The plasma dynamics in the Jovian inner magnetosphere seen by EXCEED onboard HISAKI

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"HISAKI" the Japanese Earth orbiting satellite has been launched in September 2013 from the Uchinoura space center. The EUV spectroscope "EXCEED" on board the spacecraft is observing the planets in our solar system since the end of November 2013 [Yoshikawa et al. 2014]. The performance of the instrument (effective area, spectral and spatial resolutions, and etc.) are same as been expected before the launch [Yoshioka et al. 2013]. Using the EUV spectra of the Jovian inner magnetosphere (Io plasma torus) taken by the EXCEED, the plasma dynamics such as electron transportation or local heating process have been revealed. In this presentation, we will show the whole results of Io plasma torus observation through the EXCEED, and we will also explain the way of our approach for the Jovian plasma dynamics.

EXCEEDによる木星観測- オーロラとIPTの増光と動径方向のエネルギー輸送-

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Evidence of inward energy transports in the Jovian inner magnetosphere observed by EXCEED on Hisaki

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We have quasicontinuously observed Jupiter with its moon Io in the extreme ultraviolet spectral range from Hisaki spacecraft and found the transient aurorae and Io plasma torus brightenings. They were sporadic, however, had strong ties. The transient aurora brightening occurred ~10-hour earlier than that of the torus. This is a clear evidence of radially inward transport of energy across the azimuthal flows from the outer magnetosphere of Jupiter to the inner.

Fast planetary rotation of Jupiter induces azimuthal flow pattern that governs the plasma motion with the magnetic field in the Jovian magnetosphere. We have quasi-continuously observed Jupiter with its moon Io in the extreme ultraviolet spectral range from Hisaki spacecraft and found the transient aurorae and Io plasma torus brightenings. They were sporadic, however, had strong ties. The transient aurora brightening occurred ~10-hour earlier than that of the torus. This is a clear evidence of radially inward transport of energy across the azimuthal flows from the outer magnetosphere of Jupiter to the inner.

Local electron heating in the Io plasma torus associated with Io observed by HISAKI

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Io-correlated brightness change in Io plasma torus (IPT) has been discovered by Voyager and show an evidence of local electron heating around Io. However, the amount of observation data is still limited to investigate its detail properties. In addition, the clear Io-correlated change has not been detected by EUVE and Cassini observations. Cause of the Io-correlated effect is still open issue. The HISAKI satellite was launched on Sep. 14, 2013 and started observation of IPT and Jovian aurora for more than two months since the end of Dec. 2013. Observation of IPT with HISAKI showed clear Io-correlated brightness change since the Voyager observation. The amplitude of the periodic variation associated with Io's orbital period was larger in the short wavelength than in long wavelength. The wavelength dependence suggests significant electron heating and/or hot electron production. The Io phase dependence shows that bright region is located just downstream of Io. These are evidence of local electron heating around/downstream of Io and consistent with the Voyager result. The brightness also depends on system-III longitude and has local maximum around 120 and 300 degrees. Based on an empirical model of IPT, electron density at Io also shows maxima around the same longitudes. This suggests that the electron heating process is related with plasma density at Io. Candidate mechanisms which are responsible for the electron heating are (1) energy transfer via Coulomb interaction from electron beam produced by Io-Jupiter's ionosphere coupling to thermal electron in IPT and (2) ion cyclotron waves excited by picked-up ion downstream of Io and electron heating via wave-particle interaction.

Multi-wavelength observations of Jovian aurora coordinated with Hisaki and other space telescopes

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From January to April 2014, two observing campaigns by multi-wavelength remote sensing from X-ray to radio were performed to uncover energy transport process in Jupiter's plasma environment using space telescopes and ground-based facilities. These campaigns were triggered by the new Hisaki spacecraft launched in September 2013, which is an extremely ultraviolet (EUV) space telescope of JAXA designed for planetary observations.

In the first campaign in January, Hubble Space Telescope (HST) made imaging of far ultraviolet (FUV) aurora with a high special resolution (0.08 arcsec) through two weeks while Hisaki continuously monitored aurora and plasma torus emissions in EUV wavelength with a high temporal resolution (more than 1 min). We discovered new magnetospheric activities from the campaign data: e.g., internally-driven type auroral brightening associated with hot plasma injection, and plasma and electromagnetic filed modulations in the inner magnetosphere externally driven by the solar wind modulation.

The second campaign in April was performed by Chandra X-ray Observatory (CXO), XMM newton, and Suzaku satellite simultaneously with Hisaki. Relativistic auroral accelerations in the polar region and hot plasma in the inner magnetosphere were captured by the X-ray space telescopes simultaneously with EUV monitoring of aurora and plasma torus. Auroral intensity in EUV indicated a clear periodicity of 45 minutes whereas the periodicity was not evident in X-ray intensity although previous observations by CXO indicated clear 40-minute periodicity in the polar cap X-ray aurora.

In this presentation, we show remarkable scientific results obtained these campaigns.

イオトーラスへのプラズマ注入・MI 結合過程のモデル化の検討

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Studies on the models of Io torus plasma injection and M-I coupling processes

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From the Galileo spacecraft observations, it has been suggested that a hot/tenuous plasma injection into the cold/dense Io torus causes many fluid instabilities, wave-particle interactions, and maintenance of the persistent structure [e.g., Frank and Paterson, 2000; Schneider et al., 2001; Bagenal and Delamere, 2011]. Recently, the EXCEED/HISAKI space telescope captured many excellent features of the Io plasma torus and the associated auroral responses at Jupiter [Private comm. with F. Tsuchiya and T. Kimura, 2014]. Two-dimensional MHD simulations of interchange instability at the Io torus were performed in order to extract the key parameters for torus structures and to estimate the time scale of radial plasma transport [Hiraki et al., 2012].

We now extend our model into the ones where the hot plasma injection and the M-I coupling processes can be treated. We will develop a fluid model including compressional effects, or baroclinicity, along with the magnetic curvature, the centrifugal force, and the corotation lag of plasma; the density and temperature can be separated. In order to address the development of auroral structures at Io footprint, we need to examine the field-line wave activities caused by an electromotive force due to the torus plasma fast rotation. We will analyze the properties of Alfven eigenmodes that couple to the Jovian ionosphere (unstable modes), and the wave pattern is strongly deformed by the effect of Io torus high density.

ガリレオ探査機による観測以来、低温/濃厚なイオトーラスへの高温/希薄なプラズマの注入によって、様々な流体不安定、波動-粒子相互作用、トーラスの永続的な形状維持が引き起こされることが指摘されている [e.g., Frank and Paterson, 2000; Schneider et al., 2001; Bagenal and Delamere, 2011]。最近の EXCEED/HISAKI 宇宙望遠鏡による観測では、イオプラズマトーラスとそれに関連した木星オーロラの応答に興味深い特徴があることが明らかになっている [Private comm. with F. Tsuchiya and T. Kimura, 2014]。我々は、イオトーラスにおける交換型不安定の２次元 MHD 計算を行い、トーラス形状を支配するキーパラメータの抽出、動径方向のプラズマ輸送の時間スケール推定を行った [Hiraki et al., 2012]。

我々は現在、高温プラズマの注入・M-I 結合過程を取り扱えるようにモデル拡張を行っている。まず、磁場の曲率、プラズマの遠心力と共回転遅延の効果に加え、圧縮性（傾圧性）を含めた流体モデルの構築を行う；これにより、密度と温度を別々に扱うことができる。イオフットプリントにおけるオーロラ構造の発達を議論するには、背景トーラスプラズマの高速回転に伴う起電力を考慮し、それに付随する磁力線上の波の活動を押さえる必要がある。我々はまず、木星電離圏と結合したアルヴェン固有（不安定）モードの特徴を解析する。その一例として、トーラスの高密度効果により、波の形状が大きく変形したモードが成長し得るのかを調べてみる。

Solar wind influence on the dawn-dusk asymmetry of the Io plasma torus observed by HISAKI/EXCEED

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The dawn-dusk asymmetry of the Io plasma torus has been seen by several observations [e.g., Sandel and Broadfoot, 1982; Steffl et al., 2004]. Ip and Goertz [1983] explained this asymmetry can be caused by a dawn-to-dusk electric field in the Jupiter's inner magnetosphere. However, the question what physical process can impose such an electric field deep inside the strong magnetosphere still remains. The long-term monitoring of the Io plasma torus is a key observation to answer this question. The extreme ultraviolet (EUV) spectrometer EXCEED onboard the HISAKI satellite was launched in 2013 and observed the Io plasma torus from December 2013 to March 2014 (75 days). We investigated the temporal variation of the dawn/dusk ratio of EUV brightness. Then we compared it to the solar wind dynamic pressure extrapolated from that observed around Earth by using magnetohydrodynamic (MHD) simulation. As a result we found clear responses of the dawn-dusk asymmetry to rapid increases of the solar wind dynamic pressure. We will present the initial results of this study.

電波干渉計及びひさき衛星を用いた木星放射線帯空間変動現象の考察

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A Study on spatial variations in Jovian radiation belt using radio interferometer and HISAKI

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In order to reveal days to weeks variation in brightness distribution of Jovian Synchrotron Radiation (JSR), we made coordinated observations using radio interferometer and HISAKI. JSR is the most effective probe for the dynamics of the Jovian radiation belt through remote sensing from the Earth. Jovian radiation belt is located in the strong magnetic field region and external forces such as solar wind disturbances are thought to be difficult to reach the radiation belt region. Although JSR has been thought to be stable for a long time, recent observations for JSR reveal days to weeks variations of total flux density and brightness distribution. It is theoretically expected that the dynamo electric field induced by diurnal neutral wind system produces dawn-dusk electric potential difference and dawn-dusk asymmetry in brightness distribution of JSR. We have evaluated this scenario by using the Very Large Array archived data, but short term variations in brightness distribution cannot be examined solely by the scenario. There is a possibility that variations related to diurnal wind system were masked by some other processes which dominated in the variations of the dawn-dusk ratio on the short time scale.

In this study, we examine the effect of dawn-dusk electric field on Jovian radiation belt. It is known from visible and ultraviolet observations that Io torus has dawn-dusk asymmetry and this asymmetry is thought to be caused by dawn-dusk electric field. In addition to that, continuous HISAKI observation reveal that dawn-dusk asymmetry of Io torus changes in days to weeks, which suggest that dawn-dusk electric field also varies in days to weeks. If this global electric field affect inside the magnetosphere, the variations in brightness distribution of JSR can be explained by dawn-dusk electric field. Therefore, we made coordinated observation of radio interferometer and HISAKI to investigate the effect of dawn-dusk electric field on Jovian radiation belt. This is the first opportunity that dawn-dusk electric field and brightness distribution of JSR can be obtained simultaneously. The radio observations were made from Dec. 31 in 2013 to Jan. 16 in 2014 with Giant Metrewave Radio Telescope (GMRT) at 610 MHz. During this period, HISAKI continuously monitored Io torus at ultraviolet wavelength.

A preliminary analysis showed that dawn-dusk peak emission ratio of JSR decreased around Jan. 4 and Jan. 10, and the dawn-dusk ratio of Io torus also changed at the same period. This result suggested that the dawn-dusk electric field affected both Io torus and the radiation belt. We will evaluate the relation between spatial distribution of JSR and dawn-dusk electric field by using the charged particle distribution model proposed by Divine and Garrett and discuss the effect of dawn-dusk electric field on Jovian radiation belt.

木星シンクロトロン放射 (Jovian Synchrotron Radiation: JSR) は放射線帯内の磁場にトラップされた相対論的電子からの放射であり、地球から木星放射線帯をリモートセンシングし、そのダイナミクスを理解する上で効果的な観測手段である。木星放射線帯は磁場が強力なため外部からの影響を受けにくいと考えられており、JSR は安定なものだと考えられていた。しかし、1990 年代の地上観測によって数日から数週間の時間スケールで JSR の強度が変動しているということが明らかになった。また、近年は電波干渉計を用いた連続観測により放射線帯の空間分布変動をとらえるという試みも活発化しており、JSR の朝夕非対称性が数日で変化することが明らかとなった。理論的には熱圏風の昼夜対流により生じる電離圏ダイナモ電場のポテンシャルが朝夕間で異なることにより、磁力線を介して電離圏と結ばれた放射線帯粒子の空間分布が変化し、JSR の輝度分布に Dawn-Dusk 非対称が生じることが予想されている。しかし、Very Large Array の公開データを用いてこの理論を検証したところ、JSR の空間変動は昼夜間対流だけでは説明できないことがわかった。従って JSR の空間分布を数日で変化させるメカニズムは全く解明されていない。

本研究では JSR の空間変動を説明するために、新たに Io トーラスに働く Dawn-Dusk 電場の存在に着目した。これまでの可視・紫外観測から Io トーラスの空間分布に朝夕非対称が生じていることがわかっており、この朝夕非対称性は Dawn-Dusk 電場によって引き起こされていると考えられている。さらに HISAKI の連続観測によって Io トーラスの朝夕非対称は数日で変化することが明らかとなり、Dawn-Dusk 電場が数日の時間スケールで変化することが示唆されている。この Dawn-Dusk 電場が内側の放射線帯にまで及んでいるとすると JSR の空間変化を説明することが可能である。そこで我々は電波干渉計とひさき衛星を用いた同時観測から Io 周辺に働く Dawn-Dusk 電場がさらに内側の放射線帯に影響を及ぼすか検証した。この検証は HISAKI 衛星によって内部磁気圏の電場変動を求め、同時に電波干渉計観測を行うことで初めて可能となった。電波観測はインドの大型電波干渉計 (GMRT) を用い、2013 年 12 月 31 日〜2014 年 1 月 16 日の期間に 9 日間実施した。観測周波数は 610MHz である。

初期解析結果からは 1 月 4 日及び 1 月 10 日付近で JSR の Dawn-Dusk 比が減少し、同様のタイミングで Io トーラスの Dawn-Dusk 比も変化していることがわかった。この結果から、Io 軌道に働く Dawn-Dusk 電場が内側の放射線帯に影響を及ぼしている可能性が示唆された。講演では JSR の空間分布と電場変動の関係を Divine & Garrett の放射線帯粒子分布の経験モデルを用いて定量的に評価し、Dawn-Dusk 電場が放射線帯に与える影響について議論する予定である。

大規模シミュレーションによる木星磁気圏の構造・ダイナミックスの研究

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Research of Jovian magnetospheric dynamics and configuration from global simulation

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Jupiter has the huge intrinsic magnetic field and rapid rotation. In addition, Jupiter locates far from the Sun as compared to the Earth. Thus it is thought that the effect of solar wind to the Jovian magnetosphere is much weak in early days. In the Galileo era, a lot of magnetospheric phenomena were observed and then theoretical analyses have been done. Then the understanding of Jovian magnetosphere made progress and the effects of solar wind to Jovian magnetosphere were appeared more and more. However, there are some outstanding problems which include the difficulty to distinguish whether the dynamics come from Jovian internal process or interaction of the solar wind. For example, *Joy et al.* [2002] indicated the bimodal distribution of the magnetopause and bow shock location using all observation results of Jupiter in those days and they cannot divide these distributions are come from whether internal or external effects. In the MHD simulation of Jovian magnetosphere, we have obtained the characteristic variation of bow shock and magnetopause locations to the solar wind dynamic pressure which may relate with the bimodal distribution.

In other case, *Woch et al.* [2002] reported that in the Jovian magnetotail the periodic plasma burst was occurred with 2, 3 days interval. Some (*Kronberg et al.*, 2005, etc) said that these periodic phenomena were caused by the only internal processes, no external effects. On the other hands, we suggested that the periodic phenomena were controlled by the configuration of Jovian magnetosphere which was dominated by the Jovian internal characters and the solar wind. Recently similar phenomena are observed by the New Horizon spacecraft. The high energy structures were observed in distant magnetotail repeatedly. *MacComas et al.* [2007] suggested that these were plasmoid which had been observed by Galileo. From the MHD simulation we have obtained the similar configuration of periodic plasmoid observed by the New Horizon and the IMF affected to the periodicity of plasmoid ejection.

Finally we will show the latest our simulation results using the massively parallel super computer. Now we perform the simulation with 0.15 R_J gird spacing and will connect the hybrid simulation around nearby Jupiter.

木星夜側磁気圏におけるリコネクションのその場観測

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In-situ observations of magnetic reconnection in the Jovian nightsidemagnetosphere

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Magnetic reconnection is commonly seen in various planetary magnetospheres. However, morphologies and roles of reconnection in magnetospheric dynamics are not necessarily the same. In a classical view, the Earth's magnetosphere is driven by the solar wind through reconnection, whilst the Jovian magnetosphere has been believed to be centrifugally-driven because of the planetary fast rotation and its internal plasma source. Due to the poor data, however, detailed study of Jovian reconnection has been difficult before the first orbiting spacecraft GALILEO. In-situ observations by GALILEO, equipped with particle detectors and electric/magnetic field sensors, indeed enabled us to refine the above classical view. We show that the plasma structure of Jovian reconnection is similar to the Earth's case despite the existence of heavy ions, whilst the global distribution of transient reconnection events is yet unique to the fast-rotating magnetosphere. Observations also suggest that the solar wind may significantly participate in prominent reconnection events, which was not anticipated in the classical view.

Oxygen torus in the inner magnetosphere of Saturn observed by Hisaki

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The water group neutrals are dominated by Saturn’s magnetosphere. In this study, we focus on oxygen dynamics in the inner magnetosphere of Saturn. Understanding of the temporal and spatial distributions of oxygen is required to understand the water group neutral dynamics in Saturn. The atomic oxygen was discovered by UVIS onboard Cassini [Esposito et al., 2005]. The spatial and temporal with time scale of several days – several tens of days distributions of oxygen are revealed by Melin et al., [2009]. "Hisaki" has been launched in September 2013. Using the EUV spectra by the EXCEED onboard Hisaki, we show the daily variation and spatial distribution of oxygen.

HISAKI/EXCEED で観測された磁気嵐中・ジオコロナの Lyman-αの増光

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The increase of the geocoronal Lyman-alpha emission observed by the HISAKI/EXCEED during the geomagnetic storms

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The Exosphere is the outmost region of the Earth's atmosphere, which is mainly composed of H and He atoms. These atoms resonantly scatter and make the ultraviolet glow surrounding the Earth. This glow is called 'geocorona'.

The past observations of the geocorona have been done mainly by the Earth-orbiting satellites. Recently, the abruptly temporary increases of the Lyman-alpha emission in 3 to 8 R_E from 6% to 17% during geomagnetic storms have been observed. However, the mechanism of the increases is not revealed. In September 2013, HISAKI/EXCEED was launched by the Epsilon rocket. It has been observing the geocorona in the orbit around the Earth. During the strong geomagnetic storms in February 2014, the increases of the Lyman-alpha emission were observed. The increases in nightside were significantly greater than the dayside.

Now, the instrument observing the geocorona LAICA onboard on the ultra small deep space satellite PROCYON which will be launched with HAYABUSA 2 is under developing. The EXCEED observes the geocorona with a narrow field of view, while in contrast, the LAICA will observe the geocorona with a wide field of view(more than 25 R_E) beyond the moon. The calibration of all optical instruments has done. In this presentation, the results of the calibration are shown.

We investigate the mechanism of the increases of the geocoronal Lyman-alpha emission during the geomagnetic storms using the results by the EXCEED observation. Collaboration between the EXCEED and the LAICA will be done.

外気圏とは地球の大気層の最も外側の領域であり、主な構成原子は水素やヘリウムである。それらの原子が太陽光により共鳴散乱し、地球全体を包む紫外グローを形成する。これをジオコロナと呼ぶ。

これまでのジオコロナの観測は地球周回衛星によるものが主である。最近では、3~8R_E の領域で Lyman-αの発光量が磁気嵐発生中に 6~17%増加するという現象が確認された。しかし、この増加のメカニズムは未だ解明されていない。

2013 年 9 月にイプシロンロケットにより打ち上げられた HISAKI/EXCEED で地球周回軌道からジオコロナの観測が行われている。2014 年 2 月に大規模な磁気嵐が確認されており、その間 Lyman-αの増光が観測された。また、昼側に比べ夜側のほうが著しく増光していることも確認された。

EXCEED の観測と並行して、2014 年 12 月にはやぶさ 2 とともに打ち上げが予定されている超小型深宇宙探査機 PROCYON に搭載されるジオコロナ観測装置 LAICA の開発を進めている。地球周回軌道から観測している EXCEED は視野が狭いが、LAICA は月以遠に達する軌道から広い視野 (25R_E 以上) で観測することができる。単体の性能試験はすべて完了し、8 月中に探査機に取り付けられる予定である。ここではその試験結果についても述べる。

本研究では、EXCEED による観測結果をもとに、磁気嵐発生時におけるジオコロナのライマンαの増光メカニズムを探る。また、将来的に EXCEED と LAICA の同時観測を行うことも検討中である。

Hisaki/EXCEED observation of solar-wind-driven atmospheric escape from Venus

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Hisaki is an Earth-orbiting spectroscopic satellite equipped with the EXCEED (EXtreme ultraviolet spectrosCope for ExosphEric Dynamics) instrument, which was successfully launched on September 14, 2013. One of the primary objectives of Hisaki/EXCEED is to study atmospheric escape from Venus responding to variations of solar and solar wind parameters, and its impact on the evolution of the planetary environment. The amount of atmospheric volatiles escaping to space from Venus still remains poorly constrained. Hisaki/EXCEED has constrained the atmospheric escape rates from Venus by measuring emissions from OII, CII, NII, OI, Lyman-alpha, etc. from the Venusian ionosphere, thermosphere, exosphere, and tail region, which are expected to significantly vary responding to Sun's EUV and solar wind variations. In this presentation, preliminary results of Hisaki/EXCEED observation of escaping planetary atmospheres together with collaborative studies with in-situ observation by the ASPERA-4 and MAG instruments aboard Venus Express and with solar wind models will be presented.

Variations of the total oxygen ion content of the Venusian ionosphere controlled by the solar wind: Hisaki and VEX observations

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Due to no intrinsic magnetic field on Venus, the solar wind directly interacts with the ionosphere of Venus [e.g., Brace et al., 1980]. The direct interaction efficiently transfers eneregy of the solar wind into the ionosphere, leading a heating and energization of the content of the ionospheric plasma. It can contribute to loss of ions from Venus. Spacecraft observations have shown that solar wind conditions affect the structure of the ionosphere and the ion escape rate at Venus [e.g., Luhmann, 1986; Dubinin et al., 2011]. In-situ data provides us detailed information of local fields and particles, so that we see locally how the fields change, how the particles get energy, and how much fluxes exist. However, we need to collect much data and accumulate them to get a global structure of the ionosphere and total ion escape rate. Since the solar wind condition changes time to time and a spacecraft can fly on limited orbits, the statistical treatment may not show the real ionospheric structure and total ion escape rate. In fact, there is large uncertainty in the total ion escape rates obtained from spacecraft to date [Dubinin et al., 2011].

On Sep 14, 2013, JAXA Hisaki spacecraft was successfully launched and injected into the orbit around the Earth. Hisaki carries the EXtreme ultraviolet spectrosCope for Exsospheric Dynamics (EXCEED) [Yoshioka et al., 2013; Yoshikawa et al., 2014] to observe planets such as Venus, Mars and Jupiter. The observation of Venus was conducted during quasi-continuous 3 periods (Mar 7 to Apr 2, Apr 24 to May 23, and Jun 24 to Jul 17). The EUV spectra obtained from EXCEED has ranges within 52 - 148 nm and slit size of the EXCEED is 60” x 400” which spatially covers Venus disk and tail where the ionospheric and escaping ions exist. Therefore the remote observation of EXCEED may allow us to obtain a global structure of the ionosphere and escaping ions in the Venus tail according to the EUV emissions.

In this study, we investigate the relationship between daily variations of the O^+ emission (83.4 nm) of the Venus disk observed by EXCEED and the solar wind dynamic pressure. We use dataset from the Analyser of the Space Plasma and Energetic Atoms (ASPERA-4) aboard ESA Venus Express to get the solar wind dynamic pressure. We also use dataset of Solar EUV Experiment (SEE) on the NASA Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) mission to remove a periodic EUV variation from the EXCEED dataset shown below. The O^+ emission is mainly dominated by the photoelectron impact on O atoms at 140 km altitude and the resonant scattering also has small contribution to this emission [Gerard et al., 2011]. Because an efficiency of the resonant scattering depends on the solar EUV flux, the O^+ emission is modulated by EUV flux variations caused by the solar rotation which has a periodicity of ˜28 days. Removing the periodic variation from the original emissions by using the solar EUV flux (83.4 nm) of the SEE dataset, we found that the high dynamic pressure triggers a gradual decrease of the O^+ emissions and it lasts for 1-2 days. We suggest that this feature is attributable to changes of the ambient electron and ion populations caused by the compression of the ionosphere depending on the solar wind dynamic pressure. After the compression ceases, the ionosphere starts to recover to be back to the pre-impact level. We find that this recovery also lasts for 1-2 days. From the ion refilling rates into the ionosphere from the recovery period, we can roughly estimate upper limit of the O^+ escape rate, meaning that we can restrict the uncertainties of previously proposed O^+ escape rates for each event.

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金星・火星観測時における EXCEED の検出器性能の変化を踏まえた散逸大気に関する解析

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Analysis of escaping atmosphere from Venus and Mars with variations of the detector during observation by the SPRINT-A/EXCEED

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The Earth sustains the environment in which creatures have lived due to the thick atmosphere and the intrinsic magnetic moment. In contrast, although Venus and Mars are Earth-like planets, with weak intrinsic magnetic dipole moments, their atmospheres are considered to have escaped or been escaping to space due to the solar wind interaction. Therefore, these two planets have environments that are thoroughly exotic compared with that of the Earth. Characterization of the formation of terrestrial planets environments and their divergent evolutions is a very important study in planetary science. Distribution of escaping ions to space, forming the ionospheric tail, is imaged by solar resonantly scattering emissions in the extreme ultraviolet(EUV) spectral range. As a result, if how much atmosphere is lost to space constantly is measured, it will allow us to estimate the total loss.

In September 2013, the EUV spectrometer EXCEED onboard the small scientific satellite SPRINT-A(HISAKI) which was launched by the Epsilon rocket and has been observing planets in orbit around the Earth can image planet and tail within the field of view. Its time resolution is about 50 minutes. Therefore, EXCEED can observe the escaping atmosphere in the nightside and the solar wind interaction with planetary atmospheres by the charge exchange process in the dayside simultaneously and with high time resolution. Since the intensity of the emissions from the escaping atmosphere is very low, the past optical observations have not given the significant information.

In this presentation, we will detect the faint emissions from the escaping atmosphere by analyzing the data with checking the performance of the instrument, especially degradation of the detector during the Venus and the Mars observation by the EXCEED.

地球には固有磁場があり、十分に大気があるため、生命が存在する。一方、地球型惑星である金星・火星の固有磁場は非常に小さいため、太陽風によって大気は宇宙空間へ散逸していると考えられる。よって、これらの惑星の大気環境は地球と大きく異なる。それらの地球型惑星の環境や異なる進化過程を特徴付けることは惑星科学にとって非常に重要なことである。宇宙空間へ散逸する電離大気は反太陽方向に尾を引き、その様子は共鳴散乱によって発光するため、撮像観測をすることができる。その結果、地球型惑星からの大気散逸の量を推定することができれば、これまでの散逸の総量を知ることが可能となる。

2013 年秋に、イプシロンロケットにより打ち上げられた惑星分光観測衛星 SPRINT-A(ひさき) に搭載された極端紫外線 (EUV) 分光装置 EXCEED は地球周回軌道から惑星を観測しており、惑星と尾部を視野内に収めることができる。また、EXCEED の時間分解能はおよそ 50 分である。そのため、惑星昼間側での大気の電離や太陽風との相互作用の結果生じる、夜側での大気の散逸の様子を同時かつ高時間分解能で知ることができる。これまでの光学観測では、散逸大気から発せられる光量もわずかであるため、有意な情報は得られていない。

本研究では、SPRINT-A/EXCEED が金星および火星を観測した期間のデータを、観測機の性能、特に検出器の劣化状態を確認しながら解析することで、散逸大気からの微弱な光の検出を試みる。

Hisaki/EXCEED および X 線望遠鏡群との協同観測における木星赤外オーロラ:K-band および L-band オーロラの比較

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Jovian IR aurora in the coordinated observation with Hisaki/EXCEED and X-ray telescopes: Comparison between K- and L-band auroras

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We have observed Jovian infrared aurora in order to evaluate the temperature and velocity fields of polar upper atmosphere and the energy of precipitating electrons. In Jan-Apr 2014, we performed the observation using SUBARU and IRTF as the coordinated observation campaign with Hisaki/EXCEED, which observed the total flux of UV aurora continuously. In April, three X-ray space telescopes were joined for spatial and temporal variations of energetic particles. IRTF L-band (3-4um) spectroscopy provided the temperature map of northern polar region using a near-IR spectrometer, CSHELL, for intermittent nights for each 2 weeks in January and April. SUBARU L-band and K-band (2-2.5um) spectroscopy obtained upper atmospheric temperature with higher accuracy using a near-IR spectrometer, IRCS. This paper focused the latter result.

In the Jovian polar region, precipitating electrons collide with upper atmosphere and heat this region. UV aurora (H and H_2) is directly excited by the collision of high-energy electrons to atmospheric H and H_2, whereas IR aurora (H_3^+ and H_2) is thermally excited by the heated upper atmosphere. The emissivity of H_3^+ aurora is related to the density of H_3^+ and the excitation rate, and includes the information of not only thermal and velocity field but also the energy of precipitating electrons: The production rate of H_3^+ at high latitude is correlated to the collision rate of precipitating electron. Therefore, the density of H_3^+ at specific altitude reflects the amount of penetrating electrons. Since higher energy electrons can penetrate to deeper region, the emission altitude of H_3^+ aurora can be correlated to the energy of precipitating electrons. L-band H_3^+ lines are emitted from lower energy state so that they are from the lower temperature area in lower altitude. For this reason, the comparison of K and L-band lines from different emission altitude can be used to estimate the energy of precipitation electrons. If it is possible, the estimation from IR aurora is valuable because (1) it can be observed from ground (2) with the information of temperature and velocity fields. This observation aimed to do the feasibility study by the quasi-simultaneous observation of K and L-band auroras.

We had 3 nights (in Feb 13,14 and Apr 19), and observed northern and aurora in Feb 13 and northern aurora in Apr 19 in a limited short period due to bad weather. The former, we could partially apply the adaptive optics. The slit was set parallel to the rotational axis and switched alternately K and L-band in every ~10min. At the moment we concentrated to the data in April that was simultaneous observation with X-ray telescopes, for the evaluation of the relative flux ratio of K and L-band aurora. Although the absolute flux is hard to be derived by the disturbance of bad weather, we found the clear difference between K- and L-band auroras: L-band aurora flux was increased at main oval and decreases at polar region, whereas similar feature was not clear in K-band aurora. We also derived the temperature of K- and L-band auroras at their emission altitude via the intensity ratio of emission lines in K-band and L-band respectively.

In this paper, we will present these results with the correlation of X-ray observation results. And we will also report the result of the observation with AO in February. Moreover, we will prepare the evaluation of the temperature map derived by IRTF observation (Jan 1,13, Apr 11,13,16,18,20,23) with the comparison of total UV emission intensity by Hisaki/EXCEED.

我々は、木星赤外線オーロラを継続観測し、高層大気温度場・速度場と降下電子エネルギーの評価を行ってきた。2014 年１－４月には、Hisaki/EXCEED との協同キャンペーンの一環として SUBARU・IRTF 望遠鏡で観測を行った。この期間、Hisaki/EXCEED は継続的に木星を観測し、紫外オーロラ全発光強度（振込電子量の指標）が得られた。4 月には３つの X 線望遠鏡観測による高エネルギー粒子の空間分布・時間変動観測も行われた。我々は IRTF で１・４月に各２週間の断続観測を行い、近赤外エシェル分光器 CSHELL で L-band(3-4 μ m 帯) 赤外オーロラの極域温度マップを得た。また２・４月の一晩ずつ SUBARU の近赤外線分光器 IRCS で L-band と K-band(2-2.5 μ m 帯) で、広波長帯準同時観測による高精度の高層大気温度場計測を行った。本講演では、SUBARU 観測結果の速報に焦点を当てる。

木星の強力な磁気圏は、電離圏・熱圏へ電流系を通して力学的・電磁気的に結合している (MIT 結合)。この結合系では、高層での中性大気・電離大気間の衝突を介して惑星自転の角運動量が磁気圏へ供給される。この角運動量輸送を担う電流を運ぶオーロラ降込電子は、高層大気へ衝突しこれを加熱する。降込電子は衝突励起によって H・H_2 紫外線オーロラを発光させ、また加熱された高層大気は熱励起によって H_3^+・H_2 赤外線オーロラを発光させる。後者は、H_3^+ 分子 H_2 分子の振動回転励起で、H_3^+ は K-band と L-band、後者は K-band に輝線を持つ。この発光は、MIT 結合に伴う大気加熱量の指標となり、地上観測も可能なため、木星 MIT 結合研究において重要な観測手段である。

赤外オーロラ発光は、高層温度場・風速場だけでなく振込電子エネルギーの情報も含む。高緯度での H_3^+ 生成の主因は降込電子の H_2 分子への衝突で、その密度は発光高度での降込電子量と相関する。より高エネルギーの電子がより低高

度に到達するため、H_3^+ オーロラの発光高度は降込電子のエネルギーに相関する。より低エネルギー準位からの遷移である L-band 発光は、より低温・低高度域で発光するため、高エネルギー電子の多い領域でより発光することが予想される。このため、L・K-band 間の発光強度比は、振込電子エネルギーに用いうる。振込電子エネルギーの推定は紫外オーロラで行われてきたが、赤外オーロラでは (1) よりアクセスの容易な地上観測において (2) 大気温度・風速情報も同時に得られうることになる。本観測は、L・K -band 準同時観測（10 min 程度の時間差）によるこの導出の初試行を目的とした。

また K-band で観測される H_3^+・H_2 発光は、発光強度の水平分布が一致しないことが知られ、この解明も目的とした。この相違は、H_3^+ 発光域は電子降込の影響が大きい高温・高高度、H_2 発光域は Joule 加熱の影響が大きい低温・低高度、と発光高度が異なることが主因と解釈されてきたが、Subaru の補償光学 (AO) を適用した我々の K-band オーロラ高度分解観測結果 (Kasaba 他, 本学会講演) では、メインオーバルから外れた領域では両者の高度域に大きな違いがなかった。MIT 結合系の角運動量・エネルギー輸送を考える上で、この高度域はエネルギー注入領域と大気応答領域という性格を有し重要であり、初の L-band 発光との準同時観測を含めた追跡を実施した。

SUBARU 観測は 2014 年 2 月 13-14 日と 4 月 19 日の３晩を予定し、荒天の中で短時間ながら 2/13 に南北両極、4 月に北極のデータを取得できた。前者の南極域では補償光学適用も実現した。両者とも、自転軸平行にスリットを空間固定し L・K-band 分光を約 10min で交互に行った。ここまで X 線との同時観測でもある 4 月のデータ解析に注力しており、L・K-band オーロラ強度比の空間分布を評価した。悪天候のため絶対強度の導出は困難ながら、L-band ではメインオーバル位置でより強度が大きく極域で小さくなるのに対し、より高高度で発光する K-band ではコントラストが不明瞭で、この両者の強度比の相違を初めて観測的に見いだした。ついで、同時観測である K-band 内・L-band 内の輝線強度比から、それぞれの発光高度での温度導出を進めている。本講演では、この結果を X 線による発光空間分布との比較と併せて報告する。また補償光学適用による高度分解観測を行った 2 月観測の結果も報告予定である。さらに IRTF 観測 (1/3,13, 4/11,13,16,18,20,23) による極域温度場マップの紫外オーロラ発光量との相関についても準備を進める。

Vertical emissivity profiles of Jovian northern H3+ and H2 infrared auroras observed by Subaru/IRCS in Dec 2011 (and Feb 2014)

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We resolved the vertical emissivity profiles of H3+ overtone, H3+ hot overtone, and H2 emission lines of the Jovian northern auroras in K-band obtained in December 2011 observed by the IR Camera and Spectrograph (IRCS) of the Subaru 8.2 m telescope with the adaptive optics system (AO188). It was not the simultaneous observation with Hisaki/EXCEED. The observation was done in December 2011. However, it is related to Fujisawa et al. in this session, so that we present the results as a linked presentation. Following observation was done in Feb 2014, during the Hisaki/EXCEED coordinated campaign. We try to compare the result of this new chance with this report.

The spatial resolution achieved was ~0.2 arcsec, corresponding to ~600 km at Jupiter.

We derived the vertical emissivity profiles at three polar regions close to the Jovian limb. The H3+ overtone and H3+ hot overtone lines had similar peak altitudes of 650-1000 km and 550-1050 km above the 1 bar level, which were 350 km and 100-600 km lower, respectively, than the model values. On the contrary, the H2 peak emission altitude was high, 700-950 km above the 1 bar level. It was consistent with the value expected for precipitation of ~1 keV electron, which favors a higher altitude emissivity profile.

We concluded that the lower peak altitudes of H3+ overtone and hot overtone lines were caused by the non-local thermodynamic equilibrium (non-LTE) effect stronger than the model assumption. We could reproduce the observational emissivity profiles from the model by including this effect. It has been proposed that neutral H2 and ionized H3+ emissions can have different source altitudes because of their different morphologies and velocities; however, our observed results with a general circulation model (GCM) show that the peak emission altitudes of H3+ and H2 can be similar even with different velocities.

In the observation of Feb 2014, we could get the vertical profile of southern aurora with the AO188 activation. The tentative result supported the conclusion of the result in the 2011 observation in the northern hemisphere. We will also report the comparison with this new result.

Coordinated observation of Io plasma torus with gourd-based telescopes and Hisaki/EXCEED

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EXCEED is an EUV spectrograph onboard an earth-orbiting space telescope, SPRINT-A(Hisaki). One of the primal mission goal of Hisaki/EXCEED is to reveal radial transport of mass and energy in the Jovian magnetosphere. At the begging of January 2014, intense campaign observations of Jovian aurora and Io plasma torus were made using Hisaki/EXCEED, Hubble Space Telescope and other ground-based telescopes covering wavelength range from EUV through IR. We will present results of spectroscopic observation of Io plasma torus using the R.C. spectrograph attached to Kitt-Peak 4-meter telescope and an Echelle spectrograph attached to Haleakala 40-cm telescope.

The 4-meter R.C. Spectrograph was set up covering 550nm through 800nm which could successfully detect NaD (589nm), SIII 631.2nm, SII 671.6/673.1nm, and OII 731.9/733.0nm as well. A field-of-view was 98 arcseconds along the slit and the slit center was pointed at the dawn or dusk edge of the centrifugal equator. We could get 54 spectra from the observation during January 4th through 10th, 2014.

The Haleakala spectrograph is a high-resolution echelle spectrograh with an integrated field unit (IFU) which enables to capture 2-d distribution of [SII] 671.6/673.1nm emission with spectral resolution of 67000 over a field-of-view of 41” by 61”. The 40-cm telescope was observing Io plasma torus all over the night during the observing campaign period.

Based on analysis of the EUV spectrum from EXCEED/Hisaki, visible spectrum from Kitt-Peak 4-meter and Haleakala 40-cm, emission peaks of SIII and OII was located outward compared to the SII emission peak which is consistent with results from previous studies. More accurate analysis including pointing calibration and flux calibration are ongoing, the result will be presented at the meeting.

Variation characteristics of Jupiter’s hectometric radiation during the Jupiter observation campaign with HISAKI

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In the last winter around Jupiter’s opposition to the earth, an intensive remote observations for Jupiter had been held by using the HISAKI(SPRINT-A) satellite and the other many optical and radio wave instruments. This observation campaign gave an important opportunity for the investigation of drivers of Jupiter’s magnetospheric activities. We have analyzed Jupiter’s hectometric radiations (HOM) by using the WIND spacecraft data for the period. HOM is known to be a counterpart of the auroral kilometric radiation (AKR) of the earth and one of indicators which reflect Jupiter’s global magnetospheric activities (Louarn et al., 1998; 2014 etc.), and is implied to have some correlation with solar wind variations (Nakagawa et al., 2000 etc.). The campaign was held around the maximum of the current solar cycle and many intensive solar bursts were included in the radio data, however a preliminary analysis indicates some correlative radio intensity enhancements with those of auroral UV emissions detected with HISAKI/EXCEED. In the presentation, we will introduce results of comparison analyses among auroral radio and optical intensities, and plasma properties relating to Jupiter’s magnetospheric activities such as expected solar wind characteristics and torus plasma.

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Hisaki による EUV 強度及び地上観測による木星デカメータ電波の比較解析

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Comparison study of EUV brightness obtained by Hisaki and Jovian decametric radiation obtained by ground-based observations

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An analysis between the variations of the extreme ultraviolet (EUV) brightness measured by Hisaki and the activity of Jovian decametric radio emissions (Jovian DAM) measured by several ground-based observations at Nancay observatory of Paris Astronomical Observatory, and at Yoneyama and Iitate Observatories of Tohoku University during Jupiter observation campaign performed in January 2014.

The EUV telescope EXCEED (Extreme Ultraviolet Spectroscope for Exospheric Dynamics) onboard the Japan's small satellite Hisaki (SPRINT-A) was launched in August 2013, and continues successful operations. One of the main purposes of this mission is to study the connections between the Io plasma torus (IPT), the Jovian aurora, and the Jovian magnetosphere in order to determine the mass and energy transfer through the Jovian magnetosphere. Based on the measurements of the EUV brightness in 105-115 nm and 64-77 nm, we can discuss the variations of Jovian aurora activity, and the variations of plasma density and electron temperature of IPT, respectively.

Jovian DAM showing clear dependence on the Io phase are known as Jovian Io-DAM. Io footprint aurora also suggest that there are energy transfer among Io, Jovian magnetosphere, and Jovian ionosphere. The energy source of Jovian Io-DAM is interactions between Io and rotating magnetosphere including IPT. Therefore we can expected that there are some correlations between the Jovian Io-DAM, and the EUV brightness variations, which are caused by the variations of Jovian auroral activity and plasma conditions in IPT.

In the presentation, we are going to indicate the spectrograms of Jovian decametric radio emissions obtained in the ground-based observations during the Jupiter observation campaign with Hisaki and other remote sensing observations performed in January 2014. Then, we will discuss the correlations with EUV brightness measured by Hisaki.

ひさき（SPRINT-A）衛星の運用状況について

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Operation status of the HISAKI (SPRINT-A) satellite

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The HISAKI (SPRINT-A) satellite was launched in September, 2013, for scientific motivations of the plasma and energy transport in the rotational magnetosphere like Jovian magnetosphere, and the atmospheric evolution of the Earth-like planets. HISAKI has an extreme ultraviolet (EUV) spectroscope (EXCEED), which is designed for the observations of EUV emissions from the Io plasma torus and the Venusian atmosphere/ionosphere. After obtaining the initial first light image in November, HISAKI continued to observe mainly Jupiter and Venus for a few months, respectively, for the first time of the world.

The satellite was developed as the first small scientific satellite of ISAS using a standard bus system called SPRINT bus. Its designed lifetime is over one year, and the time has come now. In this presentation the last one-year operation and current status of the satellite is reported, including the on-orbit functional performance of the mission instrument and the bus system components during the period. And the feasibility of the additional observation plan will be discussed.

木星磁気圏に代表される回転系磁気圏のプラズマとエネルギーの輸送プロセスと地球型惑星の大気進化を科学的な動機として、ひさき（SPRINT-A）衛星は、2013 年 9 月に打ち上げられました。ひさき衛星には、イオプラズマトーラスや金星の大気圏/電離圏からの EUV 発光を観測する極端紫外線分光器（EXCEED）が搭載されています。11 月にファーストライト画像を取得した後に、世界初の数ヵ月わたる木星と金星の観察を継続しました。

ひさき衛星は、SPRINT バスと呼ばれる標準バス・システムを使用している ISAS の最初の小型科学衛星として開発されました。その設計寿命は 1 年（最低）で、そのときが訪れました。本講演では、この 1 年のミッション機器とバス・システム機器の軌道上の機能的性能を含んで、衛星運用と現状を報告します。また、追加の観察計画の実現可能性を議論します。