ : $|E_{phi}|$˜10 mV/m, azimuthal mode number : m <= 2) propagates from the dayside to nightside, interacting with electrons. From the simulation results, we derived effective acceleration model and condition : the electrons whose drift velocities are greater than (3.14 / 2) times fast mode speed are accelerated efficiently.

Recently, the Arase (ERG) satellite and Van Allen Probes observed the rapid enhancement of electron fluxes for hundreds of keV to MeV associated with storm sudden commencement (SSC) on July 16, 2017. During the period, the sharp enhancement of the solar wind dynamic pressure from 1 nPa to 15 nPa was observed. In this event, drift echoes after the flux enhancement and magnetic field variations due to the fast mode wave propagation were observed. We will compare our simulation results with observations from Arase and Van Allen Probes, and investigate the acceleration condition of relativistic electrons associated with the SSC.

**S001-P30** **会場: Poster** **時間: 10月18日**

# Multipoint observation of Pc5 pulsations by QZS-1, THEMIS, and MAGDAS/KTN on the same geomagnetic field line

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The field-aligned structure of ultra-low-frequency waves has been theoretically investigated, but there are few observations on the same geomagnetic field line at different magnetic latitude because of rare occasions of long-time good conjunctions between multi satellites and a ground station. The QZS-1 satellite had a quasi-zenith orbit with an inclination of 45 degrees, an apogee of 6.6 [Re], and an orbital period of 24 [h]. The ionospheric footprint of keeps the good conjunction with MAGDAS/KTN station for a long time (˜3 hours) when the satellite was located near maximum magnetic latitude in the northern hemisphere (˜32 degrees).

We examined a Pc5 pulsation event during March 31, 2012 at 20:00-21:00 UT. During the event, the ground station and satellites were almost located on the close L shell of ˜9.5 in the 5-6.5 h MLT sector. The QZS-1 and THEMIS-A satellites were located at 31 and -5 degrees in magnetic latitude, respectively. The similar Pc5 magnetic oscillations were identified in the H component of KTN and the eastward component of QZS-1 with in-phase relationship, indicating the counterclockwise rotation of magnetic perturbations by the ionospheric screening effect. The amplitude at KTN (35 nT) was ˜10 times larger than the amplitude at QZS-1 (3.5 nT). THEMIS-A satellite observed the Pc5 oscillation in the electric field with the amplitude of ˜1 [mV/m] but there was no clear magnetic oscillation. The electric field oscillated in antiphase with the eastward component magnetic field at QZS-1. The ETS-8 geosynchronous satellite at L=6.6 did not observe the similar oscillation, indicating that the this Pc5 event was limited at the specific L shell. The other several good conjunction events were found, and these are going to be analyzed. We also plan to compare the observation to the field-aligned structure of electric and magnetic fields derived from model calculations of the field line resonance and the ionospheric screening effect.

# Magnetic field dipolarization in the deep inner magnetosphere: Simultaneous observations by Arase and Michibiki satellites

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Recent satellite observations by MDS-1 and Van Allen Probes statistically revealed that magnetic field dipolarization can be detected over a wide range of L in the deep inner magnetosphere (i.e., L = 3.5-6.5, which is far inside the geosynchronous altitude). It is accompanied by magnetic field fluctuations having a characteristic timescale of a few to 10 s, which is comparable to the local gyroperiod of $O^+$ ions. These magnetic field fluctuations are considered to cause nonadiabatic local acceleration of ions.

In this study, we intend to confirm the above-mentioned characteristics of magnetic field dipolarization in the inner magnetosphere, using the magnetic field data and the energetic ion flux data measured by the Exploration of energization and Radiation in Geospace (ERG) “Arase” satellite. The Arase satellite was launched on December 20, 2016 into an elliptical orbit having an apogee of 6.0 Re, a perigee of 440 km altitude, an orbital period of ~9.5 h, and an orbital inclination of ~32 degrees. During the first magnetic storm of March 27, 2017 after Arase started scientific operation, Arase observes clear dipolarization signatures around 1500 UT at L~4.6 and MLT~5.7 hr. Strong magnetic field fluctuations are embedded in the magnetic field dipolarization and their characteristic frequency is close to the local gyrofrequency of $O^+$ ions. Both $H^+$ and $O^+$ flux enhancements are observed in accordance with the dipolarization. These results are consistent with the previous results. In this event, the Quasi-Zenith Satellite (QZS)-1 “Michibiki” satellite was located at L~7.0 and MLT~23.8 hr, and observes similar dipolarization signatures with a few minute time difference. Simultaneous observations by both Arase and Michibiki provides us a unique opportunity to investigate how fast and wide the dipolarization propagates in the inner magnetosphere. In the presentation, we will show detailed analysis results of the dipolarization event on March 27, 2017 as well as similar events.

# Theory, Modeling, and Integrated studies in the ARASE(ERG) project

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The Arase satellite was launched in December 2016 as a part of the Japanese geospace research project, ERG. The science target of the ERG project is to understand underlying mechanisms of drastic variations of the geospace such as magnetic storms with a focus on the relativistic electron acceleration and loss processes in the terrestrial magnetosphere. In order to achieve the goal, the ERG project consists of the three parts, i.e., the Arase (ERG) satellite, ground-based observations, and theory/modeling/integrated studies. The role of theory/modeling/integrated studies part is to promote relevant theoretical and simulation studies as well as integrated data analysis to combine different kinds of observations and modeling. From the planning phase of the ERG satellite, there has been many efforts to develop related simulation codes and new models. In this paper, we provide an overview of simulation and empirical models related to the ERG project together with their roles in the integrated studies of dynamic geospace variations. The simulation and empirical models covered include Radial diffusion model of the radiation belt electrons, GEMSIS-RB and RBW models, CIMI model with either empirical or global MHD electric and magnetic fields, GEMSIS-Ring Current model, plasmasphere model, self-consistent wave-particle interaction simulations (Electron hybrid code and ion hybrid code), GEMSIS-POT model, and SuperDARN electric field models with data assimilation. In the presentation, some examples of integrated studies will be also reported.

# ERG-Science Center (ERG-SC): the hub of ERG science activities

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ERG-Science Center (ERG-SC) can be recognized as a set of efforts led by the joint research center for space science operated by ISEE, Nagoya University and JAXA/ISAS. ERG-SC is responsible for a wide variety of tasks for the Exploration of energization and Radiation in Geospace (ERG) project: development of science data archive and data analysis tools, planning of satellite observation, coordination with ground-based observations and simulation/modeling efforts, and promotion of inter-project collaborations. Following the provisional CDF data, level-2 data (calibrated, in physical unit) and the higher level data products of the ERG satellite are prepared and to be made available to users through the ERG-SC online data repository. Not only the satellite data but also ERG-related ground observational data have been available from the data archive. ERG-SC has developed and updated a set of IDL scripts, referred to as ERG-SC plug-in for SPEDAS (Space Physics Environment Data Analysis Software) enabling users to analyze multiple instrument data seamlessly and also combine them easily with other satellite/ground/simulation/modeling data. ERG-SC also plays a main role in making regular and campaign observation plans for the ERG satellite in concert with collaborative observation projects. In the presentation, recent updates on various activities of ERG-SC are reviewed to provide active and potential users with concise and useful information on the ERG project data and how to access/analyze them.