高分解能画像に基づくガリレオ衛星の傾斜、ラフネス特徴
Slope and roughness characteristics derived from high-resolution images of Galilean satellites

*押上 祥子[1]、平田 直之[2]、木村 淳[3]、並木 則行[1]
*Shoko Oshigami[1], Naoyuki Hirata[2], Jun Kimura[3], Noriyuki Namiki[1]

1.国立天文台、2.神戸大学、3.東京工業大学
1.National Astronomical Observatory of Japan, 2.Kobe University, 3.Tokyo Institute of Technology

Topographic data is fundamental information to investigate geology at various scales. The Galileo spacecraft has obtained high-resolution images of the Galilean satellites at a scale up to approximately ten meters per pixel, which provide an insight into diverse geologies and surface materials associated with tectonics, cratering, and sublimation. Putative subsurface oceans on Europa, Ganymede, and Callisto indicated by inductive magnetic fields and aurorae shifting are top priority for the next planetary exploration. Measuring topography at a scale of ten-meter also could be essential for designing radar sounder, laser altimeter, and lander. These instruments are expected to detect putative subsurface oceans on Jovian icy satellites. Nevertheless, no quantitative topographic data at the scale has yet been obtained, except for the surface of Europa. This is mainly consequence of previous digital elevation models (DEMs) with spatial resolutions higher than 50 m being only available for the southeast region of the Tyre crater of Europa (33 m/pixel). Current knowledge of topographic features of the Galilean satellites is only derived from stereo image (SI) analysis or photoclinometry (PC) because of the absence of laser altimetry data. The slopes and roughness strongly depend on the spatial resolution of topographic data. In general, higher spatial resolution provides steeper slope histograms. We reexamined high-resolution images obtained by the SSI camera onboard the Galileo spacecraft using SI analysis and PC.
As for SI analysis, we used Integrated Software for Imagers and Spectrometers (ISIS3) produced by USGS to calibrate the SSI raw images radiometrically and perform bundle adjustment. Then we applied NASA’s Ames Stereo Pipeline software (ASP) to compute DEMs. ASP is a suite of automated SI analysis tools developed by NASA and designed for processing planetary images. To compute the slope, we i) selected a pixel from a DEM, ii) computed a least squares plane in a seven-pixel square centered around the selected pixel, iii) obtained the gradient of the least squares plane (the slope is defined as the gradient), and iv) performed (i) to (iii) over the entire DEM. Then, the total surface area of each DEM was normalized to 1. To compute roughness, we defined the roughness as the Allan deviation of differences in height (i.e. RMS deviation). In detail, we i) measured the difference in height between two points separated by a given distance (i.e. window length) along lines of constant longitude, ii) performed (i) over the entire DEM and collected differences in height over the entire DEM, and (iii) computed the Allan deviation of all differences in height obtained in (ii).
PC uses apparent brightness to estimated slope at each pixel, assuming a photometric function. We applied a photometric function that fits lunar-like surface. In order to compute roughness, we converted the slopes into height differences for each pixel. Then we integrated the height differences along the line of sight to construct one-dimensional topographic cross-section from line to line. Here roughness is defined as the Allan deviation of differences in height between two points separated by a given distance along the line of sight. We showed an average of the Allan deviation values for each window length among the all one-dimensional topographic profiles.
As a result, we obtained the slope histograms and roughness from SI analysis and PC. We found that most of Ganymede and the region of Callisto showing abundant knobs appear to be very rough surfaces

as steep as 10 to 30º, while Europa and the region of Callisto without knobs mostly appear to be smoother than 10º. These results are far from previous estimates based on topographic data with the lower resolution. Also, this implies that instrument performances are expected to be strongly affected by the steep slopes in the former areas.

©2016. Japan Geoscience Union. All Right Reserved.

ガニメデ地下海の安定性
Stability of subsurface oceam in Ganymede

*木村 淳[1]、鎌田 俊一[2]、Vance Steven[3]、Hussmann Hauke[4]
*Jun Kimura[1], Shunichi Kamata[2], Steven Vance[3], Hauke Hussmann[4]

1.東京工業大学地球生命研究所、2.北海道大学、3.ジェット推進研究所、4.ドイツ航空宇宙センター
1.Earth-Life Science Institute, Tokyo Institute of Technology, 2.Hokkaido University, 3.JPL/Caltech, 4.DLR

The outer solar system provides potential habitats for extra-terrestrial life. Past spacecraft’s and telescopic observations support that the Jovian icy moons may harbor water oceans beneath the icy crusts. However evidence for oceans is not definitive and awaits confirmation measurements. Also their depth and composition remain unclear, as do their stability and variability with time. Here we focus on Ganymede, the largest moon in the Solar System and the primary target the Jupiter Icy Moons Explorer (JUICE). To investigate the stability of an ocean (structural, thermal and compositional change through time) assumed to be initially in an entirely liquid state, we performed numerical simulations for the internal thermal evolution using an one-dimensional spherically symmetric model for the convective and conductive heat transfer, with radial dependence of viscosity, heat source distribution, and other material properties. We take into account the energy due to decay of long-lived radioactive elements and also evaluate the effect of tidal heating. To see the temporal change of the boundary position between solid ice layers including ice shell and high-pressure ice mantle, we also evaluate the energy balance at the phase boundaries between the solid and liquid H_2O layer, and the movements of the positions of these boundaries are calculated by evaluating the heat balance between incoming and outgoing flux at the boundaries considering with latent heat (classically known as a Stefan problem).

©2016. Japan Geoscience Union. All Right Reserved.

Feasibility of the exploration of the subsurface structures of Jupiter’s icy moons by Jovian hectometric radiation

Feasibility of the exploration of the subsurface structures of Jupiter’s icy moons by Jovian hectometric radiation

*熊本 篤志[1]、笠羽 康正[1]、三澤 浩昭[2]、土屋 史紀[2]
*Atsushi Kumamoto[1], Yasumasa Kasaba[1], Hiroaki Misawa[2], Fuminori Tsuchiya[2]

1.東北大学大学院理学研究科地球物理学専攻、2.東北大学大学院理学研究科惑星プラズマ・大気研究センター
1.Department of Geophysics, Graduate School of Science, Tohoku University, 2.Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University

A new method for detection of the subsurface structures in the ice crust of Jupiter’s moons by using interference patterns found in the spectrogram of the Jovian hectometric radio emissions (HOM) have been proposed. In Jupiter icy moon explorer (JUICE) mission, plasma wave observation around icy moons are planned by using radio and plasma wave instrument (RPWI). In this observations, we will be able to obtain spectrograms of the HOM propagating from Jupiter. Because the emissions directly from Jupiter can be interfered with the emissions reflected at the icy moon’s surface and subsurface boundaries, we will find interference patterns in the measured spectrograms. In case of the Earth's Moon, the lunar orbiter SELENE detected the interference patters in the spectrograms of auroral kilometric radiation (AKR) [Ono et al., 2010; Goto et al., 2011]. Because the interference occurs between AKR directly from the earth and AKR reflected at the lunar surface, the amplitude of the interference patterns are almost constant. In case of Jupiter’s icy moons, HOM directly from Jupiter, HOM reflected at the icy crust surface, and HOM reflected at the fully-freezed/partial-melted or high/low-porosity boundary in the ice crust. Due to slight phase difference between HOM emissions reflected at the surface and subsurface boundaries, the amplitude of the interference patterns will be modulated. The depth of the liquid ocean can be determined the frequency width of the modulation. Assuming that the frequency of HOM is ~10 MHz, the permittivity of the icy crust is 3, permittivity of the melted ice is 87, loss rate in the icy crust is 2-9 dB/km, and spacecraft height is 500 km, the maximum detection depth is estimated to be 6-23 km, which is less than the estimated ice thickness of the Ganymede, 150 km [Kivelson et al., 2002]. On the other hand, we can also expect lower attenuation rate than 2-9 dB/km in a depth range where the ice temperature is much lower than 240 K. The receiver’s specifications needed for measurement of the interference patterns in the spectrogram are as follows: (1) Frequency resolution: 100 Hz, and (2) The interval of spectrum measurements: 30 sec. In addition, the following two issues have to be considered in actual application: (a) HOM itself has band structures in the spectrogram due to anisotropy of the emission at the source. (b) The roughness of the surface and subsurface boundaries has to be within the half wavelength (~15 m). (c) The delay by inhomogeneity of TEC of the moon’s ionosphere has to be less than the half of the period of the HOM (~0.05msec), which corresponds to the dTEC ~ 9.3×10^{12} m^{-2}.

キーワード：Passive subsurface radar、Jupiter Icy Moon Explorer (JUICE)、Radio and plasma wave instrument (RPWI)
Keywords: Passive subsurface radar, Jupiter Icy Moon Explorer (JUICE), Radio and plasma wave instrument (RPWI)

©2016. Japan Geoscience Union. All Right Reserved.

Software-type Wave-Particle Interaction Analyzer (SWPIA) by RPWI for JUICE: Science objectives and implementation

Software-type Wave-Particle Interaction Analyzer (SWPIA) by RPWI for JUICE: Science objectives and implementation

*加藤 雄人[1]、小嶋 浩嗣[2]、浅村 和史[3]、笠羽 康正[1]、土屋 史紀[1]、笠原 禎也[4]、井町 智彦[4]、三澤 浩昭[1]、熊本 篤志[1]、八木谷 聡[4]、石坂 圭吾[5]、木村 智樹[6]、三好 由純[7]、小路 真史[7]、北原 理弘[1]、Ondrej Santolik[8,9]、Jan-Erik Wahlund[10]

*Yuto Katoh[1], Hirotsugu Kojima[2], Kazushi Asamura[3], Yasumasa Kasaba[1], Fuminori Tsuchiya[1], Yoshiya Kasahara[4], Tomohiko Imachi[4], Hiroaki Misawa[1], Atsushi Kumamoto[1], Satoshi Yagitani[4], Keigo Ishisaka[5], Tomoki Kimura[6], Yoshizumi Miyoshi[7], Masafumi Shoji[7], Masahiro Kitahara[1], Ondrej Santolik[8,9], Jan-Erik Wahlund[10]

1.東北大学大学院理学研究科、2.京都大学生存圏研究所、3.宇宙航空研究開発機構宇宙科学研究所、4.金沢大学、5.富山県立大学、6.理化学研究所、7.名古屋大学宇宙地球環境研究所、8.Institute of Atmospheric Physics、9.Faculty of Mathematics and Physics, Charles University、10.Swedish Institute of Space Physics, Uppsala

1.Graduate School of Science, Tohoku University, 2.Research Institute for Sustainable Humanosphere, Kyoto University, 3.ISAS/JAXA, 4.Univ. Kanazawa, 5.Toyama Pref. Univ., 6.RIKEN, 7.ISEE, Nagoya Univ., 8.Institute of Atmospheric Physics, 9.Faculty of Mathematics and Physics, Charles University, 10.Swedish Institute of Space Physics, Uppsala

We present science objectives of Software-type Wave-Particle Interaction Analyzer (SWPIA), which will be realized as a software function of Low-Frequency receiver (LF) running on the DPU of RPWI (Radio and Plasma Waves Investigation; PI: J.-E. Wahlund, IRF-Uppsala, Sweden) for the ESA JUICE mission. SWPIA conducts onboard computations of physical quantities indicating the energy exchange between plasma waves and energetic ions. Onboard inter-instruments communications are necessary to realize SWPIA, which will be implemented by efforts of RPWI, PEP (Particle Environment Package; PI: Stas Barabash, IR-Kiruna, Sweden) and J-MAG (JUICE Magnetometer; PI: M. Dougherty, ICL, UK). By providing the direct evidence of ion energization processes by plasma waves around Jovian satellites, SWPIA contributes scientific output of JUICE as much as possible with keeping its impact on the telemetry data size to a minimum.
SWPIA measures the energy transfer process between energetic particles and electromagnetic plasma waves [Fukuhara et al., EPS 2009; Katoh et al., AnGeo 2013]. SWPIA will be firstly realized in the ERG satellite mission of JAXA to measure interactions between relativistic electrons and whistler-mode chorus in the Earth's inner magnetosphere. We will apply SWPIA to ion-scale wave-particle interactions occurring in the Jovian magnetosphere. SWPIA clarifies where/when/how heavy ions are energized by waves in the region close to Ganymede and other Jovian satellites. In SWPIA of RPWI for JUICE, we focus on the interactions between energetic ions (a few to tens of keV) and ion cyclotron waves (typically less than 1 Hz). SWPIA uses wave electromagnetic field and ion velocity vectors provided by RPWI sensors and PEP, respectively, with referring three-components of the background magnetic field detected by J-MAG. SWPIA measures a relative phase angle between the velocity vector vi of i-th particle of charge qi and the wave electric field vector at the timing of particle's detection (E(ti)) and computes an inner product of W(ti) = qiE(ti) dot vi, where W(ti) corresponds to the variation of the kinetic energy of the i-th energetic particle. We accumulate W for detected particles to obtain Wint = Sigma_i W(ti), and we expect statistically significant values of Wint for the case of the measurement at the site of efficient wave-particle interactions. In this presentation, we discuss details of the implementation of SWPIA of RPWI and

©2016. Japan Geoscience Union. All Right Reserved.

inter-instruments communications among RPWI-PEP-J-MAG of JUICE.

キーワード：木星磁気圏、木星衛星、波動粒子相互作用
Keywords: Jovian magnetosphere, Jovian satellite, wave-particle interactions

©2016. Japan Geoscience Union. All Right Reserved.

JUICE衛星搭載用非熱的中性粒子観測器の開発

evelopment of a low-energy energetic neutral atom analyzer (PEP/JNA) for JUICE

*浅村 和史[1]、齋藤 義文[1]、下山 学[2]、二穴 喜文[2]、三好 由純[3]、坂野井 健[4]
*Kazushi Asamura[1], Yoshifumi Saito[1], Manabu Shimoyama[2], Yoshifumi Futaana[2], Yoshizumi Miyoshi[3], Takeshi Sakanoi[4]

1.宇宙航空研究開発機構宇宙科学研究所、2.スウェーデン国立スペース物理研究所、3.名古屋大学、4.東北大学
1.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 2.Swedish Institute of Space Physics, 3.Nagoya U., 4.Tohoku U.

We are developping a low-energy (10eV-3keV) energetic neutral atom analyser (PEP/JNA) which is to be onboard European JUICE spacecraft. Ganymede has its own intrinsic magnetic moment. There is considered to be a mini-magnetosphere around Ganymede because of interactions between plasma in Jovian magnetosphere and Ganmede's magnetic field. However, its characteristics will be different from terrstrical one, since Alfven mach number of upstream plasma flow (corotational plasma flow around Jupiter) is small. JNA (Jovian Neutral Analyzer) will reveal characteristics of Ganymede's magnetosphere in terms of measurement of scattered/sputtered particles generated by precipitation of plasma particles onto Ganymede's surface. Measurement of these particles will provide spatial distribution of plasmas in remote sense, since electric/magnetic field do not affect trajectories of neutral particles. We will discuss current status of JNA.

キーワード：非熱的中性粒子、JUICE
Keywords: Energetic neutral atom, JUICE

©2016. Japan Geoscience Union. All Right Reserved.

木星の中間磁気圏の擾乱に対するイオプラズマトーラスの応答
Responses of Io Plasma Torus to middle magnetosphere of Jupiter

*鈴木 文晴[1]、吉岡 和夫[1]、村上 豪[2]、土屋 史紀[3]、木村 智樹[4]、吉川 一朗[1]
*Fumiharu Suzuki[1], Kazuo Yoshioka[1], Go Murakami[2], Fuminori Tsuchiya[3], Tomoki Kimura[4], Ichiro Yoshikawa[1]

1.東京大学、2.宇宙航空研究開発機構、3.東北大学、4.理化学研究所
1.The University of Tokyo, 2.JAXA, 3.Tohoku University, 4.RIKEN

木星の衛星イオには火山活動があり、硫黄や酸素を含むガスが内部磁気圏に放出されている。この火山ガス起源のプラズマがイオの公転軌道に沿ってトーラス状に分布していることが光学観測で明らかにされており、イオプラズマトーラス（IPT）と呼ばれている。また、木星極域にオーロラが常時発生していることも観測されている。2000年、カッシー二探査機が木星のフライバイをする際に、IPTと木星オーロラを同時に観測し、両者が非常に短い時間差で突発的に増光していることを発見した。IPTの発光は内部磁気圏の状態を反映し、木星オーロラの発光は中間磁気圏の活動度の指標となるため、内部・中間磁気圏間に未知のエネルギー輸送プロセスが存在することの証拠であると考えられた。しかし、カッシー二探査機の観測では観測休止時間が増光現象の継続時間に比べて長く，両者の相関関係や時間差の決定が困難であり、エネルギー輸送機構の特定にはいたらなかった。2013年9月にイプシロンロケットにより地球周回軌道に打ち上げられたHISAKI/EXCEEDは惑星専用の宇宙望遠鏡であり、木星磁気圏を高い時間分解能（約1時間）で、長期的かつ継続的に観測を行っている。EXCEEDのデータを使用したIPT・オーロラ増光イベントの詳細な解析により、IPTの増光は高温電子の増加に起因する現象であることが分かった。また、オーロラとIPTの増光の時間差は約11時間であり、これは中間磁気圏からIPTへの高温電子の輸送のタイムスケールを示していると考えられる。本発表では、EXCEEDの観測によって明らかになったIPT・オーロラ増光イベントの時間的、空間的な特徴を示し、木星磁気圏におけるエネルギー輸送の謎を解き明かしていく。

キーワード：木星、磁気圏、オーロラ、イオプラズマトーラス
Keywords: Jupiter, magnetosphere, aurora, Io plasma torus

©2016. Japan Geoscience Union. All Right Reserved.

Horizontal and vertical structures of the Jovian IR aurora from plasma and neutral atmospheres: Observation by SUBARU/IRCS with Adaptive Optics

Horizontal and vertical structures of the Jovian IR aurora from plasma and neutral atmospheres: Observation by SUBARU/IRCS with Adaptive Optics

藤澤 翔太[1]、笠羽 康正[1]、*北 元[1]、垰 千尋[2]、坂野井 健[3]、鍵谷 将人[3]
Shota Fujisawa[1], Yasumasa Kasaba[1], *Hajime Kita[1], Chihiro Tao[2], Takeshi Sakanoi[3], Masato Kagitani[3]

1.東北大・理・地球物理、2.情報通信研究機構、3.東北大・理・惑星大気プラズマ研究センター
1.Dep. Geophysics, Tohoku Univ., 2.NiCT, 3.PPARC, Tohoku Univ.

In the rotational driven magnetosphere of Jupiter, the momentum and energy transfers between thermosphere and ionosphere is the key part of the magnetosphere, ionosphere and thermosphere (MIT) coupling. Jovian aurora, emitted from this region through this process, does not only shows the strength of magnetospheric activities but also affects to the ion-neutral interactions.
Previous observations have shown the morphological difference between plasma (H_3^+) and neutral (IR H_2) emissions. It suggests the difference between strong electron precipitating area exciting the plasma emissions and the heated area exciting the neutral emissions. In order to investigate their emission mechanisms and relationships to the energy injection processes, the comparison between H_3^+ fundamental (v2=1→0) and overtone (v2=2→0) lines is also important. The different emission altitude of both emissions is caused by their different sensitivity to surrounding atmospheric temperature and density.
We first executed the quasi-simultaneous comparisons of the horizontal and vertical emission profiles in H_3^+ fundamental, H_3^+ overtone, and H_2 polar emissions, by the near infrared spectroscopy of Jovian polar emissions using SUBARU/IRCS on 31 January 2015. H_2 IR emission and H_3^+ overtone emissions are seen simultaneously in K-band spectra (2.03-2.22 μm), and H_3^+ fundamental emission in L-band (3.31-3.98 μm) is quasi-simultaneously taken by short interval, ~5 min. We also simulateounly took the slit viewer image of the H_3^+ fundamental line or K-band filter. During these observations, we used the adaptive optics system (AO188) when Galilean satellites could be used as a guide star, and achieved high spatial resolution, ~0.2 arcsec (~320 km of Jupiter). The slit was set along the rotational axis when AO188 could be used.
First, we compared the horizontal flux profiles. The morphological difference between H_3^+ fundamental and overtone emissions are small. Both have clear main oval emissions like the averaged UV aurora profile. On the other hand, IR H_2 emission does not show clear enhancement at the main oval. We also derived the horizontal profiles of temperature and column density from those emissions. H_3^+ fundamental lines have a better correlation with column density. H_3^+ overtone lines are more related to temperature. On the other hand, IR H_2 emission intensity does not show clear correlations.
Next, we derived the vertical structures of their volume emissivity profiles by “onion peeling” method. We confirm the result of Uno et al. (2014), the similar emission peak altitude between IR H_2 and H_3^+ overtone emissions in K-band. We also found that the peak altitude of H_3^+ fundamental emission was lower than them. Although the derived H_3^+ vertical emission profiles are not contradict to the theoretical models, and their derived temperatures represent those of emission peak altitudes, it is hard to explain the vertical profiles of IR H_2 volume emissivity by a simple ‘thermal excitation model’. It is also hard to explain the fact that the derived temperature from H_2 emissions from higher altitude (~700 K) is lower than that from H_3^+ fundamental emission in lower altitude (~1,000 K). We are now investigating possible scenarios for those points.
In May 2016, we will observe Jovian IR emission again, simultaneously with UV aurora by Hubble

©2016. Japan Geoscience Union. All Right Reserved.

Space Telescope, EUV aurora and Io torus by Hisaki/EXCEED, and the upstream solar wind by NASA Juno spacecraft approaching to Jupiter. It will be the chance to solve the problems raised in this study.

キーワード：木星、赤外線オーロラ、水平構造、垂直構造
Keywords: Jupiter, infrared aurora, horizontal profiles, vertical profiles

©2016. Japan Geoscience Union. All Right Reserved.

ひさき衛星を用いた木星紫外オーロラの太陽風応答に関する統計解析
Statistical study of the response of Jovian EUV aurora to the solar wind from Hisaki observations

北 元[1]、木村 智樹[2]、垰 千尋[3]、*土屋 史紀[1]、三澤 浩昭[1]、坂野井 健[1]、笠羽 康正[1]、村上 豪[4]、吉岡 和夫[5]、山崎 敦[4]、吉川 一朗[6]
Hajime Kita[1], Tomoki Kimura[2], Chihiro Tao[3], *Fuminori Tsuchiya[1], Hiroaki Misawa[1], Takeshi Sakanoi[1], Yasumasa Kasaba[1], Go Murakami[4], Kazuo Yoshioka[5], Atsushi Yamazaki[4], Ichiro Yoshikawa[6]

1.東北大学大学院理学研究科、2.国立研究開発法人理化学研究所仁科加速器研究センター、3.情報通信研究機構、4.宇宙航空研究開発機構　宇宙科学研究所、5.東京大学大学院理学系研究科地球惑星科学専攻、6.東京大学新領域創成科学研究科複雑理工学専攻
1.Graduate School of Science, Tohoku University, 2.Nishina-Center for Accelerator Based Science, RIKEN, 3.National Institute of Information and Communications Technology, 4.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 5.Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo, 6.Department of Complexity Science and Engineering, University of Tokyo

In order to reveal the solar wind response of Jovian extreme ultraviolet (EUV) auroral activity, we made a statistical analysis of Jovian EUV aurora obtained from long term Hisaki observation.
The EUV emission from hydrogen molecule is excited by collision with high energy electron. The main oval is one of the components of Jovian EUV aurora where the auroral particle precipitations are caused by the rotationally driven field-aligned current system. It is theoretically expected that angular velocity of magnetospheric plasma increases when the Jovian magnetosphere is compressed by enhanced solar wind pressure, which decreases the field-aligned current. Regarding this scenario, increase of the solar wind dynamic pressure is expected to be anti-correlated with the intensity of the EUV aurora. A previous observation such as that by International Ultraviolet Explorer (IUE) or Hubble Space Telescope (HST) showed the time variability of the EUV aurora, while their data still limited in continuity over solar wind variation with good time resolution. On the other hand, Hisaki satellite is an earth-orbiting EUV spectroscope launched in 2013 which has been continuously monitoring Jovian EUV auroral activity. Therefore, the Hisaki data sets are effective for investigating the solar wind response of Jovian aurora.
The purpose of this study is to investigate the solar wind response of Jovian EUV aurora observed by Hisaki. We used the EUV data set obtained from Dec. 2013 to Feb. 2014 and from Dec. 2014 to Feb. 2015. We compare the total EUV power over 900-1480 A and solar wind dynamic pressure which is extrapolated at Jupiter using a one-dimensional magnetohydrodynamic (MHD) model.
Superposed epoch analysis indicated that Jovian EUV aurora increases with the enhancement of the solar wind dynamic pressure. We also found a correlation between the total power of EUV aurora and the duration of the rarefaction region of the solar wind before the enhancement of the dynamic pressure. The similar trend could also be found in the thermal current, i.e., incoming electron flux increased with the duration of rarefaction region.
One possible scenario is that mass loading from Io increases the electron density in the Jovian middle magnetosphere and it also increases seed electron of the thermal current whose energy is several keV. The solar wind compression causes adiabatic acceleration of thermal current and then EUV aurora increases. However, it is still unclear how the angular velocity distribution and brightness distribution vary during the solar wind compression.

©2016. Japan Geoscience Union. All Right Reserved.

キーワード：木星、オーロラ、太陽風応答
Keywords: Jupiter, Aurora, Solar wind response

©2016. Japan Geoscience Union. All Right Reserved.

ひさき衛星極端紫外光観測と地上可視光観測による木星衛星イオの硫黄イオントー ラスの時空間変動

Variation in SII and SIII brightness distribution of Io plasma torus based on Hisaki/EXCEED and ground based observation data

*宍戸 美日[1]、坂野井 健[1]、鍵谷 将人[1]、土屋 史紀[1]、吉川 一朗[5]、山崎 敦[3]、吉岡 和夫[2]、村上 豪[3]、木村 智樹[4]

*Mika Shishido[1], Takeshi Sakanoi[1], Masato Kagitani[1], Fuminori Tsuchiya[1], Ichiro Yoshikawa[5], Atsushi Yamazaki[3], Kazuo Yoshioka[2], Go Murakami[3], Tomoki Kimura[4]

1.東北大学大学院理学研究科地球物理学専攻、2.東京大学大学院理学系研究科地球惑星科学専攻、3.宇宙航空研究開発機構　宇宙科学研究所、4.国立研究開発法人理化学研究所、5.東京大学大学院新領域創成科学研究科複雑理工学専攻

1.Graduate School of Science, Tohoku University, Department of Geophysics, 2.Graduate School of Science, The University of Tokyo, Department of Earth and Planetary Science, 3.ISAS/JAXA, 4.RIKEN, 5.Graduate School of Science, The University of Tokyo, Department of Complexity Science and Engineering

木星の衛星イオの軌道($6R_J$)には、イオの火山ガスに起因するプラズマトーラスが形成される。このトーラス中の硫黄・酸素イオンは、電子(5eV-1keV)との衝突励起により極端紫外から可視に渡る広い波長範囲で発光する。常に明るく光るプラズマトーラスの発光を維持するには電子の温度を5eV程度に加熱し続ける必要があり、その主要な加熱源の一つとして火山ガスの電離により生じる数100eVのピックアップイオンから電子へのクーロン衝突が考えられている。「ひさき」衛星に搭載された極端紫外線分光撮像装置 EXCEED により、2014年12月から2015年3月にかけて、イオ火山噴火に伴うとみられるイオトーラス増光現象が観測された。本研究は、EXCEED と地上からの可視光イメージング観測データを用いて、トーラス増光現象期間（2014年 12 月-2015 年 3 月）におけるイオン温度と電子温度の時間変化の特徴とこの変化が生じた領域を調べることにより、電子の加熱機構を検証することを目的とする。可視イメージング観測が1価の硫黄イオンの発光分布を約1秒角の高空間分解能で撮像できるのに対し、EXCEEDは広い波長域のスペクトル観測から、多価の硫黄イオンと電子温度の情報を得ることができる。EXCEEDが観測したトーラス増光現象期間(2014年12月-2015年3月）における1価と2価の硫黄イオン([SII]76.5nm及び[SIII]68nm)の2次元発光分布から動径幅$2R_J$（dawn側、dusk側ともに$6R_J$－$8R_J$）の南北方向発光プロファイルを得、そのスケールハイトと赤道面での最大値を導出したところ、トーラス増光現象を跨いだスケールハイトの増大が確認された。可視光イメージング観測からも同様に、1価の硫黄イオンのスケールハイトと発光強度の最大値を導出した。EXCEEDの観測から導出されるスケールハイトは空間分解能の影響を受けているため、EXCEEDとT60から導出された1価の硫黄イオンのスケールハイトとの比較から空間分解能を評価し、EXCEEDの観測から得られた硫黄イオンのスケールハイトを補正することが可能である。今後は補正後のスケールハイトと発光強度の最大値から、イオンの温度と赤道面での密度の変動を定量的に評価する予定である。発表では、このような手順で得られた硫黄イオンの温度と、EXCEEDの観測から得られた電子温度の時間変化の特徴をプラズマトーラスの増光期間を跨ぐ期間で比較した結果を報告する。

©2016. Japan Geoscience Union. All Right Reserved.

ひさき衛星によるイオ周辺の130.4nm酸素原子発光の時間変動解析

time variation of 130.4nm atomic oxygen emission near Io observed by hisaki/EXCEED

*古賀 亮一[1]、土屋 史紀[1]、鍵谷 将人[1]、坂野井 健[1]、米田 瑞生[1]、吉川 一朗[2]、吉岡 和夫[2]、村上 豪[3]、山崎 敦[3]、木村 智樹[4]
*Ryoichi Koga[1], Fuminori Tsuchiya[1], Masato Kagitani[1], Takeshi Sakanoi[1], Mizuki Yoneda[1], Ichiro Yoshikawa[2], Kazuo Yoshioka[2], Go Murakami[3], Atsushi Yamazaki[3], Tomoki Kimura[4]

1.東北大学惑星プラズマ・大気研究センター、2.東京大学、3.宇宙科学研究所、4.理化学研究所
1.PPARC, Tohoku University, 2.University of Tokyo, 3.ISAS/JAXA, 4.RIKEN

木星の衛星イオは他のガリレオ衛星と比べて木星との距離が近く、潮汐力を受けるため地質活動が活発である。イオ大気の主成分はSO2や解離してできた酸素や硫黄原子などで、残りの数パーセントが中性ナトリウムやカリウムである。この大気の起源は火山活動によるガスの噴出と表面に堆積された SO2frostの昇華が考えられ、どちらが支配的かはまだ決着が着いていない。本研究ではイオ周辺(1木星半径程度)の130.4nmの酸素原子発光強度の時間変動を明らかにすることで、大気生成プロセスの理解に寄与することを目的とする。
2014年の12月から2015年の5月にかけて地上狭帯域イメージング観測により広域ナトリウム雲の発光の増大が観測された(Yoneda et al., 2015)。この期間に火山噴出ガスの主成分である酸素原子のイオ周辺での振る舞いを明らかにするため、本研究では同時期のひさき衛星観測データを用いて、イオの1木星半径周辺の酸素原子130.4nm発光強度の時間変動を解析した。解析では、十分なS/Nを得るために、イオが朝側(イオ位相角45~135度)と夕方側(イオ位相角225~315度)にいる時の観測データをイオを中心とした60"の空間範囲について一日ごとに積算した。また、ジオコロナ起源の酸素原子発光の影響を回避するため、ひさき衛星が地方時20時から4時の観測データのみを使用した。その結果、酸素原子発光は1月上旬は11R程度であったが、1月中旬から増光を開始し、二月中旬には発光のピーク(32R)に達した後、4月末まで減光して平穏時の明るさ(10R)に戻った。また、dawn側よりdusk側の明るさが全体を通して1.2倍程度明るかった。
この解析結果から、イオ火山活動が活発になることでイオ周辺の酸素原子の量が増大することが明らかになった。より定量的に火山活動が大気生成の関係性を議論するためには、ひさき衛星の130.4nm発光強度データから酸素原子柱密度の変動に変換する必要がある。130.4nm酸素原子発光には太陽光の共鳴散乱とイオプラズマトーラスの電子衝突励起の両方が寄与しているが、寄与の大きさを見積もったところ電子衝突励起の方が共鳴散乱より数百倍大きい。プラズマトーラスの電子温度はdusk側が高いことが知られており、酸素原子のdawn-dusk非対称性を説明する上で電子衝突励起が優勢であるという見積もりの結果は整合的である。発表ではこの見積もりの結果から酸素原子柱密度を導出し火山活動の変化によりイオ大気が受けた影響を推定する。

キーワード：木星、イオ、ひさき衛星、火山活動
Keywords: Jupiter, Io, hisaki/EXCEED, volcanic activity

©2016. Japan Geoscience Union. All Right Reserved.

Science Experiments with the Trojan Asteroid Lander in the Solar Powered Sail Mission

Science Experiments with the Trojan Asteroid Lander in the Solar Powered Sail Mission

*岡田 達明[1]、ジャンピエール ビブリン[2]、ウラメッツ ステファン[3]、ビール イェンス[3]、中村 良介[4]、矢野 創[1]、癸生川 陽子[5]、青木 順[6]、河井 洋輔[6]、薮田 ひかる[6]、伊藤 元雄[7]、斎藤 義文[1]、横田 勝一郎[1]、グラン ノエル[8]、コティン エルベ[8]、ティルケル ロラン[9]、ブリオワ クリステル[9]、岩田 隆浩[1]、松岡 彩子[1]、松本 純[10]、加藤 英樹[1]、森 治[1]、川口 淳一郎[1]

*Tatsuaki Okada[1], Jean-Pierre Bibring[2], Stepahn Ulamec[3], Jens Biele[3], Ryosuke Nakamura[4], Hajime Yano[1], Yoko Kebukawa[5], Jun Aoki[6], Yosuke Kawai[6], Hikaru Yabuta[6], Motoo Ito[7], Yoshifumi Saito[1], Shoichiro Yokota[1], Noel Grand[8], Herve Cottin[8], Laurent Thirkell[9], Christelle Briois[9], Takahiro Iwata[1], Ayako Matsuoka[1], Jun Matsumoto[10], Hideki Kato[1], Osamu Mori[1], Junichiro Kawaguchi[1]

1.宇宙航空研究開発機構宇宙科学研究所、2.フランス宇宙物理学研究所、3.ドイツ航空宇宙センター、4.産業技術総合研究所、5.横浜国立大学、6.大阪大学、7.海洋研究開発機構高知コア研究所、8.パリ１２大学LISA、9.フランス国立科学研究センター、10.東京大学

1.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 2.Institut d'Astropysique Spatiale, Orsay, 3.German Aerospace Center, 4.National Institute of Advanced Industrial Science and Technology, 5.Yokohama National University, 6.Osaka University, 7.Kochi Institute for Core Sample Research, Japan Agency for Marine-Earth Science and Technology, 8.LISA, Univ-Paris-XII, 9.Centre National de la Recherche Scientifique, Orleans, 10.University of Tokyo

Scientific exploration on the Jupiter Trojan asteroid is under study for the solar-powered sail (SPS) mission. This mission includes a scientific lander jointly studied by Japanese and European engineers and scientists [1]. We present the objectives and the strawman payloads for this mission. The SPS is a candidate as the next medium class space science mission in Japan. This engineering mission is based on the technologies such as the solar sail and the ion engine system inherited from Ikaros and Hayabusa missions, respectively. With this hybrid propulsion system, the spacecraft will cruise to the Jupiter and beyond, even if a radioisotope thermoelectric generator (RTG) is not used. A Trojan asteroid will be investigated by remote sensing after rendezvous, and then a small lander will be deployed from the mothership to conduct *in situ* experiments on the asteroid. As an option, sample will be returned to the Earth. Mission duration is typically 15 years to arrive at the Trojan asteroid, and 30 years in total for Earth return. The shortest one way trip to the asteroid is less than 12 years. The lander should be designed within 100 kg wet mass. Total mission payloads should be within 20 kg, including all the science payloads, sampling and sample return systems [2].

Jupiter Trojan asteroids are located around the Sun-Jupiter Lagrange points. Most of them are volatile-rich D- or P-type asteroids, and their origin and evolution, composition and physical conditions still remain unknown. In a classical model of solar system evolution, they formed around the Jupiter orbit and survive until now. But in a recent model such as Nice model [3], they formed at the far end of the solar system and transferred inward due to dynamical migration of giant planets. Physical, mineralogical, and isotopic studies of surface materials could solve their origin and evolution processes, as well as the solar system formation [4]. To achieve these goals, *in situ* observations using the lander is planned, as well as the asteroid global characterization with a near-infrared hyperspectral imager.

Geological, mineralogical, and geophysical observations will be conducted to characterize the landing site, by using a panoramic camera, an infrared hyperspectral imager, a magnetometer, and a thermal radiometer. The surface conditions and composition will be investigated with a close-up imager and a Raman spectrometry. The imager is also used to check the conditions whether the

©2016. Japan Geoscience Union. All Right Reserved.

sampling could be done or not. If the configuration is unsuitable for sampling, the lander must relocate and change the configuration. The surface and subsurface materials will be collected into a carousel by bullet-type and pneumatic drill type samplers, respectively. Samples in the each case of carousel will be viewed by infrared microscope to identify them. Those samples will be transferred for evaporation of volatiles for high resolution mass spectrometry (HRMS). Some samples will be heated for pyrolysis for isotopic analysis. Mass resolution m/Δm > 30,000 is required to investigate isotopic ratios of D/H, $^{15}N/^{14}N$, and $^{18}O/^{16}O$, as well as molecules from organic matters (M = 30 to 1000).The MULTUM type in Japan and the Cosmorbitrap type in France are being investigated for the HRMS. A set of strawman payloads are now considered to meet the science, mission, and system requirements and constraints (total mass < 20kg, and total energy consumption < 600 WHr). They will be finally determined by the international announce of opportunity.

References: [1] Mori O. et al. (2015) *11th Low-Cost Planetary Missions Conf.,* S3-10. [2] Saiki T. et al. (2015) *ISSFD2015*, S19-3, #84. [3] Morbidelli A. et al. (2005) *Nature 435*, 462-466. [4] Yano H. et al., (2014) *COSPAR 2014*, B0.4-2-14. [5] Mori O. et al. (2016) *Lunar Planet. Sci. Conf.* , submitted.

キーワード：トロヤ群小惑星、ソーラーセイル、着陸機、高精度質量分析、ソーラー電力セイル、地下サンプル
Keywords: Trojan asteroid, Solar Sail, Lander, High Resolution Mass Spectrometry, Solar-Powered Sail, Subsurface sample

©2016. Japan Geoscience Union. All Right Reserved.