R006-01
A 会場 ：9/25　 PM1 （13:45-15:30）
13:45〜14:00

#田中　良昌 1), 小川　泰信 2), 吹澤　瑞貴 2), 細川　敬祐 3), 門倉　昭 1), 津田　卓雄 3)
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Spatiotemporal variation of 3D distribution of discrete auroral arcs

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We have analyzed the three-dimensional (3D) distribution of the discrete auroral arcs observed in Northern Europe on March 14, 2015, by using Aurora Computed Tomography (ACT), which is a method for reconstructing 3D distribution of auroral optical emission from monochromatic images taken at multi-point imager network. We compared the obtained height profiles of optical emission at 427.8nm wavelength with those of the electron density observed by the EISCAT UHF radar and found that they were very similar each other. On the other hand, the electron density estimated by the ACT analysis was smaller than that observed with the radar by a factor of about 2 and it was not clear what made the difference.

We recently improved the ACT method mainly with respect to the following points; (1) the determination of the relative sensitivity between imagers, (2) the reconstruction using multi-wavelength monochromatic images, (3) the reconstruction considering the temporal variation of electron density, and (4) the validation of the reconstruction result by simulation under realistic conditions. In this study, we present reanalysis results of the discrete arcs by using the improved ACT method. We compare the electron density estimated by ACT with the EISCAT radar observation and further discuss the spatiotemporal variation of the 3D distribution of the discrete arcs.

R006-02
A 会場 ：9/25　 PM1 （13:45-15:30）
14:00～14:15

#森井　雄大 [1), 三好　由純 [1), 栗田　怜 [2), 中村　るみ [3), 細川　敬祐 [4), 大山　伸一郎 [1), 今城　峻 [5), 小川　泰信 [6), 齊藤　慎司 [7), 浅村　和史 [8)
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Study of spatial structure of the omega-band aurora using ground-based multi-wave length cameras and magnetospheric satellites

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The omega band aurora is an aurora that appears from the late expansion phase to the recovery phase of a substorm. It is known to have a latitudinal auroral structure with a discrete auroral feature on the poleward side and a pulsating auroral structure on the equatorial side. The omega band typically drifts eastward from midnight to dawn-side. Previous ground-based studies indicated that there are strong upward and downward Field Aligned Currents (FACs) embedded in the omega band aurora. While several characteristics of the omega band aurora have been reported, the flux and characteristic energy of precipitating electrons that cause the aurora and the relationship between them, and the FACs are not yet clear. In this study, we have analyzed the optical emission at 427.8 nm and 844.6 nm of the omega band aurora with an EMCCD camera located in Tromso (69.6N degree: geographic latitude, 66.7N degree: magnetic latitude), and we have derived the spatial structure of the characteristic energy and downward energy flux of the precipitating electrons from the ratio of intensities of these emissions at the two wavelengths. As a result, no significant differences are found in the characteristic energy in the east-west direction, while the downward energy flux on the western side of the omega band is larger than that on the eastern side. In addition, during an omega band aurora event on March 2, 2017, the MMS satellites carried out a conjugate observation with the all-sky camera in Tromso on the magnetospheric side of the omega band. The satellites observed upward and downward FACs near the equatorial plane when their footprint was located within the omega band. The horizontal structure of the observed FACs is spatially smaller than that of previous studies based on ground-based observations, and we suggest that the spatial structure of FAC embedded in the omega band is smaller than previously thought.

オメガバンドオーロラはサブストーム拡大相後半から回復相にかけて起きるオーロラである。その特徴として、東側にドリフトし、また極側にディスクリートオーロラ、赤道側に脈動オーロラと、緯度方向に異なるオーロラ構造を持つことが知られている。また、オメガバンドオーロラ中には強い上向き、下向きの沿磁力線電流 (Field Aligned Current: FAC) が存在することが知られている。このようにオメガバンドオーロラは、その構造の中に様々な特徴を内包しているが、オーロラを起こしている降下電子のフラックスや特性エネルギー、またそれらと沿磁力線電流との関係は明らかになっていない。本研究ではトロムソ (69.6°　N: 地理緯度, 66.7°　N: 磁気緯度) に設置されている二波長を同時に計測する EMCCD カメラ群によって、オメガバンドオーロラの 427.8nm と 844.6nm の発光を同時に観測し、それらの発光強度比から、オメガバンドオーロラの降下電子の特性エネルギーと下向きエネルギーフラックスの空間構造を求めた。その結果、東西方向において特性エネルギーに違いは見られないものの、下向きエネルギーフラックスが西側で強くなることが分かった。さらに、2017 年 3 月 2 日は、トロムソ光学カメラで撮像されたオメガバンドの上空を MMS 衛星が通過し、磁気圏側での共役観測に成功した。MMS 衛星は、磁気圏南半球プラズマシートにおいて観測しており、そのフットプリントがオメガバンドを通過する際に、上向きと下向きの沿磁力線電流が観測された。観測された沿磁力線電流の水平構造の空間スケールは、これまで地上観測から報告されてきたオメガバンドオーロラにおける沿磁力線電流よりも空間的に小さいスケールである可能性が示唆された。

R006-03
A 会場 ：9/25　 PM1 （13:45-15:30）
14:15〜14:30

夜側で観測されたショックオーロラを構成する 3 種類の発光とその時空間発展

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A shock aurora and the delay of its three optical signatures observed at 21 MLT

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We report on the observation results of the interplanetary shock that reached Earth on 26 February 2023 and the resultant shock aurora. A rapid increase in the solar wind dynamic pressure caused by CME or CIR is known to cause geomagnetic activity called the geomagnetic sudden commencement (SC), and auroras called the shock aurora. Both propagate from the midday, i.e., the arrival region, to the night side based on the observation by the magnetometer network and the satellite imager. However, the night-side observation of the shock aurora is limited because the night-side-driven auroras, triggered by the ring current and/or plasma sheet activities, often contaminate the shock aurora. In this study, we report the observation results of the shock aurora associated with an SC detected at 19:24 UT on 26 February 2023, which happened when geomagnetic activity was nearly quiet. We used three digital cameras located in Kiruna, Sweden, and Skibotn, Norway, at 21 MLT.
In this event, we identified three auroral signatures with clear time delay, while two forms are often reported in the dayside cases. There was a brightening of the pre-existing weak arc (19:25 UT, poleward), a faint red emission (19:28 UT, equatorward), and a green discrete aurora with a spiral structure (19:31 UT, in between them in all-sky images). Data from the magnetometer network in Lapland suggested that the intensity of the upward field-aligned current (FAC) was strongest at 19:27 UT, three minutes after the onset. In the presentation, we discuss the relationship between the three types of signatures and the SC, the difference in propagation speeds of aurora and FAC, and the spatiotemporal development of the ionospheric current system estimated from the auroral morphology.

2023 年 2 月 26 日に地球へ到達した惑星間空間衝撃波とそれに伴って発生したショックオーロラの観測結果について報告する。CME や CIR などによって引き起こされる太陽風動圧の急激な増加は、地磁気急始変化（SC: sudden commencement）と呼ばれる地磁気活動や SC の到来に伴って昼側領域で発生するショックオーロラと呼ばれるオーロラを引き起こすことが知られている。これらはいずれも、磁力計ネットワークや人工衛星に搭載されたイメージャによる汎地球的な計測結果から、昼側から夜側に伝播することが知られている。しかしながら、夜側ではリングカレントやプラズマシートなどの SC とは独立した現象によって生じたオーロラが存在していることが多いため、夜側におけるショックオーロラの観測例は限られている。本研究では、地磁気活動が静穏であった 2023 年 2 月 26 日 19:24 UT に検出された SC に伴って発生したショックオーロラを、スウェーデン・キルナ及びノルウェー・シーボトン（21 MLT 付近）に設置した 3 つのデジタルカメラで観測した結果を報告する。昼側におけるショックオーロラの観測では 2 種類の形態が報告されることが多いが、本事例では 3 種類の形態が明確な時間差を伴って観測された。具体的には、SC 前から生じていた弱いアークの増光（19:25 UT）、弱いアークの赤道側における赤色の淡い発光（19: 28 UT）、弱いアークと赤色の発光の中間に現れた渦状構造を持つ緑色のディスクリートオーロラ（19:31 UT）である。光学観測に加え、北欧地域の磁力計ネットワークの計測から、上向きの沿磁力線電流の強度がオンセットから 3 分後の 19:27 UT に最も大きくなったこともわかった。発表では、3 種類の発光と SC の関係性、オーロラと沿磁力線電流の伝搬速度の違い、オーロラの形態から推察される電離圏電流の時空間発展を議論する予定である。

R006-04
A 会場 ：9/25　PM1 （13:45-15:30）
14:30～14:45

脈動オーロラの空間構造と降下電子エネルギーの制御に関するコーラス波ダクト伝搬の役割

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Possible roles of ducted propagation of chorus waves in controlling the characteristics of pulsating aurora

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Most of the diffuse auroras are known to show a quasi-periodic luminosity modulation called pulsating aurora (PsA). Magnetospheric electrons causing PsA are generally scattered through wave-particle interactions with whistler-mode chorus waves in the magnetosphere and precipitate into the ionosphere, being referred to as ”PsA electrons”. Previous studies clarified that sub-relativistic electrons originating from the radiation belt also precipitate down to lower altitudes together with PsA electrons, and strongly ionize the middle atmosphere [Miyoshi et al., 2015]. Recent numerical simulations suggested that precipitation of PsA electrons having an energy of tens of keV to sub-relativistic range require chorus waves to propagate to higher magnetic latitudes (MLAT) of ~20 deg and to resonate with the trapped highly energetic electrons [Miyoshi et al., 2015, 2020]. However, there have been no simultaneous observations simultaneous observations of PsAs and chorus waves showing such propagation to high latitudes; thus, we still do not quite well understand under what conditions PsA electrons become harder and precipitate down to lower altitudes.

To address this issue, we have investigated a PsA event from 02:10 to 04:15 UT on January 12, 2021, during which simultaneous observations with the Arase satellite, ground-based all-sky imagers and the European Incoherent SCATter (EISCAT) radar were conducted. Analyzing the simultaneous measurements, we tried to clarify the relationship between the morphology of PsA and the energy of PsA electrons, and then to understand what factors control the relationship. One of the main results is that, when the shape of PsA was patchy, the energy of the corresponding PsA electrons exceeded tens of keV. In addition, during this interval of relatively harder precipitation, chorus waves were observed by PWE/OFA on-board Arase at MLAT higher than 20 deg. Furthermore, 1) the energy flux of scattered electrons obtained by Medium-Energy Particle Experiments – Electron Analyzer: MEP-e onboard Arase, 2) the filling ratio of loss cone at the satellite location, and 3) the energy flux of PsA electrons estimated from EISCAT showed similar temporal variations. On the basis of these observational results, we hypothesize that the spatial structure of PsA and the energy of PsA electrons are controlled by the existence of ”density ducts,” which are tube-like regions where the electron density is lower or higher than the surrounding area. Those structures guide chorus waves along the magnetic field, allowing them to propagate to higher MLAT. In order to test this hypothesis, we compared the irregularity of the background electron density measured by Arase in the magnetosphere with the emission intensity of PsA patches at the spacecraft’s footprint. The irregularity of ~2—18% in the electron density possibly due to the existence of ducts show a good spatiotemporal correspondence with the emission intensity of PsA patches, which supports the above-mentioned hypothesis. However, the current hypothesis was proposed based on a single case study, and its universality, the background parameters and the physical process have not yet been understood well. To further test the hypothesis, we conducted a similar comparison using waves/particle data in the magnetosphere and the ionization profiles and optical data in the ionosphere obtained during other conjugate observations of PsA. In the presentation, we will show the observational results from multiple event analyses and discuss the background parameters of the ducts, the formation process, and the validity of the ducts as one of the factors controlling the morphology of PsA and the energy of the PsA electrons.

ディフューズオーロラの多くは，脈動オーロラ（Pulsating Aurora: PsA）と呼ばれる準周期的な輝度変調を示すことが知られている．PsA の発光をつくり出す磁気圏電子は，一般に磁気赤道面付近で発生する自然電磁波「ホイッスラーモードコーラス波」との波動粒子相互作用によって散乱され電離層に降下し，「PsA 電子」と呼ばれる．これまでの研究によって，放射線帯を起源とする相対論的な電子も PsA 電子とともに低高度まで降下し，中層大気を強く電離することが明らかにされている (Miyoshi et al., 2015). 近年の数値シミュレーションでは，数十 keV を超える準相対論的なエネルギーを持つ PsA 電子の降下には，コーラス波動が磁気緯度（MLAT）~20º の高緯度まで伝搬し、磁気圏に捕捉されている高エネルギー電子と共鳴することが必要であることが示されている (Miyoshi et al., 2015; 2020). しかし，PsA とコーラス波動の同時観測で，このような高緯度への伝搬を示す実例はなく，どのような条件下で PsA 電子のエネルギーが準相対論的になり、低高度まで降下するかは明らかになっていない.

この問題を解決するために，あらせ衛星・地上光学・EISCAT レーダーによる PsA の同時観測が成立し，PsA の形態遷移が顕著であった 2021 年 1 月 12 日 02:10—04:15 UT の事例について解析を行なった．これにより，磁気圏と電離圏で得られたデータの総合的な解析を通じて，PsA の形態と PsA 電子のエネルギーの関係を明らかにし，さらにその関係を制御する要因の解明を試みた．主な結果の一つは，PsA パッチ状の空間構造を持つ場合，対応する PsA 電子のエネルギーが数十 keV を超え 100 keV に近い値（準相対論的）となっていたことである．また，この比較的高いエネルギーを持った PsA 電子が降下していた時間帯において，あらせ衛星は高磁気緯度（MLAT >20º）でコーラス波を観測していた．さらに，1）あらせ衛星の中間エネルギー電子分析器（MEP-e）によって得られた磁気圏電子のエネルギーフラックス，2）磁気圏電子のロスコーン充填率，3）EISCAT レーダーによる電離分布から推定された PsA 電子のエネルギーフラックスの間には，時間変動に良い相関が確認された．これらの観測結果から，PsA の空間構造と PsA 電子のエネルギーは「密度ダクト (電子密度が背景密度よりも数 % から数十 % 高い，あるいは低い管状の領域)」の存在によって制御されているという仮説を立てた．磁気圏における電子密度のダクト構造は，コーラス波が磁場に沿ってより高い磁気緯度へ伝搬することを可能にすると考えられている．この仮説を検証するために，あらせ衛星から得られた電子密度の不規則性と，電離圏高度 100 km の衛星のフットプリントにおける PsA の発光強度を比較したところ，密度ダクトの存在に起因すると考えられる電子密度の不規則性（～2—18%）と PsA パッチに対応した発光強度の時空間変動が良く対応しており，上記の仮説を支持する結果が得られた．しかし，この「密度ダクト仮説」は単一の事例から提唱されたものであり，その普遍性，および背景パラメータに対する依存性や物理過程は十分に理解されていない．そこで，他の PsA の地上-衛星同時観測イベントについても同様に，磁気圏の波動や電子のデータ，電離圏の電離高度分布，PsA パッチに対応した発光強度の比較・解析を実施した．本発表では，その具体的な観測結果を示しながら，PsA の 形態と PsA 電子のエネルギーを支配する要因の一つと考えているコーラス波ダクト伝搬の背景にある磁気圏や電離圏におけるパラメータや物理過程，およびその妥当性について議論する予定である．

R006-05
A 会場 ：9/25　PM1 （13:45-15:30）
14:45～15:00

脈動オーロラに伴う幅広いエネルギー帯の電子の降りこみ：あらせ衛星-EISCAT の共同観測及びシミュレーション

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Wide energy electron precipitation associated with pulsating aurorae: Arase-EISCAT conjugate observations and simulations

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Wave-particle interactions with lower-band whistler-mode chorus (LBC) waves near the magnetic equator result in electron precipitation with energies from a few to a few tens of keV, leading to the diffuse and pulsating aurora (PsA). In addition to the low-energy electrons, recent studies have shown that relativistic electrons with energies from several hundreds of keV to several MeV are scattered by LBC waves propagating towards higher latitudes along field lines, and these electrons precipitate into the thermosphere as well as the mesosphere in association with PsA (Miyoshi et al., 2015, 2020, 2021). To understand electron precipitation over a wide energy range associated with PsA, we investigate an energetic electron precipitation event observed at Tromsoe, Norway, from 02:00 to 06:00 UT on March 12, 2022, using data from the Arase satellite and the European Incoherent Scatter (EISCAT) radar. First, we use the inversion method to estimate an energy spectrum of precipitating electrons from the height profile of electron density obtained by the EISCAT radar. The result shows precipitation of electrons over a wide energy range, and particularly strong precipitation is observed for low-energy (<several tens of keV) electrons. Next, we estimate the electron lifetimes using the quasi-linear pitch angle diffusion coefficient derived from the plasma wave and the ambient magnetic field data obtained from the Arase satellite. The result is that the estimated lifetimes are shorter than the strong diffusion limit especially for low-energy electrons, which is consistent with the EISCAT observations. We estimate the lifetimes as a function of the magnetic latitudes, and we find that the chorus waves observed at the Arase satellite position do not contribute to causing precipitation of hundreds of keV electrons, and propagation of LBC waves to the higher magnetic latitudes is important to cause wide energy electron precipitation. Finally, we conduct a data-driven simulation (GEMSIS-RBW, Saito et al., 2012) including non-linear wave-particle interactions. As similar to the quasi-linear analysis, strong precipitation of low-energy electrons has been reproduced in the simulation. Our integrated study combining with the data analysis and data-driven simulations strongly suggest that chorus waves propagating to high latitudes cause precipitation of electrons over a wide energy range.

R006-06
A 会場 ：9/25　PM1 （13:45-15:30）
15:00〜15:15

#八島　和輝 [1), 田口　聡 [1), 小池　春人 [1), 細川　敬祐 [2)
(1 京大理,(2 電通大

Intense low-energy electron precipitation associated with poleward expansion of red auroras near the nightside polar cap boundary

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Auroras often show poleward expansion near the nightside polar cap boundary, some of which are accompanied with clear red emission. This type of emission is caused by the rapid motion of intense low-energy electron precipitation, which is believed to be accelerated by Alfven waves that are occurring along the magnetic field lines connecting to the plasma sheet boundary layer. Previous studies based on satellite observations have unveiled the detailed energy profiles of that low-energy electron precipitation, and their spatial features. However, how the low-energy precipitation develops, which plays a crucial role in the dynamic poleward motion of the red aurora is still unknown. In this study, to understand the temporal characteristics of the low-energy electron acceleration, we created a group of models to derive the 2-D distribution of the low-energy electron flux from the 630-nm all-sky imager data obtained at Longyearbyen, Svalbard, by utilizing the Global Airglow model. We also tested the validity of those models by using examples of the conjugate observation of red auroras by the all-sky imager at Longyearbyen and low-energy electron precipitation by the DMSP satellite. We report on the characteristics of the variability of the intense low-energy electron precipitation revealed by applying our models to a large number of all-sky image data that captured the poleward expansion of red auroral arcs near the nightside polar cap boundary, and discuss what they imply for the injection of the Alfven waves along the magnetic field lines connecting to the plasma sheet boundary layer.

R006-07
A 会場 ：9/25 PM1 （13:45-15:30）
15:15〜15:30

オーロラ X プロジェクト：南極・極冠域の大気電離の研究

#片岡 龍峰[1), 坂野井 健[2), 細川 敬祐[3), 村田 健史[4), 水野 亮[5), 三好 由純[5), 加藤 千尋[6), 三宅 晶子[7), 海老原 祐輔[8), 藤田 茂[9), 中野 慎也[9,13), 中溝 葵[4), 山岸 久雄[1), 行松 彰[1,13), 田中 良昌[1,12,13), 小川 泰信[1,13), 村瀬 清華[13), 中村 勇貴[10), 渡辺 正和[11), 小財 正義[12), 西山 尚典[1,13), 門倉 昭[1,12,13), ムナカタ カズオキ[6)
([1] 極地研,([2] 東北大学,([3] 電気通信大学,([4] 情報通信研究機構,([5] 名古屋大学,([6] 信州大学,([7] 茨城高専,([8] 京都大学,([9] 統計数理研究所,([10] 東京大学,([11] 九州大学,([12] 極域環境データサイエンスセンター,([13] 総合研究大学院大学

AuroraXcosmic project to study the atmospheric ionizations in southern polar cap

#Ryuho Kataoka[1)],Takeshi Sakanoi[2)],Keisuke Hosokawa[3)],Ken Murata[4)],Akira Mizuno[5)],Yoshizumi Miyoshi[5)],Chihiro Kato[6)],Shoko Miyake[7)],Yusuke Ebihara[8)],Shigeru Fujita[9)],Shinya Nakano[9,13)],Aoi Nakamizo[4)],Hisao Yamagishi[1)],Akira Sessai Yukimatu[1,13)],Yoshimasa Tanaka[1,12,13)],Yasunobu Ogawa[1,13)],Kiyoka Murase[13)],Yuki Nakamura[10)],Masakazu Watanabe[11)],Masayoshi Kozai[12)],Takanori Nishiyama[1,13)],Akira Kadokura[1,12,13)],Kazuoki Munakata[6)]
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Japanese Antarctic research program AJ1007 (Space environmental changes and their effects on the Earth's atmosphere explored from the polar cap region, 2022-2027), auroraXcosmic project in short, is supported by NIPR/JARE. We are studying space weather and space climate from Antarctica to understand how the Earth system is open to space, focusing on the southern polar cap where the atmosphere is directly affected by various types of energetic particles from space. In this presentation, we would like to share the current status of the project, such as all-sky camera development and the installation plan via the international collaborations, with new model development toward the space weather reanalysis data study.

R006-08
A 会場 ：9/25　 PM2 （15:45-18:15）
16:00〜16:15

SC 研究の今後の課題

#荒木　徹 [1)]
[(1] 京大理

Future Problems of SC research

#Tohru Araki[1)]
[(1]Formerly Graduate School of Science Kyoto University

There is a model that divides the SC disturbance field Dsc into DL + DPpi + DPmi, but this is related to the interpretation of the waveform distribution on the ground, and does not give the full picture of the SC phenomenon. The SC observed on the whole earth and in the whole magnetosphere shows different faces depending on the latitude, altitude, LT of the observation point. By analyzing each of the faces we can know the complex reactions of the system composed of the magnetosphere, ionosphere and conducting earth. The current issues for this analysis are summarized below.
1. SC as a nonlinear phenomenon: large amp litude SC.
1a: Instantaneous formation of radiation belts,
1b: Presence of large and short pulses in the magnetosphere,
1c: Response of the magnetosphere and ionosphere.
2. SC in the polar cap.
2a: Observation of the new polar cap current system proposed by Fujita et al.(2021),
2b: IMF dependence of polar cap SCs,
2c: Polarization of SCs.
3. SC in middle and lower latitudes.
3a: Relationship between equatorial enhancement and polar electric field,
3b: SC D/Y component behavior,
4. Solar wind shock/discontinuity of the pre-satellite era.
These issues are discussed with examples.
Many Japanese have contributed to SC research since Prof. Aikitsu Tanakadate, who was the coordinator of the SC committee at IGGU-STME（the predecessor of the current IUGG-IAGA）. The number of citations of papers seems to be the highest among Japanese. I hope that many people will join SC research and that this tradition will be preserved.

SC 擾乱場 Dsc を，DL+DPpi+Dmi　と分けるモデルがあるが，これは，SC 地上波形分布の解釈に関するもので，これで SC 現象の全貌が判る訳ではない．全地上・全磁気圏で観測される SC は，観測点の緯度・高度・LT・季節・太陽活動度などに依存して異なる顔を見せるから，その注意深い解析から，太陽風動圧急変化に対する磁気圏-電離層-導体地球系の複雑な反応が判ってくる．以下に，この解析のための現段階の課題を纏める．
１．非線形現象としての SC:　大振幅 SC
1a：放射線帯の瞬時形成
1b：磁気圏内大短パルスの起源と伝搬
１ c：磁気圏・電離層の反応
２．極冠内 SC
2a：新極冠電流系（計算機実験：Fujita et al., 2021）に対応する観測
2b：極冠内 SC の IMF 依存性
2c：SC の偏波
３．中低位緯度の SC
3a：equatorial enhancement と極電場の関係
3b：SC の D/Y 成分の振舞い
４．飛翔体観測以前の太陽風衝撃波/不連続面
これらの課題について，例を示しながら述べる．
現在の IUGG-IAGA の前身である IGGU-STME で，SC 調査委員会のまとめ役をされた田中館愛橘先生以来，SC 研究には多くの日本人が貢献してきた．論文の引用数も，日本人のものが最も多いと思われる．多くの方々が SC 研究に入り，この伝統が守られることを期待したい．

R006-09
A 会場 ：9/25　PM2 （15:45-18:15）
16:15〜16:30

沿磁力線電流ダイナモと地磁気サブストーム発達の関係について

#海老原　祐輔 [1], 田中　高史 [2]
([1] 京大生存圏,([2] 九大

Relation between field-aligned current (FAC) dynamo and evolution of geomagnetic substorm

#Yusuke Ebihara[1],Takashi Tanaka[2]
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Field-aligned currents (FACs) are known to give rise to enhancements of the ionospheric currents that characterize the evolution of geomagnetic substorms from the growth phase to the recovery phase. The generation of the FACs is a key in understanding the geomagnetic substorm, but it is a long-lasting issue. By incorporating a new method into the global magnetohydrodynamics (MHD) simulation, we have identified key regions that act as the generator of the FACs, that is, FAC dynamos. Hereinafter, we call it an FAC dynamo. In the FAC dynamo, (1) the field-perpendicular current is converted to FAC, (2) plasma performs negative work against the magnetic tension force so as to excite the Alfven waves, and (3) rate of change in the FACs is nonzero, according to Ampere's and Faraday's laws. We backtraced packets of the Alfven waves from the ionosphere to the magnetosphere, and identified two regions that probably act as FAC dynamos. One is located in the flank (low-latitude) magnetopause region, which generates most of the Region 1 FACs. Solar wind plasma pulls newly reconnected magnetic field lines. When the Region 1 FACs develop, the two-cell ionospheric convection is enhanced, giving rise to the geomagnetic disturbances that characterize the growth phase of the geomagnetic substorm (Ebihara and Tanaka, 2022). The other one is located in the near-Earth region in the nightside equatorial region. Azimuthally flowing plasma driven by the near-Earth reconnection pulls the magnetic field lines so as to generate the Region 1-sense FAC. When the Region 1-sense FACs arrives at the Earth, substorm expansion begins (Ebihara and Tanaka, 2023). From these results, it can be said that the evolution of the geomagnetic substorm is characterized by the development of the FAC dynamo. We will overview the FAC dynamos in the magnetosphere by showing 3-dimensional distribution of them, and relation to the magnetospheric and ionospheric disturbances.

R006-10
A 会場 ：9/25　 PM2 （15:45-18:15）
16:30〜16:45

北向き IMF での磁気圏電離圏対流と null-separator 構造

#藤田　茂 [1), 渡辺　正和 [2), 蔡　東生 [3), 田中　高史 [4)
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The magnetosphere-ionosphere convection in the northward IMF condition and the null-separator structure

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The magnetosphere-ionosphere convection in the northward IMF condition has three modes; one is the round cell convection confined in the polar cap (the lobe cell), the next is round cell convection crossing the open-closed boundary (the merging cell), the last is the crescent cell convection in the nightside polar cap [Tanaka, 1999]. The crescent cell convection crosses the open-close boundary. Tanaka [1999] and Watanabe et al. [2005] revealed that crescent cell convection belongs to the exchange cell convection. We reconsidered how these convections occur under the null separator structure of the magnetic field lines when IMFBz is positive and IMFBy is negative.

The main findings of this research are as follows;
1) The cylinders of the null-separator structure form the lobes. The cylinders have slots open to the solar wind. Solar wind plasma can enter the lobe through this slot. The plasma pressure increases in this slot region in the lobe. This structure is the plasma bulge [Tanaka et al., 2017]. Furthermore, when IMFBy is negative, the plasma entering the lobe, when viewed from the tail, convects in two vortex modes: clockwise on the equator near the plasma sheet and counterclockwise on the opposite side.

2) We examined the streamlines of plasma convection originating from the solar wind. There are two modes of convection streamlines. We consider the streamlines starting the solar wind in the northern hemisphere.
First, the convection streamlines starting from the pole side of the separator line and penetrating the cusp traverse a segment of magnetic field lines extending from the northern ionosphere to the null point of the overdraping field.
Second, among the convection streamlines generated from the opposite side of the separator line, those that cross the field line segment from the null point of the overdraping magnetic field line to the solar wind in the northern hemisphere enter the lobe of the southern hemisphere at first and reach the lobe of the northern hemisphere.

3) The solar-wind magnetic field lines carried by the convection starting from the pole side of the separator line (the first case of #2) first cause reconnection with the open magnetic field lines passing through the northern hemisphere null point. After that, the magnetic field lines ride on the counterclockwise convection in the lobe mentioned in 1). This results in round cell convection in the ionosphere. When the starting point of convection in the solar wind is close to the separator line, the convection crosses the open/close boundary. At this time, whenever convection crosses an open-close field line boundary, reconnection occurs at the northern hemisphere null point. Conversely, the convection that started from a slightly distant place causes reconnection only once at a null point in the northern hemisphere and then becomes lobe cell convection that convects only within the lobe.

4) The convection from the solar wind on the equator side of the separator line (the second case of #2) first causes reconnection at the null point in the southern hemisphere. After that, it crosses the closed magnetic field line region of the plasma sheet and enters the northern hemisphere. In the northern hemisphere, it enters the lobe's clockwise convection region. This creates crescent cell convection in the ionosphere.

Tanaka, T. (1999), Configuration of the magnetosphere-ionosphere convection system under northward IMF conditions with nonzero IMF By, J. Geophys. Res., 104(A7), 14683-14690, doi:10.1029/1999JA900077.
Tanaka, T., T. Obara, M. Watanabe, S. Fujita, Y. Ebihara, and R. Kataoka (2017), Formation of the Sun-aligned arc region and the void (polar slot) under the null-separator structure, J. Geophys. Res. Space Physics, 122, doi:10.1002/2016JA023584.
Watanabe, M., K. Kabin, G. J. Sofko, R. Rankin, T. I. Gombosi, A. J. Ridley, and C. R. Clauer (2005), Internal reconnection for northward interplanetary magnetic field, J. Geophys. Res., 110, A06210, doi:10.1029/2004JA010832.

R006-11
A 会場 ：9/25　 PM2 （15:45-18:15）
16:45〜17:00

極冠分岐の磁場トポロジー

#渡辺　正和 [1), 蔡　東生 [2), 熊　沛坤 [2), 藤田　茂 [3), 田中　高史 [4)
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Magnetic field topology of polar cap bifurcation

#Masakazu Watanabe[1)],DongSheng Cai[2)],Peikun Xiong[2)],Shigeru Fujita[3)],Takashi Tanaka[4)]
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The polar cap is defined as the region of closed magnetic fields in the ionosphere and forms usually a simply connected disk. In global magnetohydrodynamic simulations for northward interplanetary magnetic field (IMF), there often occurs a phenomenon in which the simple connectivity is broken. For example, an "island" or "exclave" of the open flux region emerges inside the dawnside or duskside auroral oval. Interestingly, under this configuration, closed field lines and IMF lines are tangled in the magnetotail. We refer to such a non-disk polar cap as just described as a "bifurcated" polar cap. Although polar cap bifurcation can occur even for steady solar wind or steady IMF conditions, it occurs almost certainly with a 40-50min timelag after a solar wind or IMF jolt impinges on the magnetosphere. The basic magnetic field structure of the magnetosphere consists of two magnetic nulls and two separators connecting them (the 2-null, 2-separator structure). Polar cap bifurcation indicates the breakdown of the basic structure. In this study, we propose a magnetospheric magnetic topology model that produces the polar cap bifurcation. Although the basic structure with the two nulls (an A type null in the Northern hemisphere and a B type null in the Southern Hemisphere) is still retained, each null becomes multiple to form a cluster (a null cluster of A type in the Northern Hemisphere and a null cluster of B type in the Southern Hemisphere). The multiplied nulls are expected to be higher order in the sense that they cannot be expressed by linear approximation. Although the internal structure of the null cluster is still unclear, this null clustering model can successfully explain the polar cap bifurcation and the associated tangling of closed lines and IMF lines in the magnetotail.

極冠は極域電離圏の開磁力線領域と定義され、通常は単連結の円板である。惑星間空間磁場北向き時のグローバル磁気流体シミュレーションでは、極冠の単連結性が崩れる現象がしばしば現れる。例えば、朝方側（または夕方側）のオーロラオーバルの中に開磁束領域の「島」あるいは「飛び地」が出現する。興味深いことに、このとき磁気圏尾部では閉磁力線と惑星間空間磁力線が絡み合う構造が出来ている。このように、電離圏高度でみたとき、極冠が円板でなくなることを「極冠分岐」と呼ぶ。極冠分岐は定常太陽風かつ定常惑星間磁場の下でも発生し得るが、太陽風または惑星間空間磁場に擾乱を与えると、40 − 50 分の時間差でかなりの高確率で出現する。磁気圏磁場は、零点 2 個とそれらを結ぶ 2 本のセパレータで構成される「2-零点，2-セパレータ構造」が基本である。極冠分岐現象は、この基本構造が壊れることを意味する。本研究では、極冠分岐を起こす磁気圏磁場トポロジーのモデルを提唱する。零点 2 個（北半球に A 型、南半球に B 型）の基本構造は保たれているものの、各零点が多重化する。すなわち、北半球では複数の A 型零点から成る零点群が形成され、南半球では複数の B 型零点から成る零点群が形成される。多重化した零点は（線形近似では表現できないという意味で）高次の零点と予想される。この零点群モデルは、内部構造は依然不明だが、極冠分岐やそれに伴う尾部での閉磁力線と惑星間空間磁力線の絡みをうまく説明できる。

R006-12
A 会場 ：9/25　 PM2 （15:45-18:15）
17:00〜17:15

#橋本　翼 [1), 吉川　顕正 [2), 田中　高史 [3)
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Scattered perpendicular flow speed in the dayside reconnection regions due to change in the IMF Bz direction

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In the dayside magnetopause, southward Interplanetary Magnetic Fields (IMFs) are known to form a continuous reconnection flow by Dungey cycle reconnection. On the other hand, northward IMFs form a magnetic barrier due to the accumulation of the northward IMFs. This magnetic barrier is disrupted when southward IMFs reach the dayside magnetosheath region and reconnect with northward IMFs. In this study, we implemented the 3D MHD Reproduce Plasma Universe (REPPU) code to reproduce this phenomenon and discover its features. We visualized the magnetic field lines and the plasma flow perpendicular to the magnetic field lines (Vperp). Simulation results revealed a scattered Vperp pattern due to reconnection between the incoming southward IMFs with the accumulated northward IMFs. The reason of the occurrence of this phenomenon was that the in-flow magnetic field strength of this IMFs reconnection was weaker than the Dungey cycle reconnection. Therefore, the reconnection jet became slower and the magnetic field lines did not immediately move downstream from the reconnection region, which caused the scattering of the plasma flow. In this presentation, we will describe this phenomenon, and the input conditions of this IMFs reconnection, including the feature of the scattered Vperp distribution.

南向き惑星間空間磁場（IMF）が地球に吹き続けると、昼側磁気圏境界面でダンジ―サイクルリコネクションが生じ、連続的なリコネクションフローが形成される。一方、北向き惑星間空間磁場（IMF）が地球に吹き続けると、昼側磁気シース領域にはそれらが積み重なり磁気バリア領域が形成される。この磁気バリア領域は、次に南向き IMF が到達したとき、IMF 同士でリコネクションし、その領域は破壊されていく。本研究では、三次元 MHD コードである REPPU コードを用い、この現象の再現と特徴の抽出を行った。可視化した物理量は、主に磁力線構造と磁力線に垂直なプラズマフロー (V ⊥) である。このシミュレーションの結果、IMF 同士のリコネクションによりできた磁力線の間に点在化する V ⊥の構造が見られた。このような構造形成の理由としては、ダンジ―サイクルのリコネクションなどに比べ、IMF 同士のリコネクション時のインフロ―における磁場強度が弱いため、リコネクションジェットも弱い。そのため磁力線が下流に移動しづらく、リコネクション頻度の減少、次のリコネクションが起こるまでに時間がかかることで、点在化するような構造が可視化されたと考えられる。本発表では、IMF 同士のリコネクションについて、点在化する V ⊥や現象についてより詳しく述べていく。

R006-13
A 会場 ：9/25　 PM2 （15:45-18:15）
17:15〜17:30

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Outflow jets from lobe reconnection: Roles of shear flow in reconnection

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One of the key parameters controlling magnetic reconnection is the bulk flow that is predominantly aligned with the reconnecting magnetic field. Several simulation studies and theoretical predictions have suggested that the reconnection rate and the outflow jet speed can be reduced as flow shear in the bulk flow increases. More recent simulations have indicated that the reconnection rate is not necessarily affected by the presence of shear flow. Further studies need to be done to clarify the role of shear flow in the reconnection process. For the northward interplanetary magnetic field, reconnection can occur at high latitudes of the Earth's magnetopause, where the magnetosheath flow in the tailward direction acts as shear flow. In this study, we investigate the role of shear flow in reconnection on a basis of data from high-latitude lobe reconnection events observed by spacecraft. We first devised an automated lobe reconnection detection routine that can apply for data from Cluster spacecraft, and then collected the lobe reconnection events by examining data obtained by Cluster-3 spacecraft for more than 5 years. The statistical analysis revealed that the ion outflow jet tends to increase as the velocity of the magnetosheath flow tangential to the current sheet increases. This indicates that a process is occurring that ion acceleration is enhanced as the shear flow increases. It was also found that the ion temperature in the outflow jets tends to be higher in the earthward flow region than in the tailward flow region, suggesting that the conditions under which flow shear is occurring act to heat the ions. We will discuss these tendencies in terms of the turbulent nature of the Hall electric field which is caused by complicated counterstreaming ion distribution consisting of the downstream-flowing magnetosheath ions and the earthward-flowing ions from reconnection.

R006-14
A 会場 ：9/25　 PM2 （15:45-18:15）
17:30〜17:45

#関　華奈子 [1), 佐伯　僚介 [2), 桂華　邦裕 [1), 齋藤　義文 [3), 篠原　育 [3), 宮下　幸長 [4,5)
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Dependence of ion and electron properties in the central plasma sheet on the solar wind conditions: Long-term Geotail observations

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Observations have shown that conditions in the Earth's plasma sheet is largely changed by the solar wind conditions. There is good correlation, for example, between solar wind density and plasma sheet density. The cold and dense plasma sheet is formed under northward IMF (interplanetary magnetic field), while the hot and tenuous plasma sheet is formed under southward IMF [e.g., Terasawa et al., 1997]. From these facts, the major plasma source of the plasma sheet is considered to be the solar wind and the plasma supply mechanisms depend largely on the IMF orientation. One of the important parameters to give us a clue of the supply mechanisms is the temperature ratio between ions (T_i) and electrons (T_e). The solar wind plasma is heated as entering into the magnetosphere. The temperature ratio (T_i/T_e) in the magnetosheath is often higher than that in the plasma sheet. Wang et al. [2012] showed that there is dawn-dusk asymmetry of T_i/T_e in the plasma sheet. However, how ion and electron temperatures and their ratio change with the solar wind conditions is far from understood.

Utilizing long-term magnetotail observations by the Geotail spacecraft at tailward distances of 10-30 R_e during a period over a solar cycle from 1995 to 2006, we here investigate statistical properties of the central plasma sheet (CPS). We conducted statistical analyses with calibrated LEP-EA ion and electron data as well as the magnetic field data onboard Geotail. We selected CPS observations and derived temperature and density using the same method and criteria as Terasawa et al. [1997]. The results show that the plasma sheet density (temperature) has a good correlation with the solar wind density (kinetic energy) throughout the solar cycle. We find clear dawn-dusk asymmetry in T_i/T_e. The average T_i/T_e is higher on the duskside than on the dawnside only under northward-Bz-dominant IMF conditions. Observations also indicate that the dawn-dusk asymmetry of T_i/T_e is caused by high-density, low temperature, and high-T_i/T_e plasma entry from dusk, which has properties similar to the magnetosheath plasma. The IMF dependence of the T_i/T_e asymmetry cannot be explained by previously considered the magnetic drift effects [e.g., Wang et al., 2012]. Our statistical results suggest that the shocked solar wind plasma can easily enter the duskside plasma sheet rather than the dawnside during northwad IMF periods. A possible scenario to explain these observations is an asymmetric plasma entry by Kelvin-Helmholtz instability (KHI), since previous studies have suggested higher occurrence frequency of KHI in the duskside than dawnside [e.g., Bouhram et al., 2005; Taylor et al., 2012]. In the presentation, we will also report on empirical models of the central plasma sheet ion and electron temperatures as well as density based on the long-term observations.

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R006-15
A 会場 ：9/25 PM2 （15:45-18:15）
17:45〜18:00

サブストーム時の地球近傍プラズマシートにおけるイオンの加速率のエネルギー、ピッチ角、質量、電荷依存性

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Energy, pitch angle, mass and charge dependent acceleration of ions in the near-Earth plasma sheet during substorms

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The energetic ions are known to be abruptly enhanced in the near-Earth plasma sheet during the substorm expansion. Recent studies have shown that the enhancements of the ions depend on energy, mass and charge, but the reason is not well known. We have investigated energy, pitch angle, mass and charge dependent acceleration of H, He and O ions in the near-Earth plasma sheet during substorms by tracing the ions backward in time in time-dependent magnetic and electric fields obtained by the global magnetohydrodynamics (MHD) simulation. When the dipolarization of the geomagnetic field lines takes place, the ions are accelerated adiabatically and nonadiabatically. The significant acceleration occurs near the equatorial plane where the curvature radius of the magnetic field line is small. The acceleration is found to depend entirely on the location in the near-Earth plasma sheet. "Void structures" (Nakayama et al., 2016) appear in energy- time spectrograms in particular regions, in which acceleration of the ions does not occur at low energies. The degree of the acceleration in the void structures is found to depend on mass and pitch angle. We will discuss the dependence of the acceleration of the ions, or furthermore, the dependence of the differential flux of the ions which are correlated with the acceleration, and compare with satellite observations.

R006-16
A 会場 ：9/25　 PM2 （15:45-18:15）
18:00～18:15

プラズマ粒子シミュレーションのためのロスコーン分布の乱数生成法

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Loading loss-cone distributions in particle simulations

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The loss-cone distribution is one of the most characteristic velocity distributions in space plasmas, in particular in the inner magnetosphere. Many scientists study wave-particle interaction and other issues by means of kinetic simulations in a loss-cone distributed plasma, such as the subtracted Maxwellian, the Dory-type loss-cone (DGH in short) distribution, and the kappa loss-cone (KLC) distributions. This presentation will provide numerical recipes to initialize loss-cone type velocity distributions.

First, we propose rejection algorithms to initialize the subtracted Maxwellian. Depending on the shape parameter beta, one can select an appropriate envelope distributions to efficiently generate the distribution. Second, we propose a simple algorithm to initialize the DGH distribution. Third, inspired by algorithms for the student's t-distribution and for the DGH distribution, we construct a novel algorithm to initialize a Summers-type KLC distribution.

All these distributions have a hole rather than a loss cone near the velocity center, because the density cavity is modeled by the perpendicular velocity. To better express the loss cone, we propose to use a pitch angle instead. To this end, we propose a transform algorithm that converts a spherically-symmetric distribution into a loss-cone distribution. This allows us to generate a loss-cone and KLC distributions from the Maxwell and kappa distributions straightforwardly.

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A New Technique for Space Plasma Measurements Using Floating-mode Avalanche Photodiode Combined with Electrostatic Energy Analyzer

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A novel type of instrumental development based on a “floating-mode” avalanche photodiode (APD) combined with an electrostatic energy analyzer was conducted toward future space plasma exploration missions. A “cusp-type” electrostatic analyzer (MEP-e: Medium-energy particle experiments-electron analyzer) with normal-mode (non-floating-mode) APD onboard the ERG (Arase) satellite for the geospace exploration was able to cover an energy range up to ~87 keV and a wide angular coverage with a 360-deg. field-of-view (FOV). Although the original lowermost energy of MEP-e is ~7 keV, the combination of the floating-mode APD with the cusp-type analyzer could lead us to more comprehensive and accurate electron measurements in a much wider energy range from a few eV to hundreds of keV. While this measurement concept was originally initiated before the ERG mission formally started, our recent experimental results verified that this “combination” technique could drastically improve both the quality and quantity of the space plasma observations, firstly in terms of the electron energy analyses. While a high voltage power supply of ~+5 kV, depending on the APD performance, is needed for the floating mode, several APD properties, represented by rough energy analysis capability for noise reduction by double energy discriminations, low dark count, compact dimension, and lightweight, could be valuable and promising also in the floating-mode APDs combined with electrostatic analyzer. When this advanced type of in-situ measurement technique is employed, for instance, in a small satellite mission under stringent resource restrictions, wide-energy/angular distributions of electrons in space could be captured by a single sensor head on a spin-stabilized satellite. It, moreover, would be possible to detect energetic ions beyond 5 keV/q and discriminate He2+ of the solar wind origin from H+ as the major ion species of the space plasma when the polarities of high voltages to the floating-mode APD and the inner shell of the electrostatic analyzer could be switched to be negative in the identical sensor head. The measurement technique developed in our experimental activities indicates that the single sensor head is alternately available for both electron and ion measurements in space.

R006-18
A 会場 ：9/26 AM1 （9:00-10:30）
9:15～9:30

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A two‐ stage deflection system for the extension of the energy coverage in space plasma three‐ dimensional measurements

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The in situ measurement of charged particles plays a key role in understanding space plasma physics. Velocity distribution functions of ions and electrons have been acquired with electrostatic analyzers onboard spacecraft. Since conventional energy analyzers (e.g., top-hat electrostatic analyzers) have essentially a two-dimensional field of view, the solid angle coverage is achieved with the aid of spacecraft spin motion or with additional entrance deflection systems in front of the electrostatic analyzer. In the latter case, however, the full angular scan is realized only in the lower energy range (typically only up to 5 – 15 keV/e), due to the limitation of the electric field applied to the deflector. Here we propose a novel deflection system for extending the energy coverage up to tens of keV. This is especially useful for plasma observations in situations where the anisotropy of the energetic part (>10 keV) of charged particles plays an essential role in plasma dynamics and hence is of significant interest.

R006-19
A 会場 ：9/26　AM1 （9:00-10:30）
9:30〜9:45

#カリオコスキ　ミラ [1), 浅村　和史 [2), 篠原　育 [3), 三谷　烈史 [4), 堀　智昭 [5), 三好　由純 [6), 東尾　奈々 [1), 高島　健 [1)
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New method for calibrating Arase HEP-L data using XEP data and Geant4 simulation of MeV electron contamination

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[(1]Japan Aerospace Exploration Agency,[(2]Japan Aerospace Exploration Agency,[(3]Japan Aerospace Exploration Agency/Institute of Space and Astronautical Science,[(4]Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science,[(5]Institute for Space-Earth Environmental Research, Nagoya University,[(6]Institute for Space-Earth Environement Research, Nagoya University

The Arase satellite observes the dynamics of the Earth's radiation belts, including the electron fluxes over a wide energy range from a few electronvolts to several MeV. The measurements of the Arase high-energy electron experiment (HEP) instrument have been previously calibrated based on the modeled response functions of the instrument's energy channels. This utilized Geant4 simulations of electrons impacting the detectors of the instrument when arriving through the collimator hole. The current study presents a new, additional method for calibrating the HEP-L instrument data by exploring the level of contamination at the ~100 keV energies caused by penetrating MeV electrons. The estimation is performed using a Geant4 simulation of the HEP-L instrument, where the energy deposition of 1-10 MeV electrons to the detector layers is modeled. These MeV electrons do not only enter the instrument through the collimator but have enough energy to penetrate through the outer structure of the instrument. In the simulation, the electrons are initialized isotropically over a hemispherical dome around the instrument. The simulation results of the response of the HEP-L instrument's keV energy channels are used to estimate the level of contamination in the actual HEP-L measurements. Additionally, the actual measurements of MeV electrons from the extremely high-energy electron experiment (XEP) are utilized in the comparison and calibration. HEP-L measurements are also compared to measurements at the similar energy from the medium-energy particle experiment electron analyzer (MEP-e). The ratio of HEP-L and MEP-e fluxes is analyzed based on the level of MeV electron flux measured by XEP and the contribution of MeV electrons at lower energies is taken into account based on the Geant4 simulation. The new correction factors derived from MeV electron contamination are applied to comparisons of Arase data with Van Allen Probes observations during close conjunctions of the spacecraft. In particular, the pitch angle distributions are studied as they shed light on the wave-particle interactions occurring in the radiation belts. Previous comparisons have considered only the omnidirectional fluxes which offer a limited view of the radiation belt dynamics.

R006-20
A 会場 ：9/26　 AM1 （9:00-10:30）
9:45～10:00

光電子と衛星帯電によるスプリアス太陽向き電場成分の除去

#中川　朋子 [1), 堀　智昭 [2), 中村　紗都子 [3), 笠羽　康正 [4), 小路　真史 [2), 三好　由純 [5), 松田　昇也 [6), 笠原　禎也 [7), 篠原　育 [8)
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Subtraction of spurious sunward electric field component generated by photo-electrons and spacecraft charging

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The Electric Field Detector (EFD) of the Plasma Wave Experiment (PWE) instrument onboard the Arase satellite measures the magnetospheric electric field with two sets of double probes. The electric field measurement of Arase suffers from a spurious pseudo-sunward electric field component induced by spacecraft charging and photoelectrons. When detecting the spurious sunward electric field, EFD recorded a distorted waveform of spin modulation in the electric potential difference between the probes and the spacecraft. It is found that the distorted waveform is due to a combined electric potential applied by two model charges each representing the photoelectron cloud and spacecraft charging. Fitting some parameters of the two charges to the observed waveforms, we estimated the amounts of the two charges and the positions of the center of the photoelectron cloud. In this fitting process, it is assumed that the spacecraft charting is displaced by 1 m from the center of the trajectory of the spin motion of the probes toward the direction of the photoelectron cloud. The resultant fitted parameters have successfully reproduced the observed distortion in the waveforms of the potential difference. By subtracting the distorted component, we try to derive the magnetospheric electric field from raw potential waveforms obtained by Arase.

磁気圏の電場を観測することは、磁気圏対流など、グローバルな磁気圏のダイナミクスをとらえるうえで重要である。磁気圏の DC 電場を観測するには、人工衛星から伸展したプローブ間の電位差を計測するダブルプローブ法が多く使われてきた。衛星の自転（スピン）周期の間で一定とみなせるような DC ないし低周波の電場であれば、そのスピン面内成分は、スピン周期の正弦波振動として検出される。これにより DC 的なオフセット成分を分離し、低周波電場を得るというデータ処理が従来行われてきた。
このような電場計測は、衛星からの光電子放出により大きな影響を受けることが知られている。過去においては、衛星からの光電子がプローブに流入することにより日照側プローブの電位が下がり、偽の太陽向き電場として検出されると考えられた。ジオスペース探査衛星「あらせ」のプラズマ波動・電場観測器 (Plasma Wave Experiment / Electric Field Detector, PWE/EFD) においても、偽の太陽向き電場が観測されている。このような時、あらせ衛星の高時間分解能の衛星¬・プローブ間電位差データは、ピークに凹みのある特徴的な波形を示していた。
この特徴的な波形は、衛星から放出された光電子雲と衛星表面の帯電を各１個の正電荷・負電荷で代表させることでモデル化すると、それぞれの作る電位構造の和で再現できることがわかった。光電子雲と衛星帯電が衛星のスピン軸からずれていれば、自転に伴ってプローブと各電荷との距離が変わり、電荷に近い位置に鋭いピークを持つ電位差波形が得られる。正負の電荷の位置が異なるため、両者の作る電位差波形は同じではなく、足し合わせると正弦波とは異なる歪んだ波形となる。ただし正負の電荷が極限まで近づくと（双極子電場）正弦波に漸近する。歪んではいても、スピン周期の成分を持つため、従来の方法のように単に正弦波でフィッティングすると、偽の太陽向き電場として観測されてしまうのである。
衛星¬・プローブ間電位差波形の歪みは、正負の電荷の位置と電荷量によって変化するため、波形の歪みから光電子雲および衛星帯電の影響を逆算、差し引くことに一部成功した。観測される電位差波形には、光電子および衛星帯電による成分と、これとは独立な外部電場による成分が含まれ、それぞれ位相の異なるスピン周期の正弦波成分を含む。そこで、まず単純な正弦波フィッティングをして DC オフセット成分とスピン周期成分を除き、光電子および衛星帯電による特徴的な高調波成分だけを抽出、これをもとに観測波形の歪みを最もよく再現する衛星帯電の電荷量、光電子雲の電荷量と位置を求めた。また衛星筐体のサイズなどを考慮し、衛星帯電の位置は、衛星の自転に伴うプローブの円軌道の中心から光電子のいる方向（太陽に近い方向）に１mと仮定した。
これにより、光電子放出が卓越する領域での「偽太陽向き電場」の除去がある程度できるようになった。しかしそのなかでも、短時間、波形の歪みが消失し光電子および衛星帯電の影響を算出できなくなるケースがあった。その原因は調査中である。

R006-21
A 会場 ：9/26　AM1 （9:00-10:30）
10:00～10:15

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Low-cost magnetometers using MI sensors: Estimation of magnetospheric plasma mass density from multi-point observation

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Magneto-impedance (MI) effect was discovered about 25 years ago and a micro-size magnetic sensor that utilizes this effect becomes commercially available. We made some modifications to the commercially available MI sensors as they can cover the range of the geomagnetic field. For the period of March 30 to April 27, 2018, we conducted experimental observations of geomagnetic field variations with the MI sensors at Mineyama observation site, which is located about 100 km north-west of Kyoto. Data obtained with the MI sensors were compared with those from the fluxgate magnetometer that has been working at the site. Results showed that the MI sensor recorded geomagnetic variations with amplitudes of ~1 nT that were also detected with the fluxgate magnetometer. This suggests that MI sensors are useful for research in geomagnetism or space physics, although they are much less expensive than fluxgate magnetometers.

Nomura [2021] developed a triaxial magnetometer which is composed of the MI sensors, Raspberry Pi, low-cost 24-bit A/D converters, and stable power supply circuits. This magnetometer is named MIM-Pi, and the cost of MIM-Pi is about one-tenth of that of fluxgate magnetometer. However, the result of the test at Inabu observation site in Japan showed that MIM-Pi had step noises with amplitudes of 2 － 3 nT which originated from an A/D converter. Therefore, we replaced the A/D converter with a new A/D conversion module (ADPi) and confirmed that modified MIM-Pi did not have such step noises. Long-term observation at Inabu with MIM-Pi has been performed since November 19, 2021 to January 14, 2022. The results show that MIM-Pi can record Sq variations and geomagnetic pulsations with amplitudes of 1 － 2 nT that were also detected with the fluxgate magnetometer. We also performed long-term observation at Kakioka Magnetic Observatory and found that MIM-Pi can identify Pc4 pulsations. To install MIM-Pi in a field, we made a jig for MI sensors and a case for the controller. The continuous observations with MIM-Pi's have been started at Kawatabi Observatory from September 9, 2022, at Shirakami observation site from November 15, 2022 and at Mutsu observation site from May 31, 2023. Comparing the acquired geomagnetic data with temperature data, we found that the data acquired by MIM-Pi was affected by temperature variations. We also found that Pc4 and Pi2 pulsations were recorded with MIM-Pi. From the frequencies of Pc4 pulsations, we estimate the plasma mass density in the inner magnetosphere. In presentation, we will show the MIM-Pi data and initial analysis results about the estimation of the plasma mass density. Future deployment of MIM-Pi in Tohoku-Hokkaido region will be also discussed.

R006-22
A 会場 ：9/26　AM1 （9:00-10:30）
10:15〜10:30

地球磁気圏に付随した電荷交換 X 線放射の変動予測モデリング

#伊師　大貴 [1), 石川　久美 [2), 江副　祐一郎 [2), 三好　由純 [3), 寺田　直樹 [4)
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Modeling of charge exchange X-ray emission associated with the Earth's magnetosphere

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We report on modeling of soft X-ray emission produced in the Earth's magnetosphere. Highly charged solar wind ions produce soft X-rays through charge exchange (CX) with neutral materials in the Earth's exosphere. The magnetosheath and cusps should be growing in soft X-rays due to dense populations of solar wind plasma and exospheric neutrals, which provides a means of X-raying the Earth's magnetosphere (e.g., Ezoe et al. 2018 JATIS). This emission is problematic for astronomical observations due to temporally variable foregrounds that often contaminate signals from astronomical objects (e.g., Ezoe et al. 2011 PASJ, Ishikawa et al. 2013 PASJ, Ishi et al. 2019 PASJ). However, it remains difficult to predict its contamination level.

We built an empirical CX model by combining an exospheric hydrogen distribution model, CX cross section values based on ground experiments and theoretical calculations, solar wind ion data taken with WIND and ACE satellites, and magnetic field models of the Earth's magnetosphere (Ishi et al. 2023 PASJ). We then compared model results with five Suzaku observations of bright CX events where the strongest oxygen emission lines can be seen. The modeled intensities of OVII emission lines were consistent with the observed ones except for an intense geomagnetic storm event, while those of OVIII emission lines were underestimated by a factor of 5-10. After scaling, our model reproduced OVII and OVIII light curves including short-term variations due to line-of-sight directions traversing cusp regions during an orbital motion. In this paper, we discuss these results as well as future prospects with XRISM and GEO-X.

本講演では、地球磁気圏に付随した電荷交換 X 線放射のモデル化と X 線天文衛星「すざく」で観測された発光例との比較について報告する。近年「すざく」衛星などの X 線観測において、地球磁気圏起因と考えられる X 線放射が発見されてきた (Ezoe et al. 2011 PASJ, Ishikawa et al. 2013 PASJ, Ishi et al. 2019 PASJ など)。太陽風に含まれる酸素や炭素などの多価イオンが地球周辺に薄く広がる外圏の主に水素原子から電子を奪う電荷交換反応 (Charge eXchange; CX) に伴う X 線である。太陽風密度が増す衝撃波後方の遷移領域、外圏密度が濃くなる地球近傍のカスプ領域で強く放射されていると考えられており、X 線は昼側磁気圏構造を可視化する全く新しい手段となり得る (江副 2018 天文月報, Ezoe et al. 2018 JATIS など)。本放射は基本的に磁気圏内から行われる X 線観測において、常に前景放射として存在するものであり、発光分布や強度の正確な見積もりは重要である。

そこで我々は、太陽風変動、地球外圏分布、磁気圏形状を包括的に取り入れた予測モデルを構築した (伊師 2023 博士論文, Ishi et al. 2023 PASJ)。ACE および WIND 衛星の太陽風イオン測定値、地球外圏の水素密度の経験式、地上実験および理論計算にもとづく CX 断面積・遷移確率を視線方向に積分し、放射強度を見積もる。積分領域にあたる遷移領域やカスプ形状はバウショック・磁気圏界面の経験モデルおよび Tsyganenko 地球磁場モデルで再現し、ショック下流の太陽風パラメータはランキン・ユゴニオを仮定した。「すざく」衛星の明るい発光 5 例において、予想発光強度を観測値と比較した結果、磁気嵐時かつ視線方向が夜側を向いていた 1 例を除き、OVII 発光強度はモデル誤差の範囲内で一致した。一方、OVIII 発光強度は全事象で 5-10 倍以上過少評価した。前者は磁気嵐時の内部磁気圏への太陽風流入、後者は太陽風 O8+ 測定値または断面積に原因があると考えられる。各輝線の時間変動についても比較すると、数時間程度の変動だけでなく、衛星が地球周回中、視線方向がカスプ領域を横切る際に生じる 5-10 分程度の突発的な変動も再現できることが分かった。以上の結果を議論し、XRISM 衛星や GEO-X 衛星での展望を述べる。

R006-23
A 会場 ：9/26 AM2 （10:45-12:30）
11:00〜11:15

#中溝　葵 [1), 吉川　顕正 [2,5), 中田　裕之 [3), 深沢　圭一郎 [4), 田中　高史 [5)
(1 情報通信研究機構,(2 九州大学大学院理学研究院,(3 千葉大学大学院工学研究院,(4 京都大学学術情報メディアセンター,(5 九州大学国際宇宙惑星環境研究センター

Evolution of M-I convection depending on the Alfven conductance as simulated by global MHD model with Alfvenic coupling

#Aoi Nakamizo[1),Akimasa Yoshikawa[2,5),Hiroyuki Nakata[3),Keiichiro Fukazawa[4),Takashi Tanaka[5)
(1NICT,(2Faculty of Science, Kyushu University,(3Graduate School of Engineering, Chiba University,(4Academic Center for Computing and Media Studies, Kyoto University,(5i-SPES

In global magnetosphere models, the magnetosphere-ionosphere coupling process is conventionally described in the following manner. (1) First, at the inner boundary, which is usually placed at the altitude of 2 –　3 Re, the distribution of FAC is calculated from the magnetic field. (2) The FAC is mapped to the ionospheric altitude and input to the ionospheric potential solver. (3) Then the calculated potential is mapped back to the inner boundary and the magnetospheric bulk velocity is updated there.

Here we would like to point out that this conventional coupling scheme has two issues.

The first issue is about the way of exchanging information of physical quantities at the inner boundary. The ionospheric input, FAC, is specified only by the magnetic field, whereas the quantity updated by ionospheric output is only the velocity. Therefore, the current continuity, momentum and energy conservations are not guaranteed before and after this procedure. The second issue concerns the ionospheric potential solver. The potential solver calculates the electrostatic potential so that it is consistent with the input FAC for the given conductance distribution. This means that it is designed to generate no FACs in the ionosphere. However, in reality, the ionospheric current divergence will be released partially to the magnetosphere due to the finite Alfven conductance.

Considering these two issues of the conventional scheme, a new scheme called Alfvenic Coupling was proposed by Yoshikawa et al. [2010]. In this scheme, both the magnetic field and velocity disturbances (FAC and potential) are input to the ionospheric solver and updated with the required consistency for the current closure condition including the Alfvenic disturbances.

We have implemented this scheme into the global MHD model to investigate the dynamics of M-I coupled system. In this study, we perform simulation by setting a fixed ratio of the Alfven conductance to the Pedersen conductance to examine the effect of the Alfvenic coupling. As the ratio increases, the ionospheric potential is intensified, and its distribution is more deformed. This tendency is consistent with a theoretical prediction [Yoshikawa & Fujii, 2018]. We will also show how the evolution of magnetospheric convection field differs for the convectional and Alfvenic coupling schemes.

R006-24
A 会場 ：9/26　 AM2 （10:45-12:30）
11:15〜11:30

#吉川　顕正 [1)]
(1 九大/理学研究院

Development of Affine connections to describe 3D evolving magnetic vector fields and its application to space physics

#Akimasa Yoshikawa[1)]
(1 Department of Earth and Planetary Sciences, Kyushu University

We have developed a new connection form to describe the magnetic vector field as a set of different magnetic field lines (vector bundles) and their interrelationships.

In this methodology, the geometry of magnetic field lines as spatial vector curves is grasped by employing magnetic field lines as the principal curves of the Frenet dynamic coordinate system, and by connecting the principal and secondary normals of neighboring magnetic field lines, vector curves are formed.

By adopting this connection form, the magnetic field vector space is filled by the connected local orthonormal coordinate system.

Conventional vector analysis applied to vector bundles of various physical quantities that emerge there can be uniquely described by the torsion and curvature of the principal, normal, and subnormal vector curves of the magnetic field that form the 3D network, as well as their spatial gradient distributions of vector amplitude.

In this talk, I will reconstruct the spatial geometry of the current distribution associated with the spatio-temporal evolution of the magnetic field using this framework, and discuss the importance of linking the development of physical and geometric quantities through specific examples for various types of Ohm’s law for magnetic fields induction.

R006-25
A 会場 ：9/26　AM2 （10:45-12:30）
11:30〜11:45

#田口　聡 [1), 小池　春人 [1), 細川　敬祐 [2)
(1 京大理,(2 電通大

Alfvenic features at 500 km altitude for the cusp aurora

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(1Department of Geophysics, Graduate School of Science, Kyoto University,(2Graduate School of Informatics and Engineering, University of Electro-Communications

Previous studies based on satellite observations have shown that Alfvenic features can be seen in the cusp, coexisting with the low-energy electron precipitation. It is not yet well understood how those Alfvenic features are related to the temporal characteristics of the cusp aurora, such as the increase in aurora brightness near the equatorward boundary of the main cusp region, and the poleward motion of the cusp aurora detached from the main cusp region. In this study, we examined data from the conjugate observation of cusp auroras obtained at a wavelength of 630 nm by a ground-based all-sky imager and the electric and magnetic fields obtained at the cusp at an altitude of about 500 km by the SWARM spacecraft. The result of the analysis shows that there is a common signature consistent with Alfven wave trapping at frequencies of 0.6 Hz to 1.2 Hz, and that the electric field power of the wave varies depending on the relative position inside the cusp or the time elapsed since the initial brightening. We discuss the reasons for this dependence.

R006-26
A 会場 ：9/26　AM2 （10:45-12:30）
11:45〜12:00

#石丸　宏樹 [1), 今城　峻 [1), 三好　由純 [2), 風間　洋一 [3), 浅村　和史 [4), 松岡　彩子 [1),Wang Shiang-Yu[3),Tam Sunny W.Y.[5),Jun Chae-Woo[2), 篠原　育 [6)
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The altitude distribution of electron conic source estimated with the Arase satellite

#Hiroki Ishimaru[1),Shun Imajo[1),Yoshizumi Miyoshi[2),Yoichi Kazama[3),Kazushi Asamura[4),Ayako Matsuoka[1),Shiang-Yu Wang[3),Sunny W.Y. Tam[5),Chae-Woo Jun[2),Iku Shinohara[6)
(1Graduate School of Science, Kyoto University,(2Institute for Space-Earth Environement Research, Nagoya University,(3Academia Sinica Institute of Astronomy and Astrophysics,(4Japan Aerospace Exploration Agency,(5National Cheng Kung University,(6Japan Aerospace Exploration Agency/Institute of Space and Astronautical Science,(7Japan Aerospace Exploration Agency/Institute of Space and Astronautical Science

We examined the source altitude of electron conics by analyzing high-angular resolution electron data obtained by the Arase satellite. We surveyed electron conic events between August and September 2017 and identified electron conics with ion beams observed at an altitude of ~30,000 km above the auroral acceleration region, on 31 August, 16 September and 25 September. Assuming that the observed electron conics have adiabatically moved upward from the source altitude and undergone a potential difference along the dipole field line, we fit energy-dependent loss cone curves to the electron flux distribution of the conics to estimate the mirror ratio and the potential difference between the source and the satellite altitude. The center and the upper edge of the source altitude of electron conic were estimated to ~5000 km and ~10,000 km, respectively, from the estimated mirror ratio. The source altitude of electron conic approximately matched the simultaneously observed AKR source altitude, at which a parallel electric field is formed. This result suggests two hypotheses for the generation of electron conics: electron heating due to time-varying electric fields that accelerate auroral electrons, and diffusive heating due to waves, such as electrostatic waves seen around this altitude. We also compared the phase space densities of downward and upward electrons to determine their heating rates. The heating rate is proportional to the potential drop below the satellite, indicating that a large parallel electric field is associated with the electron conic generation.

R006-27
A 会場 ：9/26 AM2 （10:45-12:30）
12:00～12:15

磁気嵐時のカスプにおけるイオン流出のモデリング

#北村 成寿 [1],Glocer Alex[2]
[1 名大・宇地研,[2NASA ゴダード宇宙飛行センター

Modeling of acceleration of outflowing ions in the storm-time cusp

#Naritoshi Kitamura[1],Alex Glocer[2]
[1Institute for Space-Earth Environmental Research, Nagoya University,[2NASA Goddard Space Flight Center

In this presentation, we show the results of simulations of ion outflows associated with soft electron precipitation, frictional heating, and acceleration due to broad band ELF (BBELF) waves in an idealized cusp region during geomagnetic storms. The cusp region has been regarded as a major source of magnetospheric O^+ (and heavy ions) [e.g., Lockwood et al., JGR, 1985], which increases greatly during geomagnetic storms [e.g., Greenspan and Hamilton, JGR, 2002; Nose et al., JGR, 2005]. Under southward IMF conditions, the cusp becomes very thin in the latitudinal direction [e.g., Newell and Meng, JGR, 1987; Zhang et al., JGR, 2005]. Since a poleward flow is expected in the cusp under southward IMF conditions due to the dayside reconnection on magnetic field lines at the equatorward edge of the cusp, flux tubes cannot stay long time in the cusp. Thus, ion acceleration in the cusp seen from a convecting flux tube is not expected to last for a long time. Here we show the results of simulations of ion outflows with 2-min acceleration. Under the assumption of the latitudinal width of the cusp as 1 degree and the poleward convection velocity as 1 km/s, a convecting flux tube can stay in the cusp about 2 minutes. To investigate effects of soft electron precipitation, frictional ion heating, and ion acceleration due to broad band ELF (BBELF) waves on ion outflows, we used the kinetic polar wind outflow model (kinetic-PWOM) [Glocer et al., JGR, 2018], which uses the particle-in-cell approach with Monte Carlo collisions above 1000 km altitude. Although ion upflows (upward ion bulk flow much slower than the escaping velocity) around several hundreds of kilometers are driven by soft electron precipitation and frictional ion heating, the upward velocities are insufficient for most of O^+ to reach the altitude where acceleration due to waves become efficient within the time to pass through the cusp. O^+ density and flux at high altitudes near the cusp are controlled mostly by acceleration due to BBELF wave. Because it is impossible to travel long distance within a limited time interval (2-min here) of the acceleration, local acceleration rate and initial O^+ density at the altitudes where acceleration is effective are more important as compared with supply from the ionosphere as ion upflows. Based on this result, the solar zenith angle (sunlit or dark) at the ionospheric footprint and solar activity, which have a large impact on the temperature and scale height of O^+, can also be an important factor in determining O^+ outflow fluxes near the cusp during geomagnetic storms.

R006-28
A 会場 ：9/26 AM2 （10:45-12:30）
12:15～12:30

#山内 大輔 [1), 原田 裕己 [2), 桂華 邦裕 [3), 山本 和弘 [4), 永松 愛子 [5), 横田 勝一郎 [6), 齋藤 義文 [7)
[1 名大宇地研,[2 京大・理,[3 東大・理,[4 東大・理・地惑,[5 筑波宇宙センター,[6 大阪大,[7 宇宙研

Terrestrial-origin O+ ions below 1 keV near the Moon measured with the KAGUYA satellite

#Daisuke Yamauchi[1)],Yuki Harada[2)],Kunihiro Keika[3)],Kazuhiro Yamamoto[4)],Aiko Nagamatsu[5)],Shoichiro Yokota[6)],Yoshifumi Saito[7)]
[1Institute for Space-Earth Environmental Research, Nagoya Univ,[2Graduate School of Science, Kyoto University,[3Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo,[4Graduate School of Science, The University of Tokyo,[5Tsukuba Space Center, Japan Aerospace Exploration Agency,[6Osaka University,[7Department of Solar System Sciences, Institute of Space and Astronautical Science

Currently, lunar exploration is being planned by many countries. Among them, NASA plans to build a near-lunar manned base “Gateway” as part of a lunar exploration program called the Artemis Program. One of the main objectives of the Gateway is to elucidate the ion composition around the Moon. Prior to the launch of the Gateway, it is important to investigate the ion composition around the Moon using data from the lunar orbiter KAGUYA, which was launched by Japan in 2007. Results of such studies will be useful for a future analysis of the Gateway data. According to a previous studying using the KAGUYA data by Terada et al. [2017], O+ ions with energies of 1 – 10 keV, which are considered to be accelerated ions of Earth origin, were abundant only when the Moon was located within the Earth’s plasma sheet. O+ ions with energies below 1 keV were often observed when KAGUYA was positioned on the dayside of the Moon, and thus were concluded to be ions of lunar origin. This previous study examined in detail only one particular day (April 21, 2008) when the Moon was located within the Earth’s magnetotail. However, it is possible that some O+ ions with energies below 1 keV are also of terrestrial origin. In this study, we analyze O+ ions with energies below 1 keV for two typical events when the Moon was located within the magnetic lobe. It is found in three time intervals (14 – 21 UT on June 19, 2008, 14 – 24 UT on June 7, 2009, and 11 – 12 UT on June 8, 2009) that O+ ions coming into the polar angle of 0 degree – 22.5 degree of the PACE/IMA instrument have larger counts than those into the polar angle of 67.5 degree – 90 degree, indicating that these O+ ions are possibly terrestrial origin. We also statistically investigate the correlation between the Earth’s geomagnetic activity and the difference of the count ratios of O+ ions to the moon ions (Na+ and Al+) between the polar angles 0 degree – 22.5 degree and 67.5 degree – 90 degree using the whole mission data from KAGUYA between October 4, 2007 and June 11, 2009. In presentation, we will discuss the contribution of the low-energy O+ ions of terrestrial origin to the lunar environment.

R006-29
A 会場 ：9/27　 AM1 （9:00-10:30）
9:00～9:15

#三好　由純 1), 齊藤　慎司 2), 栗田　怜 3), 松田　昇也 4), 加藤　雄人 5), 片岡　龍峰 6), 今城　峻 7), 堀　智昭 8), 中村　紗都子 9), 三谷　烈史 10), 篠原　育 11), 笠原　慧 12), 横田　勝一郎 13), 桂華　邦裕 14), 浅村　和史 15), 松岡　彩子 16), 土屋　史紀 17), 熊本　篤志 5), 笠原　禎也 18)
(1 名大 ISEE,(2 情報通信研究機構,(3 京都大学 生存研,(4 金沢大学,(5 東北大・理・地球物理,(6 極地研,(7 京大・地磁気センター,(8 名大 ISEE,(9IAR&ISEE,(10 宇宙研,(11 宇宙研／宇宙機構,(12 東京大学,(13 大阪大,(14 東大・理,(15 宇宙研,(16 京都大学,(17 東北大・理・惑星プラズマ大気,(18 金沢大

Evolution of energy spectrum during electron accelerations in the outer radiation belt

#Yoshizumi Miyoshi1),Shinji Saito2),Satoshi Kurita3),Shoya Matsuda4),Yuto Katoh5),Ryuho Kataoka6),Shun Imajo7),Tomoaki Hori8),Satoko Nakamura9),Takefumi Mitani10),Iku Shinohara11),Satoshi Kasahara12),Shoichiro Yokota13),Kunihiro Keika14),Kazushi Asamura15),Ayako Matsuoka16),Fuminori Tsuchiya17),Atsushi Kumamoto5),Yoshiya Kasahara18)
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The Arase satellite has observed the inner magnetosphere since 2017 and thereby provided long-term data of plasma/particles and field/waves. Our previous investigations have revealed the presence of glowing peaks in the phase space density located just outside the plasmapause, indicating that non-adiabatic acceleration takes place in the small fp/fc region. In this study, we investigate the evolution of the energy spectrum during electron accelerations outside the plasmapause. We evaluated the time scales associated with the spectrum hardening, and the result shows that the equivalent temperature increase of the energy spectrum is a few tens keV/day. We compare them with a simulation of electron accelerations driven by wave-particle interactions and discuss possible acceleration mechanisms for electrons just outside the plasmapause.

R006-30
A 会場 ：9/27　 AM1 （9:00-10:30）
9:15〜9:30

#桂華　邦裕 [1), 関　華奈子 [2), 笠原　慧 [3), 横田　勝一郎 [4), 三好　由純 [5), 堀　智昭 [6), 篠原　育 [7), 松岡　彩子 [8)
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Characteristics of energetic ions contributing to the storm-time ring current: Long-term observations by Arase/MEP-i

#Kunihiro Keika[1),Kanako Seki[2),Satoshi Kasahara[3),Shoichiro Yokota[4),Yoshizumi Miyoshi[5),Tomoaki Hori[6),Iku Shinohara[7),Ayako Matsuoka[8)
(1Graduate School of Science, The University of Tokyo,(2Graduate School of Science, The University of Tokyo,(3Graduate School of Science, The University of Tokyo,(4Graduate School of Science, Osaka University,(5Institute for Space-Earth Environement Research, Nagoya University,(6Institute for Space-Earth Environmental Research, Nagoya University,(7Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science,(8Graduate School of Science, Kyoto University

This study investigates plasma transport and energization in the inner magnetosphere and the near-Earth magnetotail. It is well known that the inner magnetosphere is composed of plasma with a wide range of energies, from eV to MeV. The plasma pressure is contributed mostly from ions with energies of ~1 to a few hundreds of keV. The energetic ions are primarily transported from the near-Earth plasma sheet and energized during the transport. The spatial distribution of the energetic ions and its temporal evolution determines the variations of the plasma pressure in the inner magnetosphere and in turn the buildup and decay of the ring current.

The distribution function of the energetic ions in velocity space is a key to fully understanding the storm-time energetic ion dynamics. This study thus examines the temporal and spatial variations of phase space densities of energetic ions for different values of the first adiabatic invariant (mu). We identify the mu values that make the most significant contribution to the total plasma pressure. We then focus on the dependence of the contributing mu values on the radial distances and ion species. We primarily use data from the MEP-i (Medium-Energy Particle experiments - ion mass analyzer) on board the Arase spacecraft. MEP-i measures ions with energies of ~10 to 180 keV/q and distinguishes between different ion species. The mu values covered by MEP-i depends mostly on the radial distance because the magnetic field strength on the Arase trajectories changes predominantly with the radial distance. We confirm that the MEP-i energy range can cover typical contributing mu values, 0.05 to 0.5 keV/nT, in a wide range of the radial distances.

We conduct a statistical study for 37 magnetic storms observed by the Arase spacecraft in 2007 to present: 10 intense storms with the minimum Dst (Dst_min) smaller than -70 nT and 27 moderate storms with Dst_min between -70 and -50 nT. We perform the energy spectral analysis for different ion species to identify the contributing mu values, for each of three different storm phases: the main phase, around storm maximum, and early recovery phase. The MEP-i observations show that the plasma pressure is maximized at L of 3 to 4; the maximum pressure is predominantly contributed from ions with mu values of 0.1 keV/nT or slightly lower on average. The results suggest that lower-energy ions of hot plasma sheet populations (typically 1-10 keV) make the important contribution to the core part of the storm-time ring current. At higher L shells, L>4, the contributing mu values are 0.1 keVnT or higher, up to 0.3 keV/nT, and more importantly, different between ion species. It is higher for heavier ions such as O+ than H+. The results suggest that heavier ions are energized more preferentially in the near-Earth magnetotail and that mass-dependent energization processes contribute to the plasma pressure in the outer part of the ring current.

R006-31
A 会場 ：9/27　 AM1 （9:00-10:30）
9:30～9:45

#永谷　朱佳理 [1), 三好　由純 [2), 浅村　和史 [3),Kistler Lynn[9), 中村　紗都子 [4), 小路　真史 [5), 篠原　育 [6), 小川　泰信 [7), 関　華奈子 [8)
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Statistical analysis of magnetospheric molecular ions from the Arase observations

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In the Earth's magnetosphere, several kinds of ions originate from both the solar wind and the ionosphere. Molecular ions in the magnetosphere are originated in the Earth's ionosphere. The Arase satellite has observed various kinds of ions since 2017, using two ion analyzers, LEPi and MEPi, which cover the energy range from 10 eV/q to 180 keV/q.

Using the data from the MEPi instrument, a previous study has investigated variations of molecular ions in response to magnetic storms and solar wind conditions, and molecular ions have been observed in the inner magnetosphere even during small magnetic disturbances [Seki et al., 2019]. However, observations about molecular ions are still relatively limited in comparison to other ion observations, and mechanisms of molecular ion outflow from the ionosphere as well as the long-term variations in the magnetosphere have not been well known.

In this study, we analyzed the time-of-flight (TOF) data from LEPi [Asamura et al., 2018] onboard Arase to investigate variations of molecular ions in the inner magnetosphere and their correlation with magnetic activity condition as well as the solar cycle. LEPi covers the energy range from 10 eV/q to 25 keV/q and obtains flux as a function of energy and TOF. The TOF measurements of LEPi have been operated in the outbound pass every four revolutions around the Earth. The estimated counts of molecular ions are derived by fitting the empirical function using a non-linear least square method to the TOF profiles. The count data are calibrated with the long-term trend of the MCP efficiency of the LEPi instrument.

Using this data set, we investigate relationships between molecular ion counts and geomagnetic index as well as solar wind parameters. The results indicate that molecular ion counts exhibit a significant correlation with magnetic storms (Sym-H index) as well as solar wind speed. Moreover, we found that molecular ions and oxygen ions have similar responses to these parameters, suggesting that the same mechanisms contribute to outflows of both the oxygen ions and the molecular ions. We found the long-term variations associated with the solar cycle. It is worthwhile to note that counts of the molecular ions have increased significantly after the commencement of the 25th solar cycle, suggesting that the solar EUV largely controls the scaleheight of molecular ions in the ionosphere and counts of the molecular ions in the magnetosphere increase.

R006-32
A 会場 ：9/27　 AM1 （9:00-10:30）
9:45～10:00

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Statistical study of the overlap region between plasmasphere and ring-current ions using the Van Allen Probes satellites

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In the Earth's inner magnetosphere at the region about 4-6 times of the Earth's radius, low-energy dense plasma in the plasmasphere partially overlaps with the high-energy plasma regions called the ring-current. The interaction of these two plasma regions through Coulomb collisions and various electromagnetic waves causes acceleration and disappearance of the particles. Past conjugate observations using magnetospheric satellites and ground-based all-sky cameras have shown that Stable Auroral Red arcs, Isolated Proton Aurora, and STEVE, which are optical phenomena seen at subauroral latitudes, always originate in this region. However, there are limited number of conjugate observations between magnetospheric satellites and ground-based all-sky cameras, and no statistical analysis has been conducted about the overlap of the plasmasphere and the ring-current region. This study aims to statistically characterize the geomagnetic index, local time, and solar activity dependence of the overlap region using the Van Allen Probes-B satellite in the inner magnetosphere. We defined the region of overlapping of plasmasphere and ring-current ions as the region where the plasma density is higher than 300 cm^-3 and total ion energy flux is higher than 5x10^10 keV cm^-2 s^-1 sr^-1 for the HOPE ion energy range of 0.001 - 55.650 keV. This criterion of overlap is defined based on our previous study of the source region of STEVE, SAR arcs and red/green arcs using 9 ground-satellite conjunction events (Sugimura et al., JpGU2023). We found 50570 data points of overlaps during the 3-year data a from January 2015 to December 2017. The preliminary analysis shows that the plasmasphere and ring current overlap most frequently from midnight to dusk local times. From superposed epoch analyses, the AL index is ranging from -200 nT to -250 nT during +-3 hours from the overlap time. The SYM-H index was ~-25 nT during the overlapping time. These results indicate that the overlapping of plasmasphere and ring-current ions occur during geomagnetically active time from midnight to dusk local times. This result indicates the preferable condition of STEVE and SAR arcs at subauroral latitudes.

R006-33
A 会場 ：9/27　AM1 （9:00-10:30）
10:00〜10:15

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Severe erosion of the plasmasphere caused by the ring current particle injection into the deep inner magnetosphere

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The geomagnetic storm that commenced on 8 September 2017 has a Dst minimum of -147nT and appears to be a medium-sized magnetic storm at first glance, but it is known that it is a peculiar magnetic storm in various ways. For example, it is an extreme erosion of the plasmasphere to around L=1.6, and a strong SAPS generation.
To investigate the cause of the extreme erosion of the plasmasphere during the Sep 2017 magnetic storm, data from plasma wave and plasma particle measurements onboard the Arase satellite are analysed and compared with the same data during the Aug 2018 magnetic storm.
Using the low-energy and mid-energy plasma instruments (LEPi, LEPe, MPEi, MEPe) onboard the Arase satellite, we can comprehensively investigate the fluxes of electrons and ions with different energies. Also, the in-situ electron density can be estimated by using the upper hybrid resonance frequencies detected from the plasma wave spectrum obtained by the plasma wave experiment (PWE).
In the September 2017 event, the ion pressure peaks around L = 2.7-3.0, whereas in the August 2018 event it peaks around L ~3.5. In addition, the electron pressure has a peak around L~2 in the September 2017 event, whereas it has a peak around L=5.5 in the August 2018 event. These differences could be related to the stronger Ey field input into the magnetosphere by the solar wind during the September 2017 event.
The above plasma pressure implies that the September 2017 magnetic storm has an eastward current inside L<3. When this current forms a current closure with the ionosphere, the electric field created by the charge-up is the dawn-to-dusk E-field which is in the same direction as the global convection E-field. This would be the cause of the extreme erosion of the plasmasphere.

あらせ衛星に搭載されたプラズマ粒子計測器（LEPi, LEPe, MPEi, MEPe）を用いて、異なるエネルギーを持つ電子とイオンのフラックスを包括的に調べることができる。またプラズマ波動スペクトルから高域混成周波数を抽出することで衛星位置の電子密度を推定することができる。あらせ衛星のプラズマ波動計測器は広い周波数帯をカバーしており、衛星近地点付近（高度~400km）の極めて高い周波数の高域混成波もとらえることができる。
2017 年 9 月 8 日に発生した磁気嵐は、Dst 指数の最小値がー 147nT で一見中規模の磁気嵐に見えるが、さまざまな点で特異な磁気嵐であったことがわかっている。たとえばそれはプラズマ圏の L=1.6 付近までの極端な剥ぎ取りであり、強い SAPS の発生である。
我々の先行研究で、この極端なプラズマ圏の縮小は、6 時間以上にもわたって地上磁気赤道領域に侵入し続けた対流電場の影響であることが示唆されたが、対流電場が継続し続けた理由は明らかにされなかった。そこで、この磁気嵐中のリングカレント粒子フラックスの発達を、同程度の Dst 指数最小値を持つ 2018 年 8 月 25 日の磁気嵐と比較した。
その結果、2018 年イベントの主相では H ＋、He ＋、O ＋イオンが L ＞ 4 に分布しているのに対し、2017 年イベントの主相ではイオンが L~2 付近まで侵入していたことが明らかになった。また 2017 年イベントでは 50~180keV のプロトン、10~120keV の O+ が L=2 － 4 で大きく増加していた。これらの粒子分布の結果、2017 年 9 月のイベントでは、イオンが担うプラズマ圧力は L=2.7-3.0 付近でピークを持つのに対し、2018 年 8 月のイベントでは L~3.5 付近でピークを持っていた。また電子が担うプラズマ圧力は 2017 年 9 月のイベントでは L~2 付近でピークを持つのに対し、2018 年 8

月のイベントでは L=5.5 付近でピークを持っていた。この違いは、2017 年 9 月イベントでは、太陽風が磁気圏に強力な Ey 場を入力したことに関連していると考えられるだろう。

上記のプラズマ圧力から、2017 年 9 月イベント中、L<3 の深内部磁気圏では、東向きの部分的環電流が流れていたことが推測される。この電流が電離層との電流回路を形成すると、これによって生成される電場は、夜明けから夕暮れに向かう向きであり、対流電場を強める向きとなる。 これがプラズマ圏の極度の浸食の原因となったと考えられる。

R006-34
A 会場 ：9/27　AM2 （10:45-12:30）
10:45〜11:00

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Pressure and temperature distribution of ions/electrons in inner magnetosphere during CIR/CME driven storms using Arase satellite

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Geomagnetic storms are caused by corotating interaction regions (CIRs) associated with high-speed solar wind streamers (HSSs), and coronal mass ejections (CMEs). Due to the large-scale solar wind structures, there are significant differences of the storm evolutions between these two storm drivers. These differences involve the dynamics of radiation belts, the ring current, the Earth's plasma sheet, magnetospheric convection, and the saturation of the polar cap potential etc. It has been shown that ion and electron distributions of CME/CIR-driven storms are different, especially for recovery phase [Miyoshi and Kataoka, 2005]. The plasma temperature and rate of ion heating in the plasma sheet are important elements of understanding how the dynamics of the ring current and the magnetosphere vary between these two types of storms. We will examine statistically the spatial and temporal distribution of electrons and ions pressure/temperature during main phase, early recovery and late recovery phases for the selected CIR and CME storms using in situ plasma/particle data obtained by Arase during 2017-2022.

R006-35
A 会場 ：9/27　AM2 （10:45-12:30）
11:00～11:15

2022 年秋の SuperDARN とあらせ衛星共役観測によって捉えられたイモムシ型 ULF 波動について

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“Catapiller-like” ULF waves detected by SuperDARN during SuperDARN-Arase conjunctions in Fall 2022

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During a four-month period spanning from September to December 2022, special time observations using the SuperDARN radars were conducted approximately five days per month in support of Arase conjunctions. These observations were targeted to observe auroral and subauroral phenomena on the nightside and duskside. The objective of the observations was to elucidate physical processes of auroral and subauroral phenomena through a comparison of data obtained through interleaved normal scans with simultaneous observations made by the ground-based instruments and the Arase satellite.

On 23 November 2022, an ultra-low frequency wave in the duskside subauroral region was observed simultaneously by multiple radars in North America. Because the wave signature in the format of the Range-Time-Intensity (RTI) plot looks very similar to a caterpillar showing periodic oscillation in the Doppler velocity data, it is referred to as the ”caterpillar-like ULF wave event” here. The center frequency of this wave was 2.3 mHz, and waves with a similar frequency were also detected in geomagnetic data from the stations within the SuperDARN radars’ field-of-view. The amplitude of the geomagnetic waves varied significantly with latitude, having a peak around 67^o magnetic latitude while those in the radar observations appeared around 70^o. From a comparison between the SuperDARN and GNSS-TEC observations, the detrended TEC showed similar periodic oscillations to the Doppler velocity perturbations observed by the SuperDARN radars. The phase difference between the detrended TEC and Doppler velocity perturbations was 120-180o. This result suggests that the TEC oscillations are driven by an external electric field originating from the magnetosphere.

The ionospheric footprint of Arase traversed the region of caterpillar ULF wave signatures on the duskside. A spatial distribution of the electron density derived from the upper limit frequency of the upper hybrid resonance waves showed no abrupt decrease associated with a plasmapause crossing. This result implies that the plasmasphere extends beyond the apogee (6.1 Re) of the Arase satellite. Therefore, the observed region of ULF signatures is located inside the plasmasphere. A ULF signature in the toroidal component with a period similar to that of the ULF waves on the ground was captured by MGF onboard Arase during the traversal over the ionospheric ULF region. In the presentation, we show the longitudinal extent of the caterpillar ULF event, which looks confined to a narrow region near the dusk terminator. We also discuss the possible generation mechanism of the waves in terms of the so-called quarter ULF wave typically occurring in a region of interhemispheric difference in the ionospheric conductivity.

夜側と夕方側のオーロラ、およびサブオーロラ帯の現象をターゲットとして、2022 年 9 月から 12 月までの 4 ヶ月間、あらせ衛星と SuperDARN レーダーによる共役特別観測が月に約 5 日間実施された。この観測の目的は、通常スキャンモードによって得られたデータ、様々な地上観測機器とあらせ衛星による同時観測との比較を通じて、オーロラおよびサブオーロラ現象の物理過程を解明することである。

2022 年 11 月 23 日に、夕方側サブオーロラ帯において、ULF 帯の波動現象が北米の複数の SuperDARN レーダーに

よって同時に観測された。レーダーデータの Range-Time-Intensity (RTI) プロットに見られる ULF 波動は、ドップラー速度データに特徴的な周期的振動が見られ、イモムシのように見えるため、ここでは「イモムシ型 ULF 波動」と呼ぶことにする。この ULF 波動の中心周波数は、2.3 mHz であり、SuperDARN レーダーの視野内にある地磁気観測点において得られた地磁気データでも同様の周波数の波が検出された。この地磁気脈動の振幅は緯度によって大きく異なり、地磁気データで磁気緯度 67 度付近において、SuperDARN データにおいて地磁気緯度約 70 度付近において最大となっていた。SuperDARN と GNSS-TEC の観測結果を比較すると、1 時間の移動平均を差し引いた TEC 値が、SuperDARN レーダーで観測されたドップラー速度変化と同様の周期振動を示し、両者の変動間の位相差は 120-180 度程度であった。この結果は、TEC 変化が磁気圏に由来する外部電場によって駆動されていることを示唆するものである。

電離圏高度におけるあらせ衛星のフットプリントは、イモムシ型 ULF 波動が観測された夕方側サブオーロラ領域を横断していた。高域混成共鳴波動の上限周波数から導出した電子密度の空間分布には、プラズマポーズを横切る際に見られる急激な電子密度の減少が見られなかった。これは、プラズマ圏があらせ衛星の遠地点（6.1 Re）を越えて広がっていることを意味している。従って、イモムシ型 ULF 現象が観測された領域は、プラズマ圏の内部に位置していたと考えられる。あらせ衛星に搭載された磁場観測機器 (MGF) によって、地上で観測された ULF 波動と同じ周期性を示し、トロイダル成分が卓越した ULF 波動がプラズマ圏内でも捉えられた。発表では、夕方側日没付近の狭い領域に見られたイモムシ型 ULF 波動の経度方向の空間的広がりを示す。さらに、電離圏電気伝導度が半球間で差のある場合によく発生する、いわゆる Quarter Wave の観点から、考えられうる波の発生機構についても議論を行う。

R006-36
A 会場 ：9/27　AM2 （10:45-12:30）
11:15〜11:30

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Excitation of internally driven ULF waves of a weakly magnetized planet based on the magnetosphere-ionosphere coupled model

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The inner magnetosphere is the region where the dipole magnetic field is dominant and strong. Since the footprint of the magnetic field is connected to the ionosphere, the environment of the inner magnetosphere is affected by the condition of the ionosphere. During geomagnetic storms, energetic particles are injected from the plasma sheet and form the ring current. Southwood [1976] proposed that ring current ions can excite ULF waves through the drift-bounce resonance, which are called as internally driven ULF waves. ULF waves are important to understand the energy input from the magnetosphere to the ionosphere, since ULF waves are associated with the FAC. Recently, Yamakawa et al. [2022] could reproduce two types of internally driven ULF waves on the dayside and the duskside based on the magnetosphere-ionosphere coupled model. Yamakawa et al. [2023, submitted] developed the simulation code for updating the density of cold plasma and investigated the effects of the dynamics of cold plasma on the excitation of ULF waves. Simulation results showed the excitation of Pc4-5 ULF waves near the plasmapause in addition to two types of ULF waves in the case of constant density [Yamakawa et al., 2022]. These studies suggest that the excitation of ULF waves and formation of ring current are affected by the condition of the ionosphere and the plasma sheet. It is important to investigate the formation of ring current and the excitation of ULF waves of weakly magnetized planets in order to understand the magnetosphere of exoplanets and future Earth. However, the structure of ring current and the plasmasphere and the excitation of ULF waves of weakly magnetized planets are far from understood.

We investigated the formation of ring current and the excitation of internally driven ULF waves based on the magnetosphere-ionosphere coupled model between GEMSIS-RC [Amano et al., 2011] and GEMSIS-POT [Nakamizo et al., 2012]. GEMSIS-RC model solves 5-D drift-kinetic equation for ion PSD and Maxwell equations self-consistently. GEMSIS-POT is a 2-D potential solver in the ionosphere. In this study, we report on internally driven ULF waves in the case of a weakly magnetized planet, whose magnetic field strength is about one-third as strong as the present Earth (10000 nT at the surface). We changed the distribution of Region 1 FAC and conductivity because of the decrease of the intrinsic magnetic field.

Simulation results showed the excitation of Pc5 waves on the dayside and nightside. The Pc5 waves on the dayside were generated by the drift resonance. By comparing with the case of the present Earth, the change of ion drift frequency resulted in the change of the wave excitation region. We will also report on global distribution of ULF waves and growth rate.

R006-37
A 会場 ：9/27　 AM2 （10:45-12:30）
11:30〜11:45

#山本　和弘 [1), 関　華奈子 [2), 山川　智嗣 [3), 天野　孝伸 [4), 中溝　葵 [5), 三好　由純 [6)
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A drift kinetic simulation of ULF wave excitation based on multi-point spacecraft observations

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In the terrestrial magnetosphere, ultra-low frequency (ULF) waves are excited by a variety of external and internal energy sources. High-speed solar wind and perturbation of the solar wind dynamic pressure are external drivers of ULF waves (e.g., Kepko et al., 2002; Zhang et al., 2010). The ULF waves driven by the external sources can accelerate energetic ions (Zong et al., 2012; Oimatsu et al., 2020) and relativistic electrons (Elkington et al., 1999) through the drift/drift-bounce resonance (Southwood et al., 1969). Therefore, these ULF waves are important for the energy dynamics in the magnetosphere. Because solar wind parameters can show dramatic variations at the same time, these external drivers of ULF waves can coexist. This makes it difficult to distinguish the excitation mechanism(s) of ULF waves for a particular event. Using a global ring current model, we discuss the possible excitation mechanisms of the ULF waves observed on 29 October 2013.

We conducted a global drift-kinetic simulation of the ring current (Amano et al., 2011) coupled with an ionospheric potential solver (Nakamizo et al., 2012). During the event, the solar wind dynamic pressure showed a step-like variation, and a moderate substorm (AL ~-470 nT) was triggered. Both toroidal and poloidal ULF waves were detected by Van Allen Probes on the duskside. From the observations of Iridium satellites, we found that the Region-1 field aligned current (R1FAC) gradually reached greater than 1.0 uA/m^2 in the expansion phase. The spatiotemporal variations of R1FAC were fitted with the Gaussian function to calculate the electric field potential in the ionosphere. With the fitted R1FAC distributions, we obtained a simulation result in which toroidal ULF oscillations of the electromagnetic fields were continuously excited. Their Poynting flux along a field line indicates that electromagnetic field perturbation propagates from the southern ionosphere to the magnetic equator in all MLT sectors except for the noon sector. This result suggests that the energy source of the toroidal oscillations is in the southern ionosphere on the nightside. To identify the cause of the toroidal waves, we changed the input parameters of R1FAC and the ionospheric conductivity. First, we fixed the location of a current sheet of R1FAC and only the current density was changeable. With this setting, we found that the toroidal oscillations still existed. If we fixed the all parameters of R1FAC, the toroidal oscillation disappeared. Next, we mirrored the background ionospheric height integrated conductivity in the southern ionosphere to the northern ionosphere. In addition, we used the background conductivity not on 29 October 2013 but on the autumnal equinox day (23 September 2013) to weaken the north-south asymmetry of the conductivity. As a result, the toroidal oscillations were still generated. We concluded that the temporal variation of R1FAC directly/indirectly drives the toroidal oscillations even if there is no north-south asymmetry of the ionosphere. If the toroidal oscillation we found is not an artificial signal, the temporal variation of the intensity of field aligned currents is a new driver of ULF waves which has been overlooked in previous studies.

R006-38
A 会場 ：9/27 AM2 （10:45-12:30）
11:45～12:00

あらせ衛星観測によるコーラス波動強度・伝搬角の経験モデルの構築

#栗田 怜[1], 三好 由純[2], 加藤 雄人[3], 齊藤 慎司[4], 松田 昇也[5], 笠原 禎也[6], 中村 紗都子[7], 松岡 彩子[8], 篠原 育[9]
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Construction of wave power and wave normal angle models of chorus waves based on the Arase PWE/OFA observation

#Satoshi Kurita[1],Yoshizumi Miyoshi[2],Yuto Katoh[3],Shinji Saito[4],Shoya Matsuda[5],Yoshiya Kasahara[6],Satoko Nakamura[7],Ayako Matsuoka[8],Iku Shinohara[9]
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Whistler mode chorus waves play crucial roles in the dynamics of the Earth's inner magnetosphere through wave-particle interactions. In particular, it has been considered that stochastic acceleration by chorus waves is responsible for the creation of relativistic electrons in the Earth's outer radiation belt during geomagnetic disturbances. The stochastic acceleration has been described by the quasi-linear diffusion regime, and modeling works successfully reproduce observed flux increase in radiation belt electrons during geomagnetic disturbances. The quasi-linear diffusion model of chorus waves requires information on wave power and wave normal angle of chorus waves, which greatly changes the timescale for the acceleration of relativistic electrons. The model describes the wave power distribution as a function of frequency using a Gaussian function. The wave normal angle distribution for a fixed wave frequency is also represented by a Gaussian function. The magnetic latitude dependence of these distributions needs to be incorporated into the model to include stochastic acceleration of electrons during the propagation of chorus waves from the magnetic equator to higher latitudes. It is also worthwhile to construct the wave power and wave normal angle models of chorus waves as input parameters of test-particle simulations which can describe nonlinear aspects of wave-particle interactions between electrons and the waves.

The purpose of this study is the development of the empirical chorus wave model based on the Arase satellite observation, which describes the wave power distribution as a function of frequency, wave normal angle distribution for a fixed wave frequency, and the MLAT dependence of these distributions. We have statistically investigated spectral matrices obtained by the Onboard Frequency Analyzer (OFA), which is a part of the Plasma Wave Experiment onboard the Arase satellite. The wave power and wave normal angle of chorus waves are derived from the OFA-MATRIX datasets, and these parameters are modeled so that the parameters can be used as inputs of the quasi-linear diffusion model. We report on the wave power distribution of chorus waves as a function of normalized frequency (f/fce) and wave normal angle distribution of chorus waves at a fixed normalized frequency. The MLAT dependence of these distributions is also shown in the presentation. The input parameters of the quasi-linear diffusion model will be derived from the obtained distributions, and diffusion rates will be shown using the parameters derived from the Arase observation.

R006-39
A 会場 ：9/27　 AM2 （10:45-12:30）
12:00〜12:15

あらせ衛星で観測されたコーラス波動に伴う電子フラックス変動現象の統計解析

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Statistical investigation of rapid change of electron flux caused by chorus waves observed by Arase

#Seiya Tokuda[1),Takahiro Zushi[2),Satoshi Kurita[3),Hirotsugu Kojima[4),Satoshi Kasahara[5),Shoichiro Yokota[6),Yoshiya Kasahara[7),Shoya Matsuda[8),Satoko Nakamura[9),Atsushi Kumamoto[10),Fuminori Tsuchiya[11),Ayako Matsuoka[12),Yoshizumi Miyoshi[13),Iku Shinohara[14)
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In the Earth's inner magnetosphere, wave-particle interaction plays an important role in the acceleration and loss of energetic electrons. Kurita et al. (2018) reported a deformation of electron pitch angle distribution caused by the upper band chorus observed by the Arase satellite. In this event, it is shown that the deformation appears where effective wave-particle interaction is expected in the velocity space and the electron flux increases within the resonance range of cyclotron resonance. In this study, we analyzed the deformation of electron pitch angle distribution associated with chorus waves from the observation result of MEP-e and PWE onboard the Arase satellite in order to understand this phenomenon. We extracted events showing a sudden increase in electron flux in association with the activation of chorus waves from observation data of MEP-e and PWE.

From the observation data from March 2017 to May 2018, 72 events were found in which electron flux change and chorus waves were observed simultaneously. In this study, the 72 events obtained were classified into three categories: events that changes from the high energy band, events that change in all energy bands simultaneously, and events that change from the low energy band. Among these events, events that changes in all energy bands simultaneously and changes from low energy band are considered that resonances occur in the observation region of the Arase satellite. In this presentation, we will show the result of analysis of these events and discuss the characteristics of the resonance of chorus waves with electrons.

地球内部磁気圏では，波動粒子相互作用によって高エネルギー電子が加速・消失することが知られている。Kurita et al. (2018) では，upper band chorus によって電子ピッチ角分布が変動する現象が報告されている。この現象では，速度空間において有効な波動粒子相互作用が期待される領域でピッチ角分布の変動が発生し，サイクロトロン共鳴の共鳴範囲内でフラックスが増加していることが示されている。本研究では，このような現象の更なる理解に向けて，あらせ衛星に搭載された MEP-e と PWE の観測データを用いて，コーラス波動に伴う電子フラックスの変動現象について解析を行った。あらせ衛星に搭載されている中間エネルギー電子分析器 (MEP-e) 及びプラズマ波動・電場観測器 (PWE) の観測データから，コーラス波動に対応して電子フラックスが急激に変動しているイベントを抽出した。

2017 年 3 月〜2018 年 5 月の観測データから、電子フラックスの変動とコーラス波動が同時に観測されている事例は 72 件発見された。本研究では、得られた 72 件のイベントを高エネルギー帯から変動しているイベント、全てのエネルギー帯が同時に変動しているイベント、低エネルギー帯から変動しているイベントの 3 つに分類した。このうち、全てのエネルギー帯が同時に変動しているイベントと低エネルギー帯から変動しているイベントでは、あらせ衛星の観測領域でコーラス波動と電子が共鳴していると考えられる。本発表では、この様なイベントについて解析を行った結果を示し、コーラス波動が電子と共鳴する際の特徴について議論する。

R006-40
A 会場 ：9/27 PM1 （13:45-15:30）
13:45～14:00

#田 采祐 [1), 三好 由純 [1), 中村 紗都子 [1), 小路 真史 [1), 堀 智昭 [1),Bortnik Jacob[2),Lyons Larry[2), 三谷 烈史 [3),Takashima Takeshi[3), 篠原 育 [3), 松岡 彩子 [4),Higashio N.[3)
(1 名大 ISEE,(2UCLA,(3 宇宙研,(4 京都大学

Influence of nonlinear EMIC waves on relativistic electrons in the outer radiation belt using the in-situ observations

#ChaeWoo Jun[1),Yoshizumi Miyoshi[1),Satoko Nakamura[1),Masafumi Shoji[1),Tomoaki Hori[1),Jacob Bortnik[2),Larry Lyons[2),Takefumi Mitani[3),Takeshi Takashima[3),Iku Shinohara[3),Ayako Matsuoka[4),N. Higashio[3)
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EMIC wave-particle interaction is believed to play a significant role in the dynamics of energetic particles in the magnetosphere. Particularly, nonlinear processes can cause rapid losses of relativistic electrons in the outer radiation belt. We recently found the triggering condition for nonlinear EMIC waves by the distortion of the dayside magnetic field in response to the intensification of the solar wind dynamic pressure. In other words, the increase in the solar wind dynamic pressure is the preferred condition for nonlinear EMIC triggering emissions. In this study, we investigate the variations of relativistic electron distributions between structureless EMIC waves and nonlinear EMIC rising-tone emission events due to dayside magnetospheric compression by the solar wind dynamic pressure using the Van Allen Probes and Arase satellites. In the preliminary result, the residual flux variations on MeV electrons and EMIC waves are observed simultaneously, and we find a clear phase space density depression of relativistic electrons in timing when EMIC waves are observed. The residual fluxes of 0.5-5 MeV electrons exhibit a similar repletion period of a few minutes with the observed EMIC rising-tone emissions, supposing that these fluctuations might be related to rapid loss of relativistic electrons due to nonlinear process. We discuss the underlying physical dynamics causing losses of relativistic electrons in the outer radiation belt by EMIC wave-particle interactions.

R006-41
A 会場 ：9/27　 PM1 （13:45-15:30）
14:00～14:15

#篠原　育 [1), 楊　敬軒 [3), 風間　洋一 [2),Wang Shiang-Yu[2), 田　采祐 [5), 笠原　慧 [3), 横田　勝一郎 [4), 桂華　邦裕 [3), 堀　智昭 [5), 浅村　和史 [1), 三谷　烈史 [1), 松岡　彩子 [6)
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Evolution of electron temperature anisotropy associated with injections and its relation to chorus wave excitation

#Iku Shinohara[1),Jingxuan Yang[3),Yoichi Kazama[2),Shiang-Yu Wang[2),ChaeWoo Jun[5),Satoshi Kasahara[3),Shoichiro Yokota[4),Kunihiro Keika[3),Tomoaki Hori[5),Kazushi Asamura[1),Takefumi Mitani[1),Ayako Matsuoka[6)
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Recent explorations of the inner magnetosphere reveal that whistler chorus waves play an essential role in accelerating and losing high-energy electrons. It is believed that electron temperature anisotropy is the free energy of chorus wave excitation and is provided by injections from the magnetotail. However, since there are fewer plasma observations in the inner magnetospheric region, the reality of the distribution of the electron temperature anisotropy is not well understood. Based on a statistical analysis of electron temperature anisotropy in the inner magnetospheric region using data obtained from low-energy and medium-energy electron instruments (LEP-e and MEP-e) onboard Arase (ERG), we confirmed that the boundary of the temperature anisotropy distribution is consistent with the marginal condition of the temperature anisotropy instability. Further, we also examined the contribution of injections to temperature anisotropy by focusing on data obtained during injection events. Our preliminary result does not show that electron injections distribute around the marginal condition of the instability. The result is partly because we evaluated the temperature anisotropy of electron injections using the average value of 10 minutes time scale, and temperature anisotropy associated with injections might be smeared out. This presentation will discuss the time and spatial evolution of temperature anisotropy associated with electron injections and its relation to instability conditions.

R006-42
A 会場 ：9/27　 PM1 （13:45-15:30）
14:15～14:30

#風間　洋一 [1), 三好　由純 [2), 栗田　怜 [3), 小嶋　浩嗣 [4), 笠原　禎也 [5), 加藤　雄人 [6), 臼井　英之 [7), 田　采祐 [8), 堀　智昭 [9), 浅村　和史 [10),Wang Bo-Jhou[1),Wang Shiang-Yu[1),Tam S.-W.-Y.[11),Chang T.-F.[11), 松田　昇也 [12), 土屋　史紀 [13), 熊本　篤志 [6), 笠羽　康正 [14), 小路　真史 [9), 北原　理弘 [6), 中村　紗都子 [15), 松岡　彩子 [16), テラモト　マリコ [17),Takashima Takeshi[10), 篠原　育 [18)
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Statistical analysis of densities and temperatures of cold and hot electrons

#Yoichi Kazama[1),Yoshizumi Miyoshi[2),Satoshi Kurita[3),Hirotsugu Kojima[4),Yoshiya Kasahara[5),Yuto Katoh[6),Hideyuki Usui[7),ChaeWoo Jun[8),Tomoaki Hori[9),Kazushi Asamura[10),Bo-Jhou Wang[1),Shiang-Yu Wang[1),S.-W.-Y. Tam[11),T.-F. Chang[11),Shoya Matsuda[12),Fuminori Tsuchiya[13),Atsushi Kumamoto[6),Yasumasa Kasaba[14),Masafumi Shoji[9),Masahiro Kitahara[6),Satoko Nakamura[15),Ayako Matsuoka[16),Mariko Teramoto[17),Takeshi Takashima[10),Iku Shinohara[18)
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Studying dynamics of plasmas is essential for understanding the global activities of waves in the Earth's inner magnetosphere. We performed a statistical analysis on densities and temperatures of cold and hot electrons in relation to whistler mode chorus waves. It is said that whistler chorus is triggered by injected hot electrons from the plasma sheet. However, a result of the data analysis indicates that hot electrons in the midnight sector are almost temperature isotropic, which does not make a growth rate positive in the quasi-linear theory. In the presentation, we will explain the results of our data analysis and discuss electron dynamics and their relation to whistler mode waves.

R006-43
A 会場 ：9/27　PM1 （13:45-15:30）
14:30～14:45

#齊藤　慎司[1], 三好　由純[2]
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Wave amplitude dependence of energetic electron precipitation associated with pulsating aurora: Test-particle simulations

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Pulsating aurora is a kind of diffuse aurora with pulsation of a few Hz. The optical emission of pulsating aurora is due to intermittent electron precipitation into the atmosphere from the outer radiation belt of the earth's magnetosphere. Whistler mode chorus waves generated in the magnetosphere are a plausible candidate to scatter the trapped radiation belt electrons into the loss cone.

In this study, test-particle simulations by GEMSIS-RBW are carried out to study the influence of large amplitude whistler chorus mode waves on energetic electrons precipitation. The simulations show that the electron flux close to the loss cone are reduced by the scattering when the whistler mode chorus waves nonlinearly trap the electrons close to the loss cone. On the other hand, nonlinear dislocation process scatters electrons into loss cone from the pitch angle away from it. The parameter study as a function of the wave amplitude indicates that the nonlinear scattering process has an important role for the suppression of the electron precipitation. The amount of electron precipitation flux is not a linear function of the wave amplitude of whistler mode chorus waves. The high amplitude whistler mode chorus waves could influence on the energetic electron precipitation associated with the emission of pulsating aurora.

R006-44
A 会場 ：9/27　 PM1 （13:45-15:30）
14:45〜15:00

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Pitch angle scattering rates and energetic electron precipitation caused by chorus emissions in the inner magnetosphere

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Energetic electron scattering is highly affected by whistler mode chorus emissions in the Earth's inner magnetosphere. Whistler mode chorus emissions are usually observed with oblique wave normal angles (WNAs), and the different WNAs influence the electron motions. This study aims to reveal the relation between wave WNAs and energetic electron precipitation, and to verify the processes of nonlinear resonances that result in electron precipitation. We utilized test particle simulations and the Green's function method to trace energetic electrons scattered by a pair of chorus emissions. We apply 12 chorus wave models with four various WNA sets (the maximum WNA are 0 deg, 20 deg, 60 deg, and 90% of resonance cone angles) and three wave amplitude sets (the maximum wave magnetic fields are 2.1 nT, 300 pT, and 50 pT) at L = 4.5. Besides, we theoretically derive the pitch angle scattering rates of resonant electrons. According to the simulation results and the theoretical pitch angle scattering rates, we find that: (1) Wave amplitudes are the most important factor affecting energetic electron precipitation; (2) Under the same wave condition, in general, the precipitation rates of low-energy (tens of keV) electrons are higher than those of high-energy (hundreds of keV) electrons because the pitch angle scattering rates of the n = 1 cyclotron resonance is higher for low-energy electrons than for high-energy electrons; (3) For large amplitude waves, the precipitation rates of the very oblique chorus waves are about 1.5 times greater than those of the parallel waves and about 1.2 times greater than those of the slightly oblique waves. It is because of active nonlinear trapping (n = 0 and n = -1 resonances) and nonlinear scattering (n = 2 resonance); (4) In the large amplitude and very oblique case, electrons can precipitate from the initial equatorial pitch angles >40 deg around 100 keV because of the strong nonlinear trapping via the n = -1 cyclotron resonance.

R006-45
A 会場 ：9/27 PM1 （13:45-15:30）
15:00〜15:15

#加藤　雄人 [1], 大村　善治 [2], 笠原　慧 [3], 篠原　育 [4], 寺本　万里子 [5]
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PCUBE: Probing, controlling, and understanding of radiation belt environments

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

Recent studies clarified that the radiation belt varies more dynamically than conventionally expected due to the rapid loss process by electromagnetic plasma waves. We proposed the numerical Green's function method (Omura et al., JGR 2015), which enables us to reproduce the variation of the radiation belt for several hours, considering the rapid loss process occurring in the time scale of less than 1 second. We further develop the proposed method for electromagnetic ion cyclotron waves and the effect of the plasma duct, which concentrates plasma waves along a specific field line where the plasma density is enhanced from those of the surroundings. Our project tries to confirm a hypothesis that the efficient loss of radiation belt electrons occurs along the plasma duct.

To investigate the relationship between the plasma duct and the rapid loss process of radiation belt electrons, we need to observe the relativistic electron precipitation and the plasma density structure simultaneously in the Earth's upper atmosphere. We develop a high-energy electron detector and a plasma density probe. The electron detector makes use of the avalanche photo-diode, which we employed in the energetic electron detector onboard the Arase satellite [Kasahara et al., EPS 2018]. The developed detector covers a wide energy range from tens to millions of electron volts. By measuring the energy dependence of precipitating electrons into the Earth, we clarify the roles of electromagnetic waves in the radiation belt loss process. We also develop the plasma density probe by miniaturizing the 1-m length plasma probe used in conventional sounding rocket experiments. We will install the originally developed probes into a CubeSat to measure the loss of radiation belt electrons inside the plasma duct.

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

Because radiation belt electrons cause satellite anomalies and radiation exposure in space, the method controlling radiation belt has been investigated for decades. Our project reveals the fundamental physics of the rapid loss of radiation belts, developing the theoretical basis to control the radiation belts.

R006-P01
ポスター１：9/24　PM1/PM2 （13:45-18:15）

カナダ・アサバスカにおける2023年９月のサブオーロラ帯オーロラのPBASEキャンペーン観測の初期結果

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Preliminary results from the first PBASE campaign observation of subauroral-latitude auroras at Athabasca, Canada, on Sept. 2023

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The international joint research of geospace variability by combining multi-point ground and satellite observations and modeling (PBASE program) has been launched in December 2022 as a 7-year program of Japan Society for the Promotion of Science (Grant-in-Aid for International Leading Research, 22K21345, https://www.isee.nagoya-u.ac.jp/dimr/PBASE/). The PBASE program aims to contribute to understanding and predicting geospace variabilities by combining ground-based and satellite observations and modeling, covering a wide area in both altitude and latitude/longitude directions. The program plans to coordinate campaign observations using ground-based instruments in winter seasons in 2023, 2024, ans 2025. In this presentation, we will report a preliminary result obtained from the first PBASE ground-satellite campaign observation of subauroral-latitude auroras at Athabasca, Canada, on September 8-14, 2023. We install two Nikon color cameras at the AUGO-I site (54.71N, 246.69E, magnetic latitudes: ~62 degree) in the Athabasca University campus and the AUGO-II site (54.60N, 246.36E) which is ~25 km separated, in order to make a triangulation of auroral structures, such as STEVE and SAR arcs, typically observed at subauroral latitudes. We also operate an all-sky airglow imager of the Optical Mesosphere Thermosphere Imagers (OMTIs) and an EMCCD camera at AUGO-II, and a low-cost ZWO camera at AUGO-I. Conjugate observation with the Arase satellite is planned at 13:00 UT on September 8, 12:00 UT on September 10, and 08:00 UT on September 15.

R006-P02
ポスター１：9/24　PM1/PM2 （13:45-18:15）

磁気嵐中に発生したオメガバンドオーロラに伴う放射線帯電子降下の時空間変動: 多周波リオメータ，EMCCD 全天カメラによる同時観測

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Energetic electron precipitation associated with omega-band auroras during a magnetic storm

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Auroras are classified into two broad categories: discrete auroras, which have a clear and distinct shape, and diffuse auroras, which have a vague and blurred shape. Most diffuse auroras show quasi-periodic brightness modulations, which are known as "Pulsating Aurora (PsA)". Along with the appearance of PsA, a large-scale wavy auroral structure called the "omega band" is often identified. Recent studies have demonstrated that highly energetic (sub-relativistic) electrons of radiation belt origin sometimes precipitate into the atmosphere during appearance of PsA and omega band. To date, however, the spatial distribution of such electron precipitations during omega bands has not yet been clarified in detail. In particular, characteristics of electron precipitation during a storm-time omega band has not been investigated due to a lack of good examples during large geomagnetic storms. One of the possible methods to reveal this issue is to visualize the spatial distribution of ionization in the lower ionosphere by combining optical data from ground-based all-sky cameras and the Cosmic Noise Absorption (CNA) measurements by riometers.

In this study, we investigated the spatiotemporal variations of CNA associated with omega bands that occurred during a geomagnetic storm by combining the observations of high-speed EMCCD all-sky cameras with a temporal resolution of 100 Hz, installed at four locations in Scandinavia (Tromsoe, Tjautjas, Sodankyla, Kevo), and spectral riometers installed at seven stations in the same region. Specifically, we examined an event of omega bands during a Coronal Mass Ejection (CME) type geomagnetic storm on March 23-24, 2023. By combining the optical data from the four EMCCD cameras, it was found that the torch structures of the omega bands drifted eastward quasi-periodically across the fields-of-view of the cameras. A comparison between the temporal variations of CNA and optical data indicated that the CNA significantly increased when the torch structures passed through the sensing areas of the riometers. Furthermore, by directly comparing the spatial structure of the omega bands and the CNA variations at the seven locations, we found that the CNA increased not in a region of discrete aurora along the edge of the omega band, but in regions inside and outside of the torch structure that was embedded in diffuse auroras. This suggests that harder electron precipitations, probably of radiation belt origin, occurs in the regions inside and outside the omega band structure where the morphology of aurora is more characterized by diffuse structures. In the presentation, we will discuss the spatial/temporal relationship between the storm-time aurora including the omega bands visualized by the wide-area imaging with the EMCCD cameras, and the synchronizing enhancements of CNA, as well as their relationship with magnetic field variations at the magnetospheric counter part responsible for the particle precipitation.

オーロラは、明瞭な空間構造を持つディスクリートオーロラと、曖昧な空間構造を持つディフューズオーロラに分類される。ディフューズオーロラの中でも準周期的に明滅を繰り返すものを「脈動オーロラ (Pulsating Aurora: PsA)」と呼ぶ。PsA の出現に伴い「オメガバンド」と呼ばれる波状のオーロラ構造が見られることがある。近年の研究によって、PsA やオメガバンドの発生に伴って、PsA を光らせる電子だけでなく、放射線帯に起源を持つ高エネルギー電子 (準相対論的電子) が降下していることが示唆されている。しかし、これまでの研究では、オメガバンド発生時の放射線帯電子降下の時空間分布が十分に明らかとなっているとは言えない。特に、規模の大きい磁気嵐中に発生するオメガバンドに伴う降下電子の時空間変動は、観測事例が少ないために未だに明らかになっていない。本研究では、2023 年 3 月に発生した磁気嵐時に観測されたオメガバンドについて、銀河電波吸収 (Cosmic Noise Absorption: CNA) を同時に観測することによって、磁気嵐時のオメガバンドに伴う下部電離圏の電離の二次元空間分布の動的特性を可視化することを目的とする。

　本研究では、北欧の 4 地点（Tromsoe, Tjautjas, Sodankyla, Kevo）に設置されている 100 Hz の時間分解能を有する EMCCD 高速撮像全天カメラと、同じく北欧の 7 地点に設置されている多周波リオメータの観測を組み合わせることによって、磁気嵐時に発生したオメガバンドに伴う CNA の時空間変動を調べた。具体的には、2023 年 3 月 23-24 日にかけて発生したコロナ質量放出 (Coronal Mass Ejection: CME) 型の磁気嵐の主相から回復相にかけて発生したオメガバンドの事例について解析を行った。まず、北欧 4 地点の EMCCD カメラ群による光学観測データを結合することによって、真夜中から明け方のローカルタイムにかけて、オメガバンドを構成するトーチ構造が準周期的に発生し東向きにドリフトしていたことが分かった。EMCCD 全天カメラによって得られた全天画像から作成したケオグラムと多周波リオメータから得られた CNA 強度の時間変化を比較した結果、トーチ構造がリオメータの観測領域を通過するタイミングで CNA

が顕著に増大していたことが明らかになった。また、オメガバンドの空間構造と 7 地点で得られた CNA 観測データを直接的に比較することによって、オメガバンドや、オメガバンドに内包される PsA のどの領域で放射線帯電子の降下が顕著であったかについても解析を行った。その結果、ディスクリートオーロラで構成されるオメガバンドの輪郭部分ではなく、ディフューズオーロラによって構成されるトーチ構造の内側や外側において CNA が増大していたことが分かった。このことは、オーロラの形態がよりディフューズになるオメガバンド構造の内外の領域において、放射線帯電子の降下が多いことを示唆する。発表では、広域撮像によって可視化されたオメガバンドを含む磁気嵐時に特徴的なオーロラ、およびそれに伴って発生した CNA 増大現象の緯度分布を示し、オメガバンドの構造と CNA の空間分布、粒子降下をつくりだす磁気圏側の磁場の変動の関連性について議論する予定である。

R006-P03
ポスター１：9/24　PM1/PM2 （13:45-18:15）

サブストームオンセット直後に見られるオーロラ形態とオンセット位置からの距離依存性に関する研究

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A study of the auroral morphology seen immediately after substorm onset and its dependence on distance from the onset location

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Temporal and spatial evolution of auroras associated with substorms has been widely investigated on various spatiotemporal scales by many researchers. In a typical pattern, equatorward-shifted auroras at the substorm growth phase abruptly increase the intensity at the substorm onset with expanding rapidly poleward. After this substorm expansion phase, diffuse auroras including pulsating auroras are developed in the whole sky. In case where a ground-based all-sky camera is operated close to the substorm onset location near midnight, the camera may capture a series of these changes in auroral morphology. On the other hand, in case where a ground-based all-sky camera is operated off dawn side from the substorm onset location, auroras with a gentle horizontal gradient in brightness may occur only in a portion of the field of view, coinciding with auroral brightness increases, but more unclear horizontal structure different from that near the onset location. We need further studies on the auroral morphological evolution around the substorm onset, considering relative distance to the onset location. A valuable method to retrieve this issue in an experimental manner should be a statistical analysis of auroral images taken from multiple ground-based optical cameras for many substorm events estimating the relative distance between the onset location and the camera field of view. This study examined the relative distance in latitude and longitude using auroral images taken immediately after substorm onsets.

The analysis was performed using auroral images taken with eight all-sky cameras operated in northern Scandinavia and Alaska in winter 2016-2022 and SuperMAG substorm lists and magnetic field data. Assuming an emission altitude of 100 km, the latitudinal coverage by all cameras installed in Northern Scandinavia and Alaska are 59.3 to 77.7 degrees and 56.

6 to 72.7 degrees, respectively. The optical filters mounted on cameras were RG665, which passes light at wavelengths longer that approximately 665 nm, and BG3, which cuts light at wavelengths between 500 and 700 nm. Both filters are suitable for measuring prompt auroral emission. For this analysis, onset times and locations were taken from a substorm list issued by SuperMAG. Of the substorm onset events listed up for the period covered by this analysis (in total, 1949), 34 events were selected under following four criteria.

1. Substorm onsets after 22 magnetic local time (MLT) at clear night with intervals of at least 2 hours and 30 minutes from the preceding and following onsets, respectively.
2. Minimum value of the SML index reaches -400 nT or lower within one hour after the substorm onset.
3. A single minimum value of SML index for one hour after the substorm onset.
4. Less than one hour difference between substorm onset longitude and longitude of a station to meet the SML minimum.

Results of this analysis suggested that diffuse auroras were found in more wide range of the relative longitude from the onset location than discrete auroras. In addition, discrete auroras tended to be identified more frequently at higher latitudes, while diffuse auroras showed the opposite trend. Analysis of the relative distances in latitude and longitude to the substorm onset location showed that both type of auroras was distributed in a wider latitudinal range at the east side of the onset location. Furthermore, diffuse auroras tended to invade the higher latitudes with displacing eastward from the onset location. Considering the latitudinal standard deviation of the substorm onset position, discrete auroras tended to occur at latitudes closer to the onset location.

R006-P04
ポスター１：9/24　PM1/PM2 （13:45-18:15）

サブストームに伴う Pi2 及び Pc4 脈動の発生特性について

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On the global characteristics of Pi2 and Pc4 wave generation associated with substorms

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Various magnetohydrodynamic waves exist in the Earth's magnetosphere. Among them, geomagnetic fluctuations with periods ranging from 0.2 to 1000s are called geomagnetic pulsations, especially those with periods ranging from 45 to 150s and continuous waveforms are called Pc4 pulsations, and those with impulsive waveforms are called Pi2 pulsations. Although Pi2 pulsations are well known to be observed at substorm onset, Pc4 pulsations observed at the explosion phase and the recovery phase of substorms aren't yet well understood in terms of their originating factors and emergence characteristics.

Li. Yan et al., (2000) investigated the dependence of the amplitude of the horizontal component of Pi2 pulsations on magnetic latitude and local time, and found that the amplitude decreased in the order of midnight, evening, and noon at the local time where the observation stations were located, and became smaller as the stations were located at lower magnetic latitude.

Furthermore, Imajyo et al., (2017) suggested that the dayside Pi2 is observed as an oscillatory component of the ionospheric current that extends into the daylight portion.

On the other hand, the Pc4 pulsation was discussed by Shishime's master paper (2013).It reported that Pc4 pulsations were observed from the explosion phase to the recovery phase of the substorm at nightside high latitudes, while it was significantly attenuated at mid and low latitudes, and appeared to be hardly propagated.

However, these results were only obtained from event studies at specific local times, and the global aspect of the event hasn't been clarified. In this presentation, I will discuss the global transmission pathways and M-I coupling circuits formed by the Pi2 and Pc4 pulsations excited during substorms by contrasting their occurrence characteristics.

地球磁気圏には様々な磁気流体波が存在する。その中でも、周期が 0.2〜1000 秒程度の地磁気変動は地磁気脈動と呼ばれ、特に 45〜150 秒程度の周期を持つ、連続した波形のものは Pc4 脈動、突発的な波形のものは Pi2 脈動と呼ばれる。Pi2 脈動はサブストームオンセット時に観測されることがよく知られているが、サブストームの爆発相・回復相において観測される Pc4 脈動については、まだその発生要因や出現特性について十分に理解されていない。

Pi2 の全球的な発生特性については、Li. Yan et al., (2000) により、Pi2 脈動の磁場水平成分の振幅について磁気緯度、地方時依存性が調査され、観測点が位置する地方時が真夜中・夕方・正午の順で小さくなり、低磁気緯度の観測点になるにつれて小さくなることが確認された。更に、Imajyo et al.,(2017) により、昼間側 Pi2 は日照部分に拡がる電離層電流の振動成分として観測されることが示唆された。一方、Pc4 脈動については志々目修論 (2013) により、夜側高緯度観測点において、サブストームの爆発相から回復相にかけて Pc4 脈動が生じていることが確認される一方、中低緯度では著しく減衰され、殆ど伝搬していないように見えることなどが報告された。

しかしながら、この結果は特定の地方時におけるイベントスタディの結果でしか無く、その全球的な様相は明らかとなっていない。本講演では、サブストーム時に励起される Pi2 脈動、Pc4 脈動の発生特性を対比させながら、それらが形成する全球的な伝達経路や MI 結合回路の議論を行う予定である。

R006-P05
ポスター１：9/24　PM1/PM2 （13:45-18:15）

MESSENGER 探査機の磁場データの統計解析に基づいた水星磁気圏の構造特定

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Identification of the Mercury's magnetospheric structure based on a statistical survey of MESSENGER magnetic field data

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Mercury has a magnetosphere similar to the Earth. The boundaries that define the magnetosphere, such as bowshock (BS) and magnetopause (MP), have been identified in previous studies. In contrast, Mercury's magnetosphere has different situations from the Earth, such as the solid planetary body occupies a large volume, the solid surface is exposed to space, and the typical spatial and time scales are smaller and shorter than those of the Earth so that it is more susceptible to solar wind variations. Previous studies, e.g., Winslow et al. (2013), identified BS and BP using magnetic field data obtained from MESSENGER. However, these studies focused on the BS and MP identifications, and structures and variations of magnetic fields found in other areas are not necessarily discussed. In this study, we try to find unique regions or events different from Earth by using MESSENGER magnetic field and plasma data and attempt to interpret these phenomena without necessarily assuming analogies from the Earth's magnetosphere.

This research also intends to prepare for Mercury's magnetospheric science by the BepiColombo fleet. BepiColombo/Mio has onboard instruments that can observe the plasma environment around Mercury more comprehensively than MESSENGER, so it is important to focus on regions and events of interest in advance for efficient data analysis. Since the region classification is the first step for magnetospheric science, this preliminary study will facilitate research after BepiColombo's arrival. In this presentation, we will present the initial results.

水星には磁気圏が存在することが知られており，Bow Shock(BS) や Magnetopause（MP）といった地球磁気圏を定義する境界が見られる．一方で，水星磁気圏は，固体惑星が大きな体積を占める，固体表面が宇宙空間に晒されている，特長スケールは地球に比べて小さいので太陽風変動の影響を大きく受けやすい，などの地球とは異なる特長がある．Winslow et al. (2013) などの先行研究では MESSENGER 衛星の磁場観測データを用いて，これらの磁気圏構造の特定が試みられている．しかし，これらの研究では BS や MP の特定を行っているものの，それ以外の領域に見られる変動構造については，必ずしも議論がなされていない．そこで，本研究では，MESSENGER の磁場データおよびプラズマデータに対して時系列データ解析を行い，何らかの地球とは異なる特徴的なイベントや領域を探索し，それらの現象に対して，必ずしも地球磁気圏からの類推を前提とせずに，物理的な解釈を試みたい．

本研究は BepiColombo 衛星の到着に向けた予備研究でもある．「みお」の搭載機器は MESSENGER よりも水星磁気圏を包括的に観測できるようになっており，効率的に観測研究を行うためには事前に注目すべき点を絞り込んでおくことが重要となる．また，BepiColombo 到着時においても，はじめに磁気圏の領域の区分け作業が必要となる．こうした解析の準備を事前に行うことによって，到着後の研究を円滑に進めることができる．本講演では，この研究の初期結果を発表する．

R006-P06
ポスター１：9/24　PM1/PM2 （13:45-18:15）

地球磁気圏 X 線撮像計画 GEO-X の現状

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Status of GEO-X mission

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GEO-X (GEOspace X-ray imager) mission is a Japanese small satellite mission aiming at visualization of the Earth's magnetosphere by X-rays and revealing dynamical couplings between solar wind and magnetosphere. In recent years, X-ray astronomy satellite observations discovered soft X-ray emission originated from the magnetosphere due to charge exchange between solar wind ions and exospheric

neutrals. From observational and theoretical studies, this emission is expected to increase largely in the sheath region because of the large ambient plasma density. Therefore, the boundary region between the bow shock and the magnetopause will be detected with the strong soft X-ray emission.

We are developing GEO-X to realize this global imaging of the magnetosphere by X-ray observations for the first time. It is a ~50 kg class small satellite carrying a novel compact X-ray imaging spectrometer. The satellite having a large delta v (>~700 m/s) to increase an altitude from piggyback launch to GTO is necessary. For this purpose, a hybrid kick motor composed of liquid N2O and polyethylene is attached to the spacecraft. A wide FOV (>5x5 deg) and a good spatial resolution (<10 arcmin) X-ray (0.3-2 keV) imager is also onboard. We aim to launch the satellite around the next solar maximum.

GEO-X (GEOspace X-ray imager) は地球磁気圏の X 線撮像とそれによる太陽風に対する磁気圏応答の理解を目指す超小型衛星計画である。近年、X 線天文衛星「すざく」などによって地球の周辺から軟 X 線が放射されていることが分かってきた。太陽風に含まれる多価イオンが地球の超高層大気である外圏の中性物質から電子を奪い、奪われた電子がイオン中で基底準位に落ちる中で発光する電荷交換反応によるものである。こうした中、観測および理論予測から、太陽風プラズマ密度は衝撃波通過後の遷移領域で高まることから、X 線を用いた昼側磁気圏のグローバル撮像が可能であることが示唆されてきた。

そこで我々は初めての磁気圏 X 線撮像を行う超小型衛星 GEO-X の開発を進めている。衛星重量は約 50 kg で、コンパクトかつ超軽量であり高感度の独自の X 線撮像分光装置を搭載する。衛星は GTO などへの相乗りから自在に軌道変換を行なって、放射源である磁気圏の外からの観測を可能にする大型の推進系 (delta v >~700 m/s) を持つ。そこで N2O とポリエチレンからなるハイブリッドキックモーターを推進系として用いる。観測装置は広視野 (5x5 deg) かつ優れた角度分解能 (10 arcmin) を実現し、磁気圏構造を分解する。打ち上げは第二十五太陽周期の極大である 2020 年台半ばを目指しており、本講演では計画の現状について報告する。

R006-P07
ポスター１：9/24　 PM1/PM2 （13:45-18:15）

EQUULEUS 搭載の極端紫外撮像装置（PHOENIX）による地球プラズマ圏の撮像

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Remote observation for Earth's plasmasphere by EUV telescope (PHOENIX) on-board nano-spacecraft EQUULEUS

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6U-size nano-spacecraft mission named EQUULEUS has been launched in November 2022 as one of the sub-payloads of NASA's Space Launch System. After the launch, the instrumental checkouts have been conducted along with orbital control for Earth-Moon L2 point (EML2). An ultra-small telescope for extreme ultraviolet (EUV) named PHOENIX is boarded on EQUULEUS. It consists of multilayer-coated mirror (diameter of 6 cm with Mo/Si coating), metallic bandpass filter, and 2-D photon counting device with microchannel plate and resistive anode. The reflectance of the mirror and transmittance of the filter are optimized for the emission line of ionic helium (wavelength of 30.4 nm) which is the second major component of the plasmasphere of the Earth. The field of view of PHOENIX is set as 11.8 degrees which corresponds to around 10 Earth size seen from moon. By flying far from the Earth, the entire image of plasmasphere can be obtained in one flame of the PHOENIX FOV. In this presentation, the mission concept and the design of the telescope, and the status of PHOENIX in orbit will be shown with some initial observational results.

R006-P08
ポスター１：9/24　 PM1/PM2 （13:45-18:15）

超小型電子計測器開発に向けたフローティングした APD による低エネルギー電子計測実験

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Establishment of low energy electron detection methods using floating APD for a development of a small-size electron analyzer

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The purpose of this study is to develop a small-size electron analyzer fitted with a nano-satellite for in-situ measurements of auroral electrons. The analyzer uses an APD (Avalanche Photodiode) as an electron detector instead of an MCP (Micro Channel Plate) in order to improve uncertainty of quantum efficiency for the detection. However, APD is not sensitive for elections with energies less than a few keV in general. We apply +4.5kV to APD which is electrically floated from ground. In this case, energy resolution becomes much worse if we only use output signals generated by APD. Therefore, APD is used in combination with an electrostatic energy analyzer. In this study, electron beams were irradiated to APD which was electrically floated from ground. We got clear signatures of incoming electrons when the beam energy was higher than 2 keV. However, the APD also detected stray electrons accelerated by the floating potential of APD. The effect due to the stray electrons should be removed in order to evaluate the detection performance of APD for lower energy electrons. Currently we are designing the new experimental setup which removes the stay electrons reachable to the APD.

We will report on the results of the laboratory testing and design of the experimental setup.

我々はオーロラ電子の観測を目的とし、超小型衛星に搭載可能な超小型電子計測器の開発を目指している。従来、磁気圏・電離圏における 10eV〜数 10keV 帯の低エネルギー電子観測には MCP (Micro Channel Plate) が用いられてきた。MCP は大面積化や、入力面を分割した粒子検出が容易に実現できるなどの利点がある一方、検出効率の不確定性が大きい。このため、我々が開発している電子計測器の検出部には比較的検出効率の不確定性が小さいと考えられる APD（Avalanche Photodiode）を使用することとしている。しかし、APD はそのままでは数 keV 以下の電子に感度を持たないため、APD 全体を周囲から絶縁し、プラス数 kV 程度の電圧を印加することによって入射電子を加速して計測することとした。この場合、APD 単体では低エネルギー電子に対するエネルギー分析が困難となるため、静電エネルギー分析部を設け、その後段に APD を配置する。 本研究ではフローティングさせた APD を用い、低エネルギー電子に対する計測性能を実験によって確認した。実験では抵抗分圧回路を用いて APD 入力面が 4500V となるように電圧を印加し、真空チャンバーにて電子ビームを照射した。APD 出力信号を用いてエネルギー分析を行った結果、2 keV 以上の電子ビームに対しては有意な分布が得られた。一方、入射電子が周囲の電極に衝突した際に発生する二次電子によると思われる分布が重畳して得られており、2keV 以下の電子については、試験セットアップの電極構造に対策が必要な状況となっている。そこで二次電子が APD 入力面に到達しない電極構造を計算機シミュレーションによって検討している。本発表では、上記 APD による電子計測実験の結果とシミュレーションの結果について報告する。

R006-P09
ポスター１：9/24　PM1/PM2 （13:45-18:15）

#風間　洋一[1), 浅村　和史[2), 田　采祐[3), 堀　智昭[4), 三好　由純[5),Wang Bo-Jhou[1),Wang Shiang-Yu[1),Tam S.-W.-Y.[6),Chang T.-F.[6), 笠原　禎也[7), 松田　昇也[8), 土屋　史紀[9), 熊本　篤志[10), 笠羽　康正[11), 小路　真史[4), 北原　理弘[10), 中村　紗都子[12), 松岡　彩子[13), 寺本　万里子[14),Takashima Takeshi[2), 篠原　育[15)
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Development of a new data calibration for the LEPe instrument on the Arase satellite

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We are now developing a new data calibration method for the LEPe (Low-energy particle experiments - electron analyzer) instrument onboard the Arase satellite. The calibration method currently being applied is built based on LEPe measurement data until the end of 2020. Since 2021, the detection efficiencies of the electron channels have decreased relatively to that of the background channel. This efficiency difference is probably due to degradation of the electron channels, as the electron channels receive a higher influx of electrons compared to the background channel. To take the time variation of detection efficiencies into account, a newly developed calibration method introduces a time parameter to the detection efficiency model. In this presentation, we describe the details of the new calibration method, which is useful for scientists to know accuracy and limitations of physical quantities obtained by the LEPe instrument.

R006-P10
ポスター１：9/24　PM1/PM2 （13:45-18:15）

超小型プラズマ波動受信器用オンボードソフトウェアの開発

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Development of onboard software for miniaturized plasma wave receiver

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In recent years, CubeSats, standardized small satellites with a cubic size of 10 cm, have gained popularity and are actively used for scientific observations. These CubeSats are expected to play a critical role in plasma wave observations by increasing the observation opportunities and enabling simultaneous multi-point observations with high spatial resolution. However, due to their limited size and power constraints, it is difficult to install a high-performance plasma wave instrument on a CubeSat.

To address this issue, we propose a miniaturized and power-efficient plasma wave receiver specifically for use on CubeSats. This new type of receiver is designed to reduce power consumption in spectrum observation by dividing the observation band into multiple frequency bands in the analog circuit and reducing the sampling frequency in the lower frequency bands. In addition, we are developing these analog circuits as Application-Specific Integrated Circuits (ASICs) to minimize circuit size.

In this receiver, the RP2040 is used for circuit control and digital signal processing such as fast Fourier transform. The RP2040 is a low-power microcontroller with two ARM Cortex M0+ CPU cores. While the Cortex M0+ is power efficient, its computational performance is not high, so an efficient implementation is needed to perform control and digital signal processing for the RP2040. In this study, our goal is to develop onboard software for the RP2040 that provides the control and digital signal processing needed for the plasma wave receiver.

In our presentation, we will show a detailed overview of the developed software and the results of the performance evaluation.

近年、CubeSat と呼ばれる 10 cm 立方サイズの標準化された超小型衛星の打ち上げが増加しており、理学観測においても CubeSat が積極的に利用されている。プラズマ波動観測においても、観測機会を増やし高空間分解能の多点同時観測を実現するためには、CubeSat は重要な役割を果たすと考えられる。しかし、十分に高性能なプラズマ波動観測装置を CubeSat に搭載することは、装置の大きさや消費電力の問題から困難である。

我々は、CubeSat への搭載を見据えた超小型かつ省電力な新型プラズマ波動受信器を提案している。この新型受信器は、アナログ回路において観測帯域を複数の周波数帯域に分割し、低周波帯域のサンプリング周波数を下げることでスペクトル観測における消費電力を大幅に低減可能な構成としている。さらに、このようなアナログ回路を専用集積回路として開発することで、回路を小型化する。この受信器において、回路全体の制御および高速フーリエ変換等のディジタル信号処理は、小型マイクロコントローラーである RP2040 を用いる予定である。RP2040 は CPU コアとして ARM Cortex M0+ を２つ搭載している。Cortex M0+ は省電力である一方、演算性能は高くないため、制御とディジタル信号処理を RP2040 のみで実行するためには効率的な実装が必要となる。本研究では、RP2040 においてプラズマ波動受信器に必要となる制御および演算を実現するオンボードソフトウェアの開発を行う。

発表においては、開発したソフトウェアの詳細と性能評価を行った結果を示す。

R006-P11
ポスター１：9/24　PM1/PM2 （13:45-18:15）

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Development of suprathermal ion energy-mass spectrometer for observations in the polar ionosphere

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In the inner magnetosphere, there are oxygen ions, nitrogen ions, and molecular ions which flow out from the ionosphere along the earth's magnetic field line. The cold ionospheric ions with energies below several eV are heated to tens of eV, which has been observed by the past satellite observations. However, possible mechanisms for the ion outflow have not been understood. While the pressure gradient drives the outflow of light ions such as protons and helium ions, the mechanism is difficult for heavy ions such as oxygen ions and molecular ions. In order to clarify the ion outflow mechanism, we are developing suprathermal ion energy-mass spectrometer for the LAMP-2 sounding rocket experiments and the future polar orbiting satellite mission "FACTORS". There are two objectives for in-situ observations of suprathermal ions in the topside ionosphere. The first is to clarify the outflow mechanism for heavy ions originated from the ionosphere. The second is to identify heating mechanisms, e.g., wave-particle interactions and joule heating at the ionospheric altitudes. The instrument consists of an electrostatic energy-per-charge analyzer and a TOF (Time-Of-Flight) based mass analyzer using the linear-electric field (LEF) method. The LEF method provides much finer mass resolution comparing to the normal (field-free) TOF analyzer. Design of the instrument is being optimized with numerical simulations in which particle trajectories inside the instrument are traced. In this presentation, we will report on the current status of the development and future plan..

R006-P12
ポスター１：9/24　PM1/PM2（13:45-18:15）

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Development of High energy electron analyzer onboard the LAMP-2 sounding rocket

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The LAMP-2 (Loss through Auroral Microburst Pulsations – 2) project is planned to elucidate the effects of energetic electrons from the Earth's magnetosphere on mesospheric neutral atmospheric modulations and atmospheric outflows.

We are designing and developing high-energy electron detectors (HEP) for LAMP-2. The LAMP-2 HEP is designed to achieve higher sensitivity and temporal resolution, while following the design of HEP instrument onboard the RockSat-XN (launched in January 2019) and LAMP (launched in March 2022) rocket experiments. The previous HEP had the total thickness of the silicon about 5 mm by stacking silicon semiconductor detectors (SSDs), while in LAMP-2, the thickness is about 8 mm to improve the detection efficiency at higher energies, 3 MeV. To increase the effective area, 28 mm square (upper layer) and 48 mm square (lower layer) SSDs are used. In addition, the speed of data processing will be increased. It takes 5 microseconds for the LAMP HEP to determine the energy of one incident electron. For LAMP-2 HEP, we are considering a design that would complete the process in 1 microsecond.

In this presentation, we will report the results of the SSD evaluation using radioisotopes and the sensitivity calculation using the Geant4 simulator.

R006-P13
ポスター１：9/24　 PM1/PM2 （13:45-18:15）

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Development of the real-time steady-state noise reduction module for plasma wave waveforms on FPGA

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Measuring plasma wave is indispensable to understand the plasma physics through wave-particle interaction in the magnetosphere. To precisely measure weak plasma waves, it is important to suppress artificial noises originated from spacecraft. We have conventionally installed a wave sensor on the tip of long extension mechanisms to reduce the artificial noises. However, it is technically difficult to install such long extension mechanisms in a small and lightweight nano-satellites. Thus, we need to develop a new technique to suppress the artificial noises contaminated in the observed waveform data. Since real-time signal processing needs a heavy computational cost, we have developed the several FPGA modules to realize real-time onboard processing under the limited computation resources.

In this study, we develop an FPGA module for noise reduction using the spectral subtraction (SS) method. Our proposed method is able to estimate quasi-stationary noise spectra contaminated in waveform data and subtract them from the waveform. We apply a recursive filter method to estimate the quasi-stationary noise spectrum by updating the previously estimated noise spectrum. By changing a parameter called forgetting factor, we can adjust a time constant of noise estimation while keeping a small memory usage on the FPGA.

We develop a noise reduction module for an Intel FPGA to confirm that the noise reduction can be performed well in the simulation. In this presentation, we report the overview of our noise reduction module and the results of the evaluation of noise reduction performance

R006-P14
ポスター１：9/24　PM1/PM2 （13:45-18:15）

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Examination of method to separate noise from natural magnetic field measured on geostationary satellite

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We examine the method to separate spacecraft noise from natural magnetic field measured on a geostationary satellite. The real-time measurement of magnetic field using in situ observation is one of powerful tools to immediately capture the magnetic storm. The separation of spacecraft noise from natural magnetic field is required, particularly using the magnetic field measurement without boom. In this study, the Fast Independent Component Analysis (FastICA) is introduced, which has applied for magnetic field data detected by two magnetometers onboard the first Quasi-Zenith Satellite (Imajo et al., 2021).

First, we evaluate the noise separation accuracy using GOES satellite data assuming that two/three/four magnetometers will be onboard a geostationary satellite. The magnetic field data including artificial noises, which factor depends on the distance from the noise source, are made from GOES satellite data. The noises are then separated from natural variations by FastICA. The noise separation accuracy is better when magnetometers are far away from each other. The number of magnetometers does not depend on the accuracy, which is not consistent with the suggestion in Imajo et al., (2021). However, the noise separation accuracy is better using more magnetometers when the noise amplitude is quite larger than the amplitude of natural variations (factor of about 10).

Next, we perform the noise separation method for ground magnetic field data assuming that the noise pattern is unknown. The ground experiment indicates that spiky noises with a period of about 2 min can be separated from natural variations. The period of spiky noise is similar with the oscillation related to the global distribution of magnetosphere (i.e., Pc5 pulsations), which suggests that the FastICA can be useful for the magnetic field measurement for the space weather.

3 次元衝突性 Hall MHD シミュレーションを用いたオーロラ加速領域における電磁場構造の解析

#川上　航典 [1), 吉川　顕正 [2), 深沢　圭一郎 [3)
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Analysis of electromagnetic field structure in the auroral acceleration region using 3D collisional Hall MHD simulation

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Understanding the formation and development of auroral particles and their acceleration mechanisms is a subject of interest in both theoretical and observational studies. Previous research has explored the double layer hypothesis and kinetic Alfven waves [Ergun et al. 2004, Chaston et al. 2002] to explain the formation of these particles. Recent observations from the ERG satellite have provided evidence that auroral particle acceleration occurs at altitudes above 30,000km [Imajo et al. 2021]. However, the physical processes responsible for the formation and evolution of these acceleration regions remain unclear.

This study focuses on the Auroral Cavity region, which is observed concurrently with the acceleration region, and aims to understand the development of the electromagnetic field and accompanying plasma diffusion based on the plasma density depletion in the Ionospheric Alfven Resonator (IAR) [Streltsov et al. 2008, Sydorenko et al. 2008]. As a first step in our research, we are currently developing a 3-D collisional Hall MHD simulation that can accurately describe the evolution of the electromagnetic field in M-I coupling system. Unlike the thin-layer approximation, our simulation incorporates the momentum exchange due to collisional effects between the ionic and neutral fluids and provides a more realistic the ionospheric response [Yoshikawa, 2013]. Additionally, the simulation enables us to illustrate electron field-aligned acceleration and ponderomotive forces acting on the MHD fluid, which are associated with the nonlinear evolution of Alfven waves under the fluid approximation. This description allows us to explore the structure formation theory as a preliminary step towards introducing kinetic theory. In this presentation, we will outline the simulation scheme and present initial results.

オーロラ粒子の形成について、これまで double layer 仮説や運動論的 Alfven 波などの加速機構が理論と観測の両方のアプローチから研究が進められてきた [Ergun et al., 2004. Chaston et al.,2002] 。さらに、近年ではあらせ衛星の観測によって高度 30,000km 以上においてもオーロラ粒子の加速が起きていることが確認された [Imajo et al. 2021] 。しかし、これらの加速領域がどのような物理プロセスのもと形成・発展するのかについては明らかでない。

そこで本研究では、IAR におけるプラズマ密度の減少に関する研究 [Streltsov et al., 2008, Sydorenko et al., 2008] を基に、加速領域と同時に観測される Auroral Cavity 領域の形成という観点から電磁場構造の発展とそれに伴うプラズマの拡散について理解を試みている。現在は研究の初期段階として M-I 結合系における電磁場の発展を記述できる 3 次元衝突性 Hall MHD シミュレーションを開発している。このシミュレーションでは、薄層近似を用いずに、イオン流体と中性流体間での衝突効果による運動量交換から記述するため、電離圏応答をより正確に記述した M-I 結合系における電磁場の発展を計算することができる [Yoshikawa, 2013] とともに、流体近似の下、Alfven 波の非線形発展に伴う電子の沿磁力線加速や MHD 流体に働くポンデロモーティブ力なども再現可能なることから、運動論を導入する前段階としての構造形成論の議論が可能となる。発表ではこのシミュレーションのスキームと得られた初期結果について報告する。

カスプ周辺の広帯域 (BBELF) 波動の統計解析

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Statistical study on broad band ELF waves in and near the cusp

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The ionosphere is an important source of magnetospheric plasma, especially for heavy ions with low charge states. The region near the cusp is one of the most important regions for ion outflows. Although ion acceleration perpendicular to the magnetic field by broadband ELF waves is thought to be important for driving ion outflows near the cusp, even the intensity of the waves is not well understood. We statistically investigate the energy input to the ionosphere and the ELF waves using data obtained by the Fast Auroral SnapshoT (FAST) satellite. The precipitating electron number density and Alfven Poynting flux in and near the cusp (0900 –　1500 MLT) exhibit a relatively good correlation with a broadband ELF wave intensity at ~10 Hz, which is close to the local O^+ cyclotron frequency at ~4000 km altitude. The correlation coefficients tend to be higher in summer or equinox than those in winter, while occurrence of very large intensity waves is apparently large in winter. Because the background plasma density is expected to small in winter, the background plasma condition may also affect the wave intensity in addition to the energy input to the ionosphere. The power law index of the electric field wave spectra between 10 and 200 Hz are － 0.5 and － 2.5 in most of cases, when the wave intensity was sufficiently larger than the noise level and fast survey data with a sampling frequency equal to or better than 512 Hz are available.

R006-P17
ポスター１：9/24　PM1/PM2 （13:45-18:15）

#小野澤　秀治 [1), 加藤　雄人 [2), 笠原　禎也 [3), 長妻　努 [4), 熊本　篤志 [1)
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Polarization properties of BBELF waves contributing to ion acceleration in the cusp region observed by the Akebono satellite

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The Earth's polar ionosphere supplies plasma containing multi-species ions such as H^+, He^+, O^+, and molecular ions to the magnetosphere. Hydrodynamic theories can explain outflows of light ions (H^+ and He^+) but are not enough to explain outflows of heavy ions. Outflowing O^+ ions ions are often observed as ion conics resulting from transverse acceleration followed by the adiabatic motion due to the mirror force. The non-Maxwellian distribution indicates wave-particle interactions play an essential role in the heavy ion outflow process. One of the most important plasma waves in the acceleration mechanism is BBELF waves. BBELF waves are characterized by their spectra showing (1) amplitude decreases following the power law from DC to several kilohertz, (2) electromagnetic in the frequency range below f_{cO}, where f_{cO} represents the cyclotron frequency of oxygen ion, and (3) electrostatic in the frequency range higher than f_{cO}. Ishigaya (2017) analyzed six ion heating events observed by the Akebono satellite. They found that the ratio of the electric field amplitude to the magnetic field amplitude (E_w/B_w) exceeded 10^8 m/s, larger than the Alfven speed (~2 x 10^6 m/s), in the frequency range between fcH and fLH in intense heating events, where fcH and fLH indicate the cyclotron frequency of proton and the lower hybrid resonance frequency, respectively. Their results suggested the importance of the enhancement of electrostatic waves in the frequency range from f_{cH} to f_{LH} in addition to the enhancement of waves below f_{cO} in intense ion acceleration events. However, the properties of wave mode have not been clarified yet.

In this study, we study the properties of plasma waves observed by the Akebono satellite during the intense ion acceleration events reported by Ishigay(2017). Firstly, we have constructed a new, 0.5-sec resolution dataset from wave spectrum data measured by VLF/MCA and the DC magnetic field data observed by MGF onboard the Akebono satellite, which enables us to analyze the oscillation direction of the wave electromagnetic field with respect to the ambient magnetic field and its frequency dependence. Secondly, we reanalyze the intense heating event observed on 11 February 1990, 18:00-18:15 UT in the northern cusp region reported by Ishigaya(2017) to investigate how the intensities of the wave electromagnetic field depend on the oscillation direction with respect to the ambient magnetic field in the frequency range up to 1 kHz. Finally, we compare the observed oscillation direction and frequency dependence with the polarization characteristics derived from the dispersion relation in cold plasma.

Results of the analysis show that the intensities of the electromagnetic field variations in the frequency range from f_{cH} to f_{LH} enhanced at a certain direction with respect to the ambient magnetic field. Based on the cold plasma dispersion relation, R-mode waves exist in the frequency range from f_{cH} to f_{LH}. The observed properties rule out R-mode waves propagating neither parallel nor perpendicular to the ambient magnetic field and suggest the presence of obliquely propagating R-mode waves during the event. We discuss the resonance condition between obliquely propagating R-mode waves and ions based on the observed properties.

R006-P18
ポスター１：9/24　PM1/PM2 （13:45-18:15）

あらせ衛星で観測された降り込み電子の統計的解析

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Statistical survey of energetic electron precipitation observed by the Arase satellite

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Energetic electron precipitation from the magnetosphere into the upper atmosphere driven by the wave-particle interactions has received a lot of attention. For example, pulsating aurora is thought to occur when tens of keV electrons trapped in the inner magnetosphere are scattered into the loss cone by whistler-mode chorus waves generated near the magnetic equator and thereby fall into the upper atmosphere.

Kasahara et al. (2018) has demonstrated that the resonant scattering by chorus waves causes the pulsation of auroras, by showing a correlation between switch on/off of whistler wave activity and the modulation in loss cone electron flux. The detailed correlation study was enabled by the high angular resolution, sufficient to resolve small loss cones, of the Medium-Energy (10-90keV) Particle experiments - electron analyzer (MEP-e) onboard the Arase satellite.

On the basis of the results by Kasahara et al. (2018), we try to statistically examine the contribution of wave-particle interaction to energetic electron fluxes inside the loss cone using MEP-e. In the case of the Earth's magnetosphere, the loss cone angle is about a few degrees. We therefore analyzed the distribution of electron fluxes whose pitch angle is $<$2 degrees and $>$178 degrees from March 2017 to September 2019 to clarify the observation occurrence frequency and spatial distribution of precipitating electrons. The result shows that precipitating electrons are observed around L=6 from the nightside to the dawnside. This result is consistent with the region where whistler waves are generated [e.g., Teng et al. (2019)]. We plan to extend this analysis to the Low-Energy (60eV-10keV) electron analyzer (LEP-e) and analyze the characteristics of electron precipitation over the wide energy range of LEP-e and MEP-e (60 eV to 90 keV).

近年、波動粒子相互作用による、磁気圏のプラズマ粒子の地球大気への降り込み現象が注目されている。例えば、脈動オーロラの発生メカニズムとしては、磁気赤道面付近で発生したホイッスラーモードコーラス波によって、内部磁気圏の数十 keV の電子がロスコーン内に散乱され、地球大気へ振り込むことで発光すると考えられており、Kasahara et al.(2018) は、脈動オーロラ発生時に、ロスコーン内部の電子フラックスの強度がホイッスラー波に合わせて変化していることを観測し、コーラス波との共鳴散乱によって脈動オーロラが発生していることを実証した。この観測は、あらせ衛星搭載の電子観測器が、観測領域でのロスコーン内の電子を直接観測するのに十分なピッチ角分解能をもっているために、はじめて得られた結果である。Kasahara et al.(2018) のイベントスタディの結果を踏まえ、我々はあらせ衛星の中間エネルギー（10-90keV）電子分析器（MEP-e）を用いて、ロスコーン内の降り込み電子の統計的解析を行うことにより、波動粒子相互作用の降り込み電子への寄与を定量的に評価したい。

ロスコーンの角度は磁気圏においては数度程度となるため、我々の解析では、平行（ピッチ角 2 度以下）および反平行（178 度以上）の降り込み電子のフラックスデータを使用した。降り込み電子の観測頻度ならびに空間分布を明らかにするため、2017 年 3 月〜2019 年 9 月までの 30 か月間の平行・反平行成分の電子のフラックス分布を解析した。また、平行・反平行成分の電子の観測機会と実際の観測の有無との差を比較した結果、平行・反平行成分電子フラックスが L=6 周辺の真夜中側から朝側領域にかけて観測頻度が高いことが分かった。これは、コーラス波の発生領域および頻度と整合的である [e.g., Teng et al. (2019)]。

今後は、低エネルギー（60eV-10keV）電子分析器（LEP-e）にまで解析範囲を広げ、幅広いエネルギー帯（60eV-90keV）での電子の降り込み特性について解析を行う予定である。

R006-P19
ポスター１：9/24　PM1/PM2 （13:45-18:15）

ERG/Arase 衛星を用いた高エネルギー電子のピッチ角分布の調査データ

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(1 ポスドク

Investigation of the pitch-angle distribution of energetic electrons using ERG/Arase satelliteData

Pankaj Soni[1],#Yoshizumi Miyoshi[1],Tomo Hori[1],Satoko Nakamura[1],Mitani Takefumi[1],Takeshi Takashima[1],Iku Shinohara[1],Ayako Matsuoka[1]
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The charged particles of solar origin enter the Earth’s magnetosphere and get trapped in the closed magnetic cavity. The energies of these particles vary from a few keV to a few MeV. The flux of these magnetospheric trapped particle first decreases, and then increases during geomagnetic storms. The correlation of electron flux variation and its effect on the change of pitch-angle distributions is not well understood. The purpose of this study is to understand the variation of energetic electron flux and pitch-angle distribution of the outer radiation belt during different phases of geomagnetic storms. We chose geomagnetic storms from 2017 to 2022 with SYM-H less than -40 nT. Using the Arase’s High-Energy Electron (HEP), and Magnetic Field Experiment (MGF) data sets, we have derived the pitch-angle distribution as a function of L, energy, and storm phases. We fitted the Legendre function with sixth-order of accuracy to model the pitch-angle distribution and classified them into three types: pancake, butterfly, and flattop. In this presentation, we present the storm phase dependence of pitch-angle distribution for multi-hundred and multi-MeV electrons.

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Translation results
Translation result
太陽起源の荷電粒子は地球の磁気圏に入り、閉じた磁気空洞に閉じ込められます。 これらの粒子のエネルギーは、数 keV から数 MeV まで変化します。 これらの磁気圏に捕捉された粒子の磁束は最初に減少し、磁気嵐の間に増加します。 電子束の変化とそのピッチ角分布の変化への影響の相関関係はよくわかっていません。 この研究の目的は、磁気嵐のさまざまな段階におけるエネルギー電子束の変化と外側放射線帯のピッチ角分布を理解することです。 SYM-H が -40 nT 未満の 2017 年から 2022 年までの磁気嵐を選択しました。 荒瀬の高エネルギー電子 (HEP) および磁場実験 (MGF) データセットを使用して、L、エネルギー、嵐の位相の関数としてピッチ角分布を導き出しました。 ルジャンドル関数を 6 次の精度でフィッティングしてピッチ角分布をモデル化し、それらをパンケーキ、バタフライ、フラットトップの 3 つのタイプに分類しました。 このプレゼンテーションでは、数百および数 MeV の電子のピッチ角分布の嵐の位相依存性を示します。

R006-P20
ポスター１：9/24　PM1/PM2 （13:45-18:15）

#滝　朋恵 [1), 栗田　怜 [2), 新城　藍里 [1), 中村　紗都子 [3), 小嶋　浩嗣 [4), 笠原　禎也 [5), 松田　昇也 [6), 松岡　彩子 [7), 風間　洋一 [8),Wang Shiang-Yu[8),Sunny W. Y. Tam[9), 田　采祐 [10), 三好　由純 [11), 篠原　育 [12)
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Estimation of low-energy electron temperature using Arase satellite interferometry observations

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Electron Cyclotron Harmonic (ECH) waves are a type of plasma waves observed in the magnetosphere. They are characterized by a harmonic structure with peaks occurring at integer multiples of the electron cyclotron frequency. ECH waves have a wave vector direction close to the perpendicular direction of the background magnetic field, with electric field oscillations perpendicular to the background magnetic field. In this study, we attempt to estimate the dispersion relation by calculating the phase velocity of ECH waves.

We analyzed the phase velocity of ECH waves using the interferometric observations from the Arase satellite. The Plasma Wave Experiment (PWE) on the Arase satellite consists of four antennas, of which two are considered as monopole antennas for the interferometric observations. Specifically, the differential measurements between antenna V1 and V2, and the satellite ground are performed. Antennas V1 and V2 rotate every 8 seconds due to the satellite spin.

We calculated the phase difference of ECH waves and obtained their spin dependence. From the numerical calculations, we proposed a method to estimate the unobserved electric field components based on the spin dependence. Using this method, we determined the wave number at each frequency from the phase velocity and examined the dispersion relation. By comparing the theoretical dispersion curve, we attempted to estimate the electron temperature of the cold population that corresponds to energies lower than the measurement range of the Low-Energy Particle Experiments - Electron Analyzer (LEP-e). We have analyzed several events and found that the frequency-wavenumber relationship generally agrees with the dispersion curves for low-energy electron temperatures of a few eV.

We will continue to consider the causes of some disagreement parts for better agreement and will also apply the analysis to more events.

R006-P21
ポスター１：9/24　PM1/PM2（13:45-18:15）

#小路　真史[1), 寺澤　賢哉[1), 三好　由純[1),Kistler Lynn[1), 浅村　和史[2), 笠羽　康正[3), 笠原　禎也[4), 松岡　彩子[5), 中村　紗都子[6), 篠原　育[7)
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Direct detection of ion pitch angle scattering by plasma waves in space plasma

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Energy exchange between charged particles and plasma waves have been supposed to contribute to loss and energization of plasmas in the magnetosphere. Especially, electromagnetic ion cyclotron (EMIC) waves can cause acceleration and scattering of ions in a wide energy range. It has been suggested theoretically that when energy is transferred from ions to EMIC waves, the pitch angle of ions decreases and ions precipitate into the Earth's ionosphere. The energy transfer between the plasma waves and ions can be evaluated by calculating the inner product of the wave electric field vector and the ion velocity vector using wave-particle interaction analysis (WPIA). We have expanded the WPIA method to directly detect the pitch angle scattering of protons by EMIC waves. On June 21, 2021, the Arase satellite successfully observed intense EMIC waves by PWE/EFD and MGF and deformation of the pitch angle distribution of ions by LEP-i simultaneously. We applied the WPIA analysis and detected the pitch angle scattering and the energy exchange. Significant Lorentz force works to decrease pitch angles of ions. At the same time, several protons increase their energy with increasing their pitch angles. These are the first direct evidence of the pitch angle scattering between EMIC waves and protons in the space plasma. We compare the WPIA results with the theoretical diffusion curve in the velocity distribution function. We also discuss what parameters contribute to the saturation and decay of EMIC wave amplitudes.

R006-P22
ポスター１：9/24　PM1/PM2 （13:45-18:15）

2023年3月の磁気嵐時に低緯度から高緯度の地上観測点とSwarm衛星で同時に観測されたPc1地磁気脈動

#能勢　正仁[1,2], 塩川　和夫[2], ワン　リージュン[3], ジョーンズ　ビル[3]
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Pc1 pulsations simultaneously observed at low- to high-latitude stations and by the Swarm satellites during the March 2023 storm

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Pc1 geomagnetic pulsation is considered to be an electromagnetic ion cyclotron waves excited by the temperature anisotropy of plasmas in the magnetosphere. Previous satellite studies [Anderson et al., 1992; Usanova et al., 2012; Keika et al., 2013] reported that Pc1 pulsations are predominantly observed in the outer magnetosphere at L>7 at daytime centered around 13 – 18 MLT. They are seldom detected in the inner magnetosphere at L<4). On the ground, MLT distribution of Pc1 pulsations at high- and mid-latitudes (L>4) is similar to those of the satellite observations [Saito et al., 1969; Plyasova-Bakounina et al., 1996]. However, Pc1 pulsations at low-latitude (L<4) show the complete different MLT distribution with the frequent occurrence at nighttime with a peak at 03 – 06 MLT [Saito et al., 1969; Kawamura et al., 1981]. The occurrence rate of low-latitude Pc1 appears to be larger than that in the inner magnetosphere at L<4. This implies that low-latitude Pc1 pulsations are not caused by a direct entry of Pc1 pulsations from the magnetosphere onto the ground along the geomagnetic field line, but due to waves indirectly propagated from the magnetosphere, although the indirect propagation path is still unclear.

We have been constructing a latitudinal network of induction magnetometers in the Russian Far East-Asia-Oceania sector and successfully detected Pc1 pulsations in the wide latitudinal range from − 21 degrees to 64 degrees geomagnetic latitude at 10 – 15 UT on March 25, 2023. This event was observed in the premidnight sector during the recovery phase of a large magnetic storm (SYM-H minimum = − 163 nT). The Swarm satellites were flying near the same MLT and provided simultaneous measurements of geomagnetic field variations that are related to the Pc1 pulsations detected at low-latitude. In this talk, results of data analysis are presented and the propagating path of EMIC waves from their excitation region to low-latitude ground stations will be discussed.

Pc1 地磁気脈動は、磁気圏においてプラズマの温度非等方性によって励起される電磁イオンサイクロトロン波動と考えられている。これまでの衛星による研究 [Anderson et al., 1992; Usanova et al., 2012; Keika et al., 2013] によれば、Pc1 地磁気脈動は主に 13 – 18 MLT 付近を中心とする昼間に、L>7 の外部磁気圏でよく観測される。一方、内部磁気圏 (L<4) ではほとんど検出されない。地上においては、高緯度・中緯度 (L>4) における Pc1 地磁気脈動の MLT 分布は、衛星観測と同様である [Saito et al., 1969; Plyasova-Bakounina et al., 1996]。しかし、低緯度 (L<4) における Pc1 地磁気脈動は、03 – 06 MLT をピークに夜間に多く観測され、全く異なる MLT 分布を示す [Saito et al., 1969; Kawamura et al., 1981]。また、低緯度 Pc1 の出現率は、L<4 の内部磁気圏における出現率よりも大きいようである。このことは、低緯度における Pc1 地磁気脈動は、磁気圏から磁力線に沿って直接地上に侵入したものではなく、磁気圏から間接的に伝播してきた波動によるものであることを示唆しているが、その間接的な伝播経路はまだ不明である。

我々は、ロシア極東-アジア-オセアニア地域に誘導磁力計の緯度方向ネットワークを構築しており、2023 年 3 月 25 日 10 – 15UT には、地磁気緯度 − 21 度から 64 度の広い緯度範囲で Pc1 地磁気脈動の観測に成功した。このイベントは、大きな磁気嵐 (SYM-H 指数最小値= − 163nT) の回復相中に、真夜中前で観測された。Swarm 衛星は同じ MLT 付近を飛行しており、低緯度で検出された Pc1 地磁気脈動に関連する地磁気変動を同時に観測していた。本講演では、このイベントのデータ解析結果を紹介するとともに、EMIC 波の励起領域から地上低緯度までの伝搬経路について議論を行う。

R006-P23
ポスター１：9/24　PM1/PM2 （13:45-18:15）

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Methods to increase the precision of the frequency of FLR in SuperDARN VLOS and the magnetospheric density

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Some of the fluctuations in the solar wind, including those causing sudden impulses (SI), propagate into the magnetosphere and excite eigen-oscillations of the magnetic field lines and the frozen-in plasma via the mechanism called field-line resonance (FLR). It is known that the gradient methods enable us to effectively extract FLR signals from observed data. From the identified FLR frequency, one can estimate the mass density of plasma along the magnetic field line because, in a simplified expression, 'heavier' field line oscillates more slowly.

We have been applying the gradient methods to the VLOS (Velocity along the Line of Sight) data of the SuperDARN radars. The radars emit azimuthally-collimated beams of radio waves in the HF range, and some of them are backscattered by the ionosphere, while some others are backscattered by the ground and sea surface. From the Doppler shift of backscattered signals, one can calculate VLOS. Ionosphere-backscattered signals yield VLOS of the horizontally-moving ionospheric plasma (at mid- to low latitudes, VLOS also has a vertical component because the ambient magnetic field is tilted), while ground/sea-backscattered signals yield VLOS corresponding to the vertical motion of the ionospheric plasma because the length of the ray path of a beam can only be changed by the vertical motion of the ionosphere.

For a 30-min-interval event after an SI, we applied the gradient methods to VLOS data obtained from different beams and range gates, and successfully identified the FLR in both the ionosphere-backscattered signals and sea surface-backscattered signals. The mass density was thereby estimated using both scatters. As a result, the latter was significantly smaller than the former. This significant difference could come from a fairly large frequency spacing of the FFT analysis due to the fairly small duration (30 min) of the event. Thus, we have been trying a few methods to increase the frequency resolution.

We have already started testing the zero-padding method, and successfully obtained higher frequency resolution. We estimated plasma densities from these higher-precision FLR frequencies and confirmed that the above-stated density difference between the ionosphere-backscattered signals and the sea-backscattered signals became smaller. We have also noticed that the Hanning data window deletes most of the first oscillation just after the SI, having the largest oscillation amplitude. We have been examining the effect of this deletion on the FLR frequency estimation, including trying another data window called the Placnk-taper window. We have also started trying the direct Fourier Transformation and the AR (AutoRegressive) method. In this presentation, we report the progress of these examinations and tests.

R006-P24
ポスター１：9/24　PM1/PM2 （13:45-18:15）

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Evolution of subauroral polarization streams as observed during SuperDARN-Arase conjunctions in Fall 2022

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A comparative study on two subauroral polarization streams (SAPS) is conducted based on simultaneous observations of the Super Dual Auroral Radar Network (SuperDARN) and the Arase satellite during the Fall 2022 SuperDARN-Arase campaign observations. The purpose of this study is to investigate how the ion injection front evolves in the equatorial magnetosphere as a SAPS emerges and subsequently intensifies. Both two SAPS events occurred in association with weak (AL >~-200 nT) substorms. The westward flow including that of the auroral oval was distributed primarily at magnetic latitudes of ~67 deg to ~75 deg over the dusk to evening sector, while the footprint of Arase was located around ~17-18 magnetic local time. Despite those similarities in the spatial configuration, however, Arase saw a series of energetic ion flux enhancements due to substorm injection at almost the same timing as a SAPS intensified in one of the two events, while it saw injected energetic ions with a significant time delay (~20 min) from the SAPS appearance in the other event. We speculate that the Arase position relative to the injection fronts was different between the two events, causing the observed difference in timing of the injection encounter. In the talk, more detailed results of the observations made by other satellites and ground instruments are presented and further discussed in terms of the evolution of SAPS and the ring current ions.

R006-P25
ポスター１：9/24　PM1/PM2 （13:45-18:15）

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Effects of ULF oscillation on the duct propagation of whistler-mode chorus emissions

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Whistler-mode chorus emissions are coherent electromagnetic plasma waves observed in the dawn sector of the inner magnetosphere during a geomagnetically disturbed period. Previous studies suggested chorus emissions play essential roles in the acceleration of relativistic electrons in radiation belts and in the pitch angle scattering of keV electrons contributing diffuse/pulsating aurora. Recent studies showed that the duct propagation of chorus to a high latitude region results in the precipitation of relativistic electrons. However, despite the investigation of the chorus for more than half a century, the condition controlling the generation and propagation of the chorus has not been fully understood. In Ono et al. [2020], the event observed by the Arase satellite on March 27, 2017, was analyzed, and the modulation of the chorus by Pc4-5 toroidal mode ULF waves was discussed. It is understood that the fluctuation of tens of keV electron flux caused by ULF leads to the modulation of chorus intensity. On the other hand, in the same event, the chorus was shown to propagate parallel to the magnetic field lines up to a magnetic latitude exceeding 10 degrees, suggesting the possibility of duct propagation. In the present study, we examine the roles of ULF waves from the point of view of the duct propagation of chorus emissions as well as the generation process of chorus emissions. We also propose a model of the duct propagation of whistler-mode waves due to the contribution of the compressional component of ULF waves.

First, we evaluate the effect of the magnetic field variation on the refractive index of whistler-mode waves. According to Smith et al. [1960], the refractive index depends not only on density but also on the magnetic field intensity. Setting the amplification factor x and y for the magnetic field intensity and electron density, respectively, we obtain a dependence of the refractive index due to the variation of either the magnetic field or number density. The obtained dependence shows that a decrease in the magnetic field intensity leads to a refractive index change corresponding to an increase in the electron density. Under the condition where the range of the variation is less than 10% of the background level, the effects of variations of the number density and the magnetic field intensity to the refractive index are comparable, while the change of the magnetic field is relatively significant.

Next, we examine whether the magnetic field fluctuations observed in the event on March 27th resulted in significant refractive index changes. In the event, during the time interval from 21:30 UT to 22:00 UT, the Arase satellite was located at L˜6.3-6.1, 04:00-04:12MLT, and from -12.7 to -10.1 degrees MLAT. The total magnetic field intensity changed within 10% with respect to the ambient magnetic field under the presence of ULF waves. Here we assume that the number density of the background plasma is constant during the event. The observation result shows that chorus emissions propagating parallel to the background magnetic field appear at timings corresponding to the decrease of the total magnetic field due to the compressional component of ULF waves. The observed property can be explained by the model we propose; chorus emissions are generated around the magnetic equator through the flux enhancement of keV electrons due to toroidal mode ULF waves, and then the generated chorus emissions propagate away from the equator guided by the duct structure produced by the compressional ULF waves. In addition, we evaluate the effect of the density variation on the duct propagation during the event. There is a possibility that density variation also occurred during the event with a magnitude similar to the magnetic field variation. The total magnetic field variation, in this case, was about 3%, corresponding to 2.7% of the density variation. Since the analysis of UHR data includes time periods that are difficult to distinguish, further investigation is necessary. We also report the results of analysis on other events of duct propagation of chorus emissions under the presence of ULF waves.

R006-P26
ポスター１：9/24　PM1/PM2 （13:45-18:15）

あらせで観測された低周波ホイッスラーコーラス波動の解析

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Analysis of low frequency whistler chorus waves observed by Arase

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The radiation belts are torus-shaped zones at 2-6 Earth radii distance from the center of the Earth, where high energy particles are trapped by the Earth's magnetic field. It is known that the acceleration and loss of the energetic particles in the radiation belts are deeply related with the energy transfer by electromagnetic waves. Whistler chorus wave is one of the electromagnetic wave modes considered to relate with the acceleration and loss processes in the radiation belts. They are generally observed at 10-80% of the local electron cyclotron frequency, and have the peak intensity at just below the half of the local electron cyclotron frequency. While the whistler chorus waves at around half of the electron cyclotron frequency have been studied by many researchers in view of the contribution to the acceleration and loss of the energetic particles, low frequency (ELF) whistler chorus waves at frequencies below 10% of the electron cyclotron frequency have not yet been well studied. Cattell et al. (2015) statistically investigated the whistler chorus waves during geomagnetic storms observed by Van Allen Probes and found that their frequencies often dramatically dropped and became much lower than the commonly observed frequencies of whistler chorus waves. Such low-frequency whistler chorus waves have been observed at low magnetic latitudes and relatively high L values. Analysis of the pointing flux suggested that these waves originated in the magnetic equator region and propagated along the magnetic field lines to high latitudes. In this study we analyze the magnetic field data obtained by the Arase satellite, study the properties of ELF whistler chorus waves and discuss their contribution to the energy transfer process. As the first step, we analyze typical events of ELF whistler chorus waves measured by the fluxgate and search coil magnetometers onboard the Arase satellite. In the future, we will analyze also simultaneous electric field and plasma particle data to clarify the energetic exchange between the ELF whistler chorus waves and particles in the radiation belts.

地球の周辺 2-6 地球半径の距離に、高エネルギープラズマが地球磁場によって捕捉されている放射線帯と呼ばれるドーナツ状の領域が存在している。この放射線帯を形成している高エネルギープラズマの生成・消滅には、電磁波によるエネルギー授受が深く寄与していることが知られている。ホイッスラーコーラス波と呼ばれる電磁波は、一般的に周波数が電子サイクロトロン周波数の 10-80% であり、この中心周波数は電子サイクロトロン周波数の半分程度とされている。ホイッスラーコーラス波による放射線帯粒子の生成・消滅への寄与は多くの研究者により調べられてきたが、その中で電子サイクロトロン周波数の 10% 以下の (ELF 帯) 低周波ホイッスラーコーラス波はまだあまり研究が進んでいない。Cattell et al. (2015) では、Van Allen Probes で観測された地磁気嵐時のホイッスラーコーラス波を統計的に解析した結果、一般的によく観測されるホイッスラーコーラス波の中心周波数よりも極端に低い低周波ホイッスラーコーラス波がしばしば観測されることが報告されている。このような低周波ホイッスラーコーラス波は比較的大きな L 値をもつ磁気低緯度領域で観測されている。さらに、ポインティングフラックスを調べ、この波は磁気赤道付近で発生し、磁力線に沿って高緯度領域に伝播していることが見出された。本研究では、あらせ衛星が取得した磁場データを解析し、低周波ホイッスラーコーラス波について、その性質を解析し、エネルギー授受との関連を調べている。具体的には、あらせ衛星に搭載されているフラックスゲート磁力計とサーチコイル磁力計のデータを使って、ELF 帯のホイッスラーコーラス波の典型イベントを解析し、その性質を明らかにすることを目指している。将来的には、磁力計のデータだけでなく、電場やプラズマ粒子などの同時データを解析する。

R006-P27
ポスター１：9/24　 PM1/PM2 （13:45-18:15）

あらせ衛星で観測されたNWC送信局信号の伝搬特性解析

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Propagation characteristics analysis of NWC transmitter signals observed by the Arase satellite

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Propagation direction of plasma waves is crucial to understand the environment of the terrestrial inner magnetosphere. Several methods have been proposed to determine the propagation direction of plasma waves using electromagnetic field data obtained by scientific satellites. However, evaluating the accuracy of determined direction of natural plasma waves is difficult because there are several uncertainties to compare with the theoretical wave propagation direction. In this study, we analyze the propagation direction of artificial signals transmitted from the North West Cape (NWC) transmitter in Australia using the electromagnetic waveform data observed by the Arase satellite. We statistically evaluate the propagation characteristics to validate the accuracy of the estimation results.

First, considering the characteristic that a VLF signal propagate roughly along a magnetic field line, we extract the time periods when the magnetic footprint of Arase was in $\pm$ 10 degrees geographic latitude and longitude from the position of NWC station. Second, we collect the NWC signal events from the waveform data observed by the Waveform Capture (WFC) of the Plasma Wave Experiment aboard the Arase satellite. We analyze the electromagnetic power spectrum, WNA (wave normal angle), polarization, planarity, and the angle of pointing vector against the magnetic field line of the signals to investigate their characteristics. We found that the amplitudes of the signals were modulated in many of the cases, and the WNAs of these events showed rapid changes within a short period. We also conduct a hodograph analysis of the events, and confirmed that most of events is plausibly a single wave. As a next step, we investigate the relationship between amplitudes and WNAs, revealing a positive correlation between the signal amplitude and the stability of the WNA. We determine a typical WNA by taking a moving average of the sum of squares of the amplitudes with a 5-degree interval and normalized it by the observation time length. Finally, we investigate the relationship between the determined WNA and the magnetic latitude of the observation point. The results showed that the WNA tended to increase as the distance from the NWC station increased.