PPS01-01 会場:A03 時間:5 月 26 日 12:00-12:15

木星型惑星を想定した雲対流の数値計算
Numerical Modeling of Moist Convection in Jovian Planets

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木星・土星の大気では水などの凝結を伴う強い積乱雲が生成することが知られており, 天王星・海王星でも同様の対流雲の存在が理論的に推定される. 木星型惑星の雲対流は, 地球大気の場合と同様に, 大気の成層構造と物質分布の決定に重要な役割を担っていると考えられている. しかし, 厚い雲に覆われた巨大惑星の雲層を遠隔観測するのは困難であり, 巨大惑星における雲対流と平均的大気構造との関係については未だ明らかとなっていない点が多い. この問題に対し我々は, 複数成分の凝結および化学反応を考慮した雲対流モデルを開発し, 木星大気条件において, 雲の生成消滅が繰り返された結果として決まる統計的平衡状態での大気構造を調べてきた (Sugiyama et al., 2009,2011, 2014). 本発表では, 土星と天王星を想定した同様の 2 次元数値計算を実行し, 雲対流と平均的大気構造との関係を議論する.

モデルは準圧縮系方程式 (Klemp and Wilhelmson, 1978) に基づく. 雲微物理過程は Nakajima et al. (2000) と同様に, 地球で良く利用されている単純な雲微物理パラメタリゼーション (Kessler, 1969) を用いて定式化した. 放射過程は陽に計算せず, 水平一様かつ時間変化しない熱強制で代用する. 土星・天王星では雲層における正味の放射加熱・冷却の鉛直プロファイルが観測されていないため, 木星の観測結果に基づき 2 bar 高度から対流圏界面 (0.1 bar) の間を冷却することにした. 統計的平衡状態に至るまでの計算時間を短縮するため, 熱強制の値は木星大気における観測値より 2 桁大きい -1 k/day とする. 計算領域は水平方向に 7680 km とする. 鉛直計算領域の大きさは, 土星条件で 480 km, 天王星条件で 650 km とする. 解像度は水平方向と鉛直方向共に 2 km とする. 下部境界での温度圧力は熱平衡計算 (Sugiyama et al., 2006) に基づいて決定した. 下部境界での凝結性成分気体の存在度は, 現実的ではないが, 研究の出発点として太陽組成と同じとする.

土星条件と天王星条件の計算結果の大きな特徴は, H2O 持ち上げ凝結高度に対応する湿潤対流層下部で強い上昇流が見られる一方で, 湿潤対流層上部に狭くて強い下降流が多数見られることである. 強い下降流が存在するという特徴は, 狭くて強い上昇域と広くて弱い下降域によって特徴づけられた木星条件の計算結果と対照的である. 土星と天王星において下降流の大きさは上昇流と同程度の 50 m/s 以上であり, 湿潤対流層の上部では鉛直速度の歪度は負である. 天王星条件で得られた歪み度が最も小さく, このことは土星よりも天王星の方が下降流が卓越することを意味する. 土星条件と天王星条件において下降流が卓越するのは以下の 2 つの理由による. 1 つは対流運動が, 下からの加熱ではなく, 対流圏界面付近 ($0.1 < p < 2$ bar) での冷却によって駆動されるためである. もう 1 つの理由は, 対流圏上部の温度が木星大気よりも低温なことである. 土星と天王星では H2O の凝結がより下層 (高圧) で始まる. 湿潤対流層の上部では H2O 混合比がほぼゼロとなるため, その高度領域では H2O の凝結潜熱の寄与が非常に小さくなる.

キーワード: 木星大気, 湿潤対流, 数値計算, 雲解像モデル
Keywords: atmosphere of Jovian planets, moist convection, numerical modeling, cloud resolution model

PPS01-02 会場:A03 時間:5月26日 12:15-12:30

The radiative cooling and the solar heating in Jovian troposphere
The radiative cooling and the solar heating in Jovian troposphere

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For Jupiter, the atmospheric energy balance is important to understand not only its characteristic atmosphere circulation but also the thermal history over 4.5 Ga. To estimate effects of solar heating and thermal radiation cooling, radiative transfer models are useful. Some previous studies discussed the heating rate in the stratosphere in order to analyze the mechanism of thermal inversion layer formation (Yelle et al., 2001), whereas that in troposphere has been little treated because the temperature profile can be simply explained by the adiabatic profile. However, the tropospheric thermal balance must be important because this region emits the major part of Jovian thermal radiation and allows cloud activities by generating the convective instability.

So far, we have been developing a radiative-convective equilibrium model to calculate the thermal structure of H_2-rich atmosphere. By using this model, here we examine how major condensable gases (H_2O, CH_4, NH_3) and isolation affect the cooling rate profile in jovian troposphere. For this purpose, we solve 1-D radiative transfer equation in a plane-parallel, non-gray, cloud-free atmosphere over 0-25,000cm^{-1} which covers both the planetary radiation and solar radiation. H_2-He collision induced absorption (Borysow 1992, 2002), H_2O, CH_4, NH_3, PH_3, H_2S and GeH_4 line absorptions (HITRAN2012), and Rayleigh scattering are considered as optical parameter. Canonical mixing ratios of these heavy species are given as three times the solar abundance, respectively. Depletion of condensable species due to condensation is also taken into account.

From our results, we found that the cooling is strongly affected by thermal emission from gaseous NH_3 associated with slight contribution from H_2 and He. The cooling rate profile shows a peak around 0.59 bar and its value is -2.3x10^{-7} K/sec. The calculation without NH_3 shows peak (-6.6x10^{-8} K/sec) around 0.8bar. H_2O and CH_4 have little contribution in upper troposphere, but their contribution increase in deep atmosphere (below 1bar). Solar radiation with wave number between 2,500-10,000 cm-^{1} (wavelength of 1-4 micron meter) significantly heats stratosphere, but its effect becomes weaker as pressure increases, then almost vanishes below 1 bar level. Solar radiation with higher wave number between 10,000-25,000 cm^{-1} (0.4-1 micron meter) almost uniformly heats the stratosphere (7.1x10^{-8} K/sec) and its effect also becomes weaker in the deep atmosphere. Those heating compensate the radiative cooling, and change the sign of heating rate from minus to plus below 1.2 bar level.

These results show that the cooling in troposphere is virtually dominated by NH_3. One might consider that our estimation depends on the abundance of NH_3 in the deep atmosphere, which is not well constrained at present. But the atmospheric cooling occurs basically in the upper troposphere where the NH_3 abundance follows the saturation vapor pressure curve. Therefore, the uncertainty in NH_3 abundance in deep atmosphere may have a limited effect on the cooling profile in troposphere. More significant factor may be the abundance of H_2S relative to NH_3. It is expected to be 1/3 if we assumed solar abundance, but the actual abundance is poorly constrained especially for H_2S. If the ratio becomes higher, the cooling rate profile is greatly changed because of loss of NH_3 gas owing to NH_4SH formation. It indicates that unknown H_2S abundance is an important factor that controls not only NH_4SH cloud formation but also convective activities in the upper troposphere.
Keywords: Jupiter, radiative transfer, thermal equilibrium, troposphere, cooling rate

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PPS01-03 会場:A03 時間:5 月 26 日 12:30-12:45

木星成層圏のシミュレーション研究：新しい放射コードの開発と力学への影響
Simulation study of Jupiter's stratosphere: development of a new radiation code and impacts on the dynamics

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We have developed a new radiation code of radiative heating and cooling for Jupiter's upper troposphere and stratosphere (10^3 to 10^{-3} hPa) suitable for general circulation models (GCMs). It is based on the correlated k-distribution approach, and accounts for all the major radiative mechanisms in the Jovian atmosphere (heating due to absorption of solar radiation by CH_4, and cooling in the infrared by C_2H_6, C_2H_2, CH_4 and collision-induced transitions of H_2-H_2 and H_2-He). The code can be applied for Saturn and extrasolar gas giants. Vertical 1-D calculations using this code demonstrated that temperature of Jupiter's stratosphere is close to radiative-convective equilibrium, and that the radiative relaxation time decreases exponentially with height (from 10^8 s near the tropopause to 10^5 s in the upper stratosphere). The latter differs from the study of Conrath et al. (1990), which showed the very long ($\sim 10^8$ s) relaxation time approximately constant throughout the stratosphere. Our calculations with the GCM show that the radiative relaxation time suggested by Conrath et al. (1990) is too long, and cannot sustain convergence of model solutions. With the newly derived vertical profile of relaxation time, simulations converge and produce realistic temperature and wind in Jovian stratosphere.

キーワード: 木星, 成層圏, 大気放射, 大気力学, 巨大ガス惑星, JUICE
Keywords: Jupiter, Stratosphere, Atmospheric radiation, Atmospheric dynamics, Gas giants, JUICE

PPS01-04 会場:A03 時間:5 月 26 日 14:15-14:35

Cassini-Huygens ミッションによる土星系探査結果ハイライト
Cassini-Huygens Mission Highlights: Discoveries in the Saturn System

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Cassini-Huygens ミッションによる過去 11 年間に渡る土星系探査は，新しい発見と，さらなる未知の領域を拓いてきた。Cassini オービターは地球打ち上げ後の 7 年後，2004 年に土星周回軌道に入り，土星系最大の衛星 Titan に降下機を着陸させてその大気と地表の観測を行った。それ以来，Cassini による発見は土星，複雑な環構造，多様な衛星群，そして磁気圏の我々の理解を書き換え続けている。

Cassini にる数多くの発見の中でも，特筆すべきものは，比較的小さな衛星である Enceladus の南極域から噴出する氷火山状のジェット，Titan の液体有機化合物の湖沼群と前生物的な化学組成を様相する大気から降る雨，土星北半球の巨大な嵐 (1990 年以来の規模) の高解像度・複数波長による画像観測，土星キロメートル波長放射と自転速度は一致しないという計測結果，Enceladus が土星の E 環粒子と磁気圏を満たす水分子の源であること，そして環系の三次元的な力学解析の理解などがある。Cassini による土星系での発見は，惑星形成プロセスの全般的理解にも貢献している。

Cassini の過去 2 年間のみに焦点を当てても数多くの発見があった。注目すべき結果の幾つかをあげると，Titan の湖沼群は両極域に分布し，そのうちいくつかの深さの計測に成功したことや、Enceladus 表面下の海の存在を明らかにしたこと，土星北極の巨大台風，Enceladus から噴きあがるジェット粒子の大きさは潮汐力に左右され，ジェット活動は遠土点付近で最大になること，Titan の湖・Ligeia Mare の深さは 150-200m であること，環の詳細構造には隕石衝突痕，propeller 状構造の環の放射方向への伝播，そして土星内部振動などの影響が反映されること，Titan 表面下の海，太陽風と土星磁気圏の強い相互作用が超新星爆発の衝撃波の理解を助けること，そして Titan の南極域の霞層は季節的なものだということなどがある。

Cassini プロジェクト終わりに向けた Solstice ミッションは，さらなる新発見を目指すものである。ミッションの最終フェーズである「Grand Finale」は 2017 年に開始され，近土点が D 環の内側に入り，極地方大気上層をかすめるような離心率と軌道傾斜角の高い軌道を 22 周回り，今までにない精度での重力場と磁気圏の測定を行い，環系と土星の質量の確定と，今までに探査機の入ったことのない領域での様々な In-Situ 計測を行う予定である。

このプレゼンテーションでは Cassini プロジェクトのここまでの 11 年間のハイライトと，この先 3 年間ミッション終了までの計画を説明する。

Cassini-Huygens は NASA,，European Space Agency (ESA)，そしてイタリア宇宙局 (Agenzia Spaziale Italiana, ASI) の共同ミッションである。

このプレゼンテーションの内容の一部は California Institute of Technology の Jet Propulsion Lab で，NASA との契約によって行われ，アメリカ政府の予算に支えられています。R2015 California Institute of Technology

キーワード: Cassini, Saturn, Huygens, Rings, Titan
Keywords: Cassini, Saturn, Huygens, Rings, Titan

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PPS01-05 会場:A03 時間:5 月 26 日 14:35-14:50

Cassini Imaging Science at Saturn: Global Atmospheric Dynamics and Cloud Morphology
Cassini Imaging Science at Saturn: Global Atmospheric Dynamics and Cloud Morphology

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We present recent results produced by the ISS visible-wavelength imaging camera onboard the Cassini spacecraft, which has been orbiting Saturn since 2004. The atmosphere of Saturn is not static. Just like that of Earth, it harbors many phenomena with a wide range of timescales that evolve over time. Our presentation will first present a mean-state of Saturn using a global mosaic of Saturn. The cloud features of Jupiter are well-characterized due to the stark contrast presented by light and dark bands, the Great Red Spot, and other discrete vortices. In comparison, Saturn?fs cloud bands and features are more muted due to the thick global stratospheric haze layer that masks the tropospheric clouds. In addition, we emphasize that, because the rings and ring shadows obscures much of the winter planet, global maps of Saturn can be obtained only from the vantage point of an orbiting spacecraft. Using the images of Saturn obtained before and after the equinox of 2009, we have constructed global cloud mosaics of Saturn. We also present temporal evolution of the zonal wind profile between 2005 and 2013.

We will first give a global overview of cloud features on Saturn that has been observed by Cassini and then focus on individual regions of interest. Among the many cloud features, we focus on the following. The first feature we will report on is the changes exhibited by the region where the Great Storm of 2010-2011 erupted. The disturbance left behind the storm continues to evolve, and we present the latest update. Second, we present the morphology of the north polar region. The hexagonal cloud feature at 75 degree N latitude emerged from the winter shadow in 2008, and its morphology fully came into view after the equinox in 2009. The cloud contrast has been evolving with seasons, and we present our observation. We also report our observation of the north-polar vortex, and compare that to its southern counterpart.

Our study is supported by the Cassini Project, NASA Outer Planet Research Program grant NNX12AR38G, NASA Planetary Atmospheres grant NNX14AK07G, and NSF Astronomy and Astrophysics grant 1212216.

キーワード: Planetary Science, Jovian Planet, Saturn, Cassini Mission, Atmosphere, International Cooperation
Keywords: Planetary Science, Jovian Planet, Saturn, Cassini Mission, Atmosphere, International Cooperation

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PPS01-06 会場:A03 時間:5 月 26 日 14:50-15:05

Exploration of Titan’s Seas
Exploration of Titan’s Seas

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Saturn′ s moon Titan has extensive lakes and seas of liquid hydrocarbons that are a priority target of future exploration. The largest of these seas, Ligeia Mare and Kraken Mare, are ~400km and ~1000km in extent, respectively, and are composed of liquid methane and ethane at 94K, with likely traces of hundreds of other organic compounds. Titan’s seas represent a laboratory for air-sea exchange and other hydrological and oceanographic processes, as well as a site of astrobiological interest.

Observations from the Cassini spacecraft, in particular its radar instrument, have measured the depth of Ligeia Mare to be ~160m, consistent with terrestrial basins of similar size. The tidal amplitudes have been predicted to be some tens of centimeters, and as surface windspeeds grow to 1-2m/s as we approach northern summer in 2017, waves are expected to form. Cassini observations of sunglint and with radar and radio generally show the sea surface to be flat up to now, but some time-variable patches of reflectivity show that dynamic processes are active, and perhaps that waves are just beginning to form. Further Cassini observations are eagerly anticipated.

Several proposals have considered future missions to Titan’s seas. Of these, the most detailed work was for a NASA Discovery Phase A study, the Titan Mare Explorer, TiME. This envisaged a radioisotope-powered capsule in Ligeia Mare in 2023, which it would traverse over several weeks blown by the wind. Detailed designs and operations plans were developed, and prototype instrument systems (e.g. sonar transducers, liquid sampling inlets) tested in cryogenic conditions; scale model splashdown testing was also performed.

More recently, the NASA Institute for Advanced Concepts has sponsored a study of a robot submarine to explore Titan′ s seas circa 2040. This study has addressed some unique challenges such as the reconciliation of hydrodynamic design drivers with the need to accommodate a large data relay antenna.

Whether these vehicles, or other systems such as airplanes or balloons, explore Titan next, it is clear that Titan’s seas offer tremendous scientific potential and public engagement.

キーワード: Titan, Hydrocarbons, Oceanography, Exploration Vehicles, Radar
Keywords: Titan, Hydrocarbons, Oceanography, Exploration Vehicles, Radar

PPS01-07 会場:A03 時間:5 月 26 日 15:05-15:25

JUICE: A EUROPEAN MISSION TO JUPITER AND ITS ICY MOONS
JUICE: A EUROPEAN MISSION TO JUPITER AND ITS ICY MOONS

BRANDT, Pontus[1*] ; WITASSE, Olivier[2] ; TITOV, Dmitri[2] ; ALTOBELLI, Nicolas[2] ; BARABASH, Stas[3] ; BRUZZONE, Lorenzo[4] ; BUNCE, Emma[5] ; COUSTENIS, Athena[6] ; DOUGHERTY, Michele[7] ; ERD, Christian[2] ; FLETCHER, Leigh[8] ; GLADSTONE, Randy[9] ; GRASSET, Olivier[10] ; GURVITS, Leonid[11] ; HARTOGH, Paul[12] ; HUSSMANN, Hauke[13] ; IESS, Luciana[14] ; LANGEVIN, Yves[15] ; PASQUALE, Palumbo[16] ; PICCIONI, Guiseppe[17] ; PLAUT, Jeffrey[18] ; RETHERFORD, Kurt[9] ; WAHLLUND, Jan-erik[19] ; WURZ, Peter[20]
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The recently adopted European Space Agency (ESA) mission JUpiter ICy moon Explorer (JUICE), the first large mission selected by ESA within the Cosmic Vision 2015-2025 Programme, is currently planned for launch in 2022. Details of the mission are described, including the payload, planned orbits and the expected science return. The focus of JUICE is to characterise the conditions that may have led to the emergence of habitable environments among the Jovian icy satellites, with special emphasis on the three worlds, Ganymede, Europa, and Callisto, likely hosting internal oceans. Ganymede, the largest moon in the Solar System, is identified as a privileged target because it provides a natural laboratory for analysis of the nature, evolution and potential habitability of icy worlds in general, but also because of the role it plays within the system of Galilean satellites, and its unique magnetic and plasma interactions with the surrounding Jovian environment. The mission also focuses on characterising the diversity of coupling processes and exchanges in the Jupiter system that are responsible for the changes in surface, ionospheric and exospheric environments at Ganymede, Europa and Callisto from short-term to geological time scales. Focused studies of Jupiter's atmosphere and magnetosphere, and their interaction with the Galilean satellites will further enhance our understanding of the evolution and dynamics of the Jovian system.

キーワード: Jupiter, Ganymede, Europa, Callisto, Magnetosphere
Keywords: Jupiter, Ganymede, Europa, Callisto, Magnetosphere

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PPS01-08 会場:A03 時間:5 月 26 日 15:25-15:40

木星氷衛星探査計画 JUICE
Jupiter Icy Moons Explorer: JUICE

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JUICE とは、ESA が 2012 年 5 月に選定した L クラス計画であり、2022 年打ち上げ，2030 年木星系到着，2032 年ガニメデ周回軌道投入の予定である。木星到着後、まずは木星周回軌道から木星系の観測を実施し、ガニメデ周回軌道投入後はガニメデという太陽系最大の氷衛星の精査を行う。サイエンス・テーマは（１）巨大ガス惑星の世界の理解（２）氷衛星（ガニメデ，エウロパ，カリスト）の探査である。AO とその後の選定を経て決まった JUICE に搭載される 11 観測機器提供チームのうち、３つの機器 (RPWI, GALA, PEP/JNA) については日本から JUICE-JAPAN がハードウェアの一部を提供する事になり、2 つの機器 (JANUS, J-MAG) についてハードウェアの提供は無いがサイエンス Co-I として参加することとなった。海外が主体となる極めて魅力的な大型計画へ日本から機器提供という形で参加することは今後とも活用されるべきである「海外計画への参加」という枠組みであり JUICE-JAPAN はその先駆けとなる。JUICE の科学的課題は (1) 系外惑星を意識した，巨大ガス惑星の世界の理解，および、(2) アストロバイオロジーを意識した，氷衛星（ガニメデ，エウロパ，カリスト）の探査である。木星周回軌道から木星系の観測（磁気圏，木星大気，エウロパ・カリスト・ガニメデのフライバイ観測）を実施し、巨大ガス惑星の原型としての木星系探査を行うことで、「巨大ガス惑星系の起源と進化」を解明する事、４つのガリレオ衛星のうち、エウロパ・カリストのフライバイ観測、太陽系最大の氷衛星ガニメデの周回観測による精査を実施し、生命居住可能領域の探査を行うことで、「生命存在可能領域としての氷衛星地下海の形成条件」を解明することが JUICE の目的である。JUICE の打ち上げは、アリアン５で行われる。打ち上げ時ドライ重量は約 1800kg, 燃料は約 2900kg である（必要なΔ V は約 2700m/s）。3 軸制御の探査機であり、太陽電池パドル面積は 70m^2、それにより約 700W の電力を発生させる。科学観測用には、重量 104kg、電力 150W というリソースが想定されている。通信は、X および Ka バンドによる。打ち上げ後は、地球・金星・地球・地球というスウイングバイを経て、7.6 年かけて木星に到着する。ガニメデ周回軌道投入後は、ガニメデという太陽系最大の氷衛星の精査を目的とする（この精査に加えてエウロパとカリストのフライバイ観測があること、つまり、アストロバイオロジーの観点から注目を浴びる「地下海」を持つ氷衛星３つのすべてを JUICE は観測するということは、特筆に値する）。最終期には、高度 500km での周回観測を 100 日間、200km での周回観測を 30 日間実施し、最後はガニメデに衝突してミッション終了である。日本から JUICE-JAPAN として参加する、ハードウェア提供３機器 (RPWI, GALA, PEP/JNA) とサイエンス参加 2 機器 (JANUS, J-MAG) を足し合わせると、木星本体（JANUS)、木星磁気圏（PEP/JNA,RPWI,J-MAG)、氷衛星（GALA,J-MAG,JANUS）といった JUICE のサイエンス・テーマのすべてに、日本からバランス良く貢献が可能であることがわかる。2013 年 9 月に正式に JUICE-JAPAN WG が設立された後、JUICE-JAPAN WG は、平成 26 年 2 月に小規模プロジェクトの募集に対して応募し、9 月に理学委員会による MDR/SRR を通過した。その後 WG 活動として、欧州 PI との観測装置提供部分の確定作業、観測装置担当部分に関わる開発、宇宙研 SRR/所内経営審査に向けた準備等を実施。現在は、WG からプリプロジェクトへの移行時期である。今後、プリプロジェクト、プロジェクトと進み、平成 28 年度には PDR、平成 29 年度に CDR と進んでいく予定である。JUICE はプロジェクト終了までまだ約 20 年かかる長期間に渡るプロジェクトである。適宜世代交替を進めながら是非ともこの魅力ある大型ミッションへの参加を成功させたいと考えている。

キーワード: 木星, ガニメデ, 衛星探査
Keywords: Jupiter, Ganymede, Satellite Exploration

PPS01-09 会場:A03 時間:5 月 26 日 15:40-15:55

ソーラー電力セイル実証機による外惑星領域探査： クルージング科学観測と木星トロヤ群その場計測
Outer Planet Exploration by the Solar Power Sail: Cruising Observation and In-situ Investigation of Jupiter Trojans

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ソーラー電力セイル WG[1]
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After more than a decade of mission studies and front loading technology developments and verifications including IKAROS, the first deep space solar sail in the history, the Solar Power Sail mission has been proposed to JAXA/ISAS in February 2015, as a candidate of the upcoming strategic middle-class mission for a space engineering-driven mission to demonstrate the first outer Solar System exploration of Japan.

While demonstrating the solar power sail technology in the deep space at 1-5.2 AU, it is bound to Jupiter Trojan asteroids, which may hold fundamental clues of the Solar System formation and revolution discussed by two competing hypotheses between the classic model and the planetary migration model. The former suggests that Trojan asteroids are mainly survivors of building blocks of the Jupiter system, while the latter claims that they must be intruders from outer regions after the planetary migration of gas planets settled.

Right after the launch around 2021, the cruising observation will start to produce scientific results. First dust-free infrared astronomical observation beyond the zodiacal light foreground scattering will be conducted to search for the first generation light of the Universe, let alone optical observation of the zodiacal light structure of the Solar System. Extremely long baseline with the observation from the Earth, gamma-ray burst observation can identify their sources. Continuous dust impact detection will reveal the large structure and distribution of the Solar System dust disk by >4 m^2 of an large-area dust detector array deployed on the sail membrane.

After Jupiter flyby, the spacecraft will reach to a target Trojan asteroid of >20 km in size in 2030s. Both global remote observation and deployment of an autonomous lander will be conducted. On the surface of the Trojan asteroid, sampling will be attempted for in-situ TOF mass spectrometry and passing the sample container to the mothership for a possible sample return option.

This presentation discusses major scientific objectives, mission design and spacecraft system of the solar power sail, together with current development status, in-situ observation instruments and including landing and sample return from the surface of a Trojan asteroid.

キーワード: ソーラー電力セイル, クルージング観測, 木星トロヤ群小惑星, 着陸探査, その場質量分析, サンプルリターン
Keywords: Solar Power Sail, Cruising Observation, Jupiter Trojan Asteroids, Surface Exploration, In-situ Mass Spectrometry, Sample Return

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PPS01-10 会場:A03 時間:5 月 26 日 16:15-16:30

Tidal deformation of Ganymede and effects of a subsurface ocean: a model calculation in preparation for JUICE

Tidal deformation of Ganymede and effects of a subsurface ocean: a model calculation in preparation for JUICE

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One of major objectives of the JUICE (JUpiter Icy moons Explorer) mission is to characterize the extent of subsurface oceans of the moons, in particular Ganymede, and GALA (GAnymede Laser Altimeter) is planned to detect and monitor tidal deformation, which is sensitive to the interior structure. A previous study indicates that the viscosity of the icy shell is the major controlling factor of the amplitude of tidal deformation [Moore and Schubert, *Icarus*, 2003]. This result, however, is based on simple calculation results assuming a shell with uniform viscosity. For a conductive shell, the actual viscosity will depend strongly on depth; the viscosity is very high at a shallow depth and is low at the base of the shell; such a large variation in viscosity should affect tidal deformation. Thus, a detailed investigation for tidal deformation of Ganymede in light of a depth-dependent viscosity is necessary prior to the JUICE mission. In this study, we investigate the amplitude and the phase lag of tidal deformation of Ganymede assuming a depth-dependent viscosity shell model.

Preliminary results assuming a constant temperature gradient and an Arrhenius-type rheology suggest that the main control on tidal deformation is not reference viscosity (i.e., viscosity at the melting temperature) but is rigidity if the subsurface ocean is thick ($>$10 km). For a conductive shell the fluid limit of tidal deformation is unlikely to be achieved even if the reference viscosity is extremely low (i.e., 10^{10} Pa s) because of the high viscosity near the surface. The thickness of the ocean is found to be a minor control as long as a subsurface ocean exists. The phase lag can be up to several degrees, though the range of its variation for a depth-dependent viscosity model is much smaller than that for a uniform model. These results indicate that the presence of a high-viscosity near-surface layer, which has been ignored previously, has a large effect on tidal deformation on Ganymede.

On the other hand, if a subsurface ocean does not exist, the major control on tidal deformation is the viscosity of a high-pressure (HP) ice layer; the near-surface layer plays a minor role in contrast to a thick ocean case. If a HP ice layer has an extremely low viscosity (~10^{12} Pa s), such a layer behaves as fluid, leading to amplitude and phase lag similar to those for a thick ocean case. If a HP ice layer has a moderate or high viscosity, the tidal Love number h_2 would be $<$0.5, which is much smaller than that for a thick ocean case (i.e., $h_2 >$1). GALA measurements should distinguish such a difference in tidal amplitude.

Keywords: Tidal deformation, Ganymede, Subsurface ocean, JUICE, GALA

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PPS01-11 会場:A03 時間:5 月 26 日 16:30-16:45

ガニメデの内部進化と地形形成：JUICE 計画での実証に向けて
Interior evolution of Ganymede and its surface manifestation: toward JUICE measurements

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Jovian moon Ganymede is the largest moon in our solar system and its icy surface is shared by global-scaled tectonics, termed as grooved terrain, which has been interpreted as grabens resulting from lithospheric extension and the average impact crater density on the grooved terrain corresponds to an age of 2 Gyr. According to geological estimates, 3-4% increase in the satellite radius may be required for their formation. In addition, the small value of the moment of inertia factor and the strong intrinsic magnetic field observed for Ganymede are consistent with a highly differentiated interior with a conductive dense core. Hence Ganymede has likely undergone significant temperature rise inside allowing the separation of a conductive core and global expansion during its history. However, the release of accretional energy is insufficient for the melting of metallic materials. Either the short-lived radio nuclides or the late stage heavy bombardment should heat the interior too early to explain the global expansion at 2 Ga from the formation of Ganymede. Thus its mechanisms still remain an open question.

This study numerically investigates the possible influence of hydrated rock on the thermal history of Ganymede. Here we assumes that Ganymede had an initial structure with a relatively thin water ice mantle and a low temperature primordial core made of the mixture of hydrous rock and Fe-sulfide similar to hydrated primitive meteorites. This may be supported in part by the similarity in reflectance spectra among hydrated carbonaceous chondrites and asteroids near Jovian orbit. In order to investigate above influence, we perform numerical simulations for the internal thermal evolution using a spherically symmetric model for the convective and conductive heat transfer with radial dependence of viscosity and heat source distribution. The primordial core is heated by the decay of long-lived radioactive nuclides. The rise of core temperature is kept slow after the occurrence of effective thermal convection in the core having low viscosity of hydrous rock. However, once the temperature reaches the dehydration point then the highly viscous, anhydrous region begins to grow associated with the release of water to the mantle. The core temperature thereby becomes to increase faster with accelerating the further dehydration of primitive matter. Dehydration of serpentine occurs at 1 to 2 Gyr after the satellite formation, giving an explanation for the cratering age of grooved terrain, and increasing in total volume of the moon by the dehydration is expected from calculation of temperature, pressure, and density with depth profiles extending from the center to the surface of the moon using 3rd-order Birch-Murnaghan equation of state with the thermal effect incorporated into the thermal expansion coefficient. In addition, the core temperature subsequently exceeds the eutectic point of the Fe-bearing sulfide and oxide so that the formation of a conductive dense core could occur by their gravitational segregation. Meanwhile, Callisto does not heat up sufficiently to melt the sulfide component or dehydrate the primordial core because of the efficient heat loss for smaller body. The difference of radiogenic heat and moon's size between Ganymede and Callisto may have potential to create the surface and interior dichotomy between two moons.

Finally, we expect these hypothesis can be validated through the JUICE mission. Coverage and resolution of current data for Ganymede's surface acquired by Voyager and Galileo spacecraft are quite poor, and considerable part of the surface has been classified as 'unclassified unit' in the current geologic map. GALA and JANUS onboard JUICE spacecraft will perform a full global mapping of surface morphology of Ganymede, thus we will be able to constrain an amount of surface area increment associated with the groove formation and a regional surface age of each groove to see a tectonic history and interior evolution.

PPS01-12 会場:A03 時間:5 月 26 日 16:45-17:00

Geophysical Controls on the Habitability of Icy Worlds: Focus on Europa
Geophysical Controls on the Habitability of Icy Worlds: Focus on Europa

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Many icy worlds in the solar system are likely to contain inventories of liquid water comparable to Earth's. This meets only one planetary habitability requirement; less is known about whether icy world oceans permit the needed chemical disequilibria. Evidence for sustained internal heat and abundant water on Jupiter's moon Europa suggest life would have had the perceived time necessary to develop there, but sources of electron donors and acceptors critical for habitability have been difficult to assess. Past investigations assumed hydrogen production at the rock-ocean interface scales with the heat input to the rocky interior, and that subsurface weathering and alteration are inconsequential. However, estimates of hydrogen production rates on Earth show that low-temperature hydration of crustal olivine produces substantial hydrogen, on the order of 10^{11} moles yr^{-1}, comparable to the flux from volcanic activity. Here, we estimate global average rates of water-rock reaction on Earth, Mars, and icy worlds in the solar system using the pressure- and temperature-dependent physics of microfracturing in olivine. We predict hydrogen production within Europa's oceanic crust—also potentially applicable to other icy worlds—that are higher than those on Earth, even in the absence of contemporary high-temperature hydrothermal activity. Radiogenic cooling exposes unweathered rocky material progressively over time to ever greater depths. Shallower gradients in pressure and temperature in objects smaller than Earth expose new unaltered rock with an efficiency that scales as the inverse of gravity, so up to 100x more efficiently than Earth. Weathering and alteration of exposed material, mainly by serpentinization, release heat and hydrogen, which are necessary for life. We hypothesize that Europa's ocean could have become reducing during geologically brief periods when hydrogen flux from rapid reweathering far exceeded oxidant flux. thermal-orbital resonance 2 Gyr after Europa's accretion that caused oscillations in mantle heating. Europa's present-day limit of mantle tidal heating would produce volcanic hydrogen (0.6-$2x10^{10}$ moles yr^{-1}) that offsets the low end of estimated production from serpentinization alone (total range $4x10^{8}$-$5x10^{10}$ moles yr^{-1}). Evidence for subduction- like behavior in Europa's ice suggests that radiolytic oxidant flux to its ocean is at that high end of the previously estimated range ($5x10^{9}$-$4x10^{11}$ moles yr^{-1}). These factors make Europa unique among icy worlds for potentially having an oxidizing ocean with a high flux of reductants. Europa is thus a prime candidate for hosting life.

キーワード: Europa, Icy Worlds, Astrobiology, Habitability, Outer Planets, Microfracturing
Keywords: Europa, Icy Worlds, Astrobiology, Habitability, Outer Planets, Microfracturing

PPS01-13 会場:A03 時間:5 月 26 日 17:00-17:15

ハビタブルトリニティ概念のエウロパへの適用
Application of Habitable Trinity concept to Europa

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Habitable Trinity is one of the most significant condition to bear life. Habitable Trinity is the environment where atmosphere, ocean, and landmass coexist under the driving force for material circulation between trinity components. Habitable Trinity condition is the minimum requirements to emerge life. Because life body is not made from only water component. Life needs constant supply of C, H, O, N and minor elements derived from landmass such as P,K, Fe etc to maintain the body. Therefore Habitable Trinity environment is the key for life.

This requirement can be applied to other planetary bodies in the Universe. Let's think about the case of Europa, the moon of planet Jupiter. Europa has a water-ice crust on its surface and thought to have water ocean beneath it. People who think the existence of liquid water enable life be emerged insist that there is life in Europa due to the existence of water ocean under the icy crust. Once we consider the conditions of Europa based on Habitable Trinity concept, the answer is given easily, which means there is no chance to bear life on Europa. Europa does not provide the environment to maintain coexistence of atmosphere, ocean, and landmass which is constantly circulated.

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PPS01-14 会場:A03 時間:5 月 26 日 17:15-17:30

ENERGETIC NEUTRAL ATOM (ENA) IMAGING OF THE EUROPA GAS CLOUD FROM JUICE
ENERGETIC NEUTRAL ATOM (ENA) IMAGING OF THE EUROPA GAS CLOUD FROM JUICE

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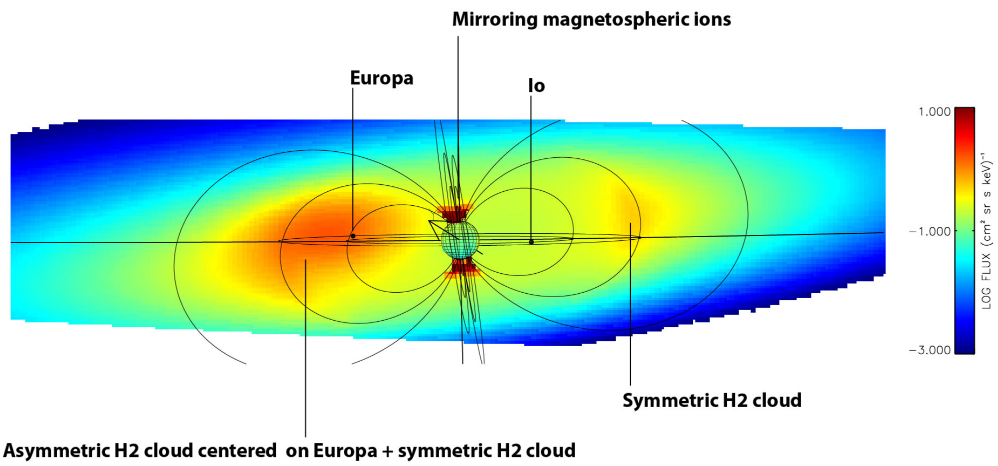
The Jupiter Energetic Neutrals and Ions (JENI) Camera is one out of six sensors of the Particle Environment Package (PEP) suite that was selected for flight on the ESA Jupiter Icy Moon Explorer (JUICE). JENI is a combined imaging energetic ion spectrometer and an ENA camera that operates in the ~0.5 keV to 1 MeV range for ions and ~0.5 ? 500 keV for ENAs and is capable of separating H, O, and S. Its angular resolution is $\leq 2^{0}$ for $\geq$10 keV H.

In ENA mode JENI's main objective is to constrain the Europa surface (or subsurface) mechanisms that release material to space by imaging the neutral gas surrounding Europa using ENAs produced when energetic ions of the Jovian magnetosphere charge exchange with the extended neutral gas atoms or molecules.

ENA observations of Jupiter by the Ion and Neutral Camera (INCA) the Cassini spacecraft have revealed ENA emissions surrounding Jupiter at about the orbital distance of Europa. The observations are consistent with a column density peaking around Europa's orbit in the range from 2×10^{12} cm^{-2} to 7×10^{12} cm^{-2}, assuming H_2, and are consistent with the upper limits reported from the Cassini/UVIS observations. Detailed analysis shows indications that the neutral gas cloud may be centered on Europa and not symmetric around Jupiter. This would directly imply that the source of the gas is Europa itself. The INCA observations also show indications of magnetospheric dynamics that result in about a factor of two variation in ENA intensity.

We describe the INCA observations and its implications for JUICE, Juno and Europa Clipper, and discuss the neutral-plasma coupling pertinent to the Europa/Io plasma/neutral environment.

キーワード: Europa, Jupiter, Torus, Magnetosphere
Keywords: Europa, Jupiter, Torus, Magnetosphere



Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PPS01-15 会場:A03 時間:5 月 27 日 09:00-09:20

Solar System Satellite Formation : an overview
Solar System Satellite Formation : an overview

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The origin of Solar System satellites is actively debated. We know understand that, despite the morphological analogy between a satellite system and a planetary system, the formation processes of satellites may be significantly different from planetary formation processes. in addition, satellites evolve quickly under the effects of tides. Different scenarios seem to be required for different types of planets (terrestrial, giant or ice giant). In this talk I will current satellite formation models and the different constrains. Based on Cassini images and numerical simulation, I will show that there is today on-going accretion processes at the edge of Saturn's rings, pointing to a new satellite formation process.

キーワード: Planet, Satellites, Formation
Keywords: Planet, Satellites, Formation

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PPS01-16 会場:A03 時間:5月27日 09:20-09:40

JUNOによる木星探査と地上からのサポート観測
The Juno Mission and the Role of Earth-Based Supporting Observations

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NASAのJUNO探査機は2011年に打ち上げられ，2013年の地球フライバイによる増速を経て2016年7月に木星に到着する計画である。木星到着後は近木点が放射線帯の内側に入る離心率の高い楕円軌道に入り，木星を約30回周回する。JUNOミッションの主な目的は木星大気深層の水分子の分布の計測，惑星近辺の重力場の解析，そして磁気圏環境の探査の3点である。これらの計測により木星内部の構造，組成，そして対流循環を三次元的に解析することが可能になる。また，それにより惑星表層の大気現象を木星の内部循環と結びつけて理解することも可能になる見込みである。これらの研究により，木星の形成と進化の過程を明らかにし，ガス惑星形成について総合的な理解を深めることも重要な目的である。

JUNO探査機に搭載される観測機器は，電磁圏環境のin-situ計測機器と，広範な周波数帯にわたって木星のリモート・センシング観測を行う機器の2つに分けられる。リモートセンシング機器が観測する波長帯はUltraviolet Spectrometer (UVS)が70-205 nm，Juno IR Auroral Mapper (JIRAM)が2-5μm，そしてMicrowave Radiometer (MWR)が1.3-50 cmとなっている。それに加え，可視光カメラJunoCamがRGBフィルターと890 nmメタン吸収帯フィルターを用いてアウトリーチ用画像を撮影する計画である。JUNOは木星を30回以上周回する予定であり，観測機器は連続的に運用されるが，リモートセンシング観測を優先して行うのは，最初の軌道と，軌道3～8だけであるため（残りの軌道は重力場観測優先），表面構造の同時観測を行うためには地上からのサポートが不可欠であり，また，Juno観測機器にカバーされない周波数帯のスペクトル観測についても，地上からのサポートが重要になる。JunoCamは可視光画像を撮影するものの，撮像用CCDは厳密な測光観測を行うのに十分な精度でキャリブレーション行うことができないため，対流圏雲構造の解析を行うには地上からの0.3-2.0μm波長でのワイドバンド・ナローバンド観測が必要になる。また，地上からの近赤外線高スペクトル解像度観測により大気の微量成分の吸収線を測ることで，JIRAMデータからは測定できない鉛直成分の風速の推定も可能になる。JUNO探査機は波長>5μmの中赤外線帯を観測する機器を搭載していないため，この波長で地上から観測を行うことにより対流圏と成層圏の温度分布と大気微量成分および高度1 bar以上の雲構造の分析も必要である。

地上観測のもう一つの重要点は，JUNOのリモートセンシング観測データは木星のごく限られた地域のみをカバーするため，地上から取れる木星全球データなしには，リモートセンシングデータを時系列に当てはめて理解することができない点である。このためには，2016年中期の木星の衝までに木星表面にある事象とそのタイムスケールを理解し，JUNOによる観測に今から備える必要がある。地上からの観測により追跡観測が必要な大気事象の例として，大赤斑，Oval BA，Brown Barges，そしてその他の渦構造や，青灰色がかった大気凝結成分の密度が低いことが知られている地域がある。これらの観測を地上から行うことにより，JUNOの軌道修正のタイミングや観測機器のポインティングなどについて，大気事象に合わせて能動的な運用する予定である。こういったサポートを行うため，JUNOチームはプロとアマチュアによる木星の国際共同観測を呼びかけている。

（JUNOプロジェクトとその研究活動はNASAからの助成を受けて行われています。）

キーワード: Juno, Jupiter, imaging, spectroscopy, astronomy
Keywords: Juno, Jupiter, imaging, spectroscopy, astronomy

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PPS01-17 会場:A03 時間:5 月 27 日 09:40-09:55

木星熱圏・放射線帯の太陽紫外線応答について
Solar UV/EUV response on Jovian thermosphere and radiation belt

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KITA, Hajime[1*] ; MISAWA, Hiroaki[1] ; TSUCHIYA, Fuminori[1] ; TAO, Chihiro[2] ; SAKANOI, Takeshi[1] ; KASABA, Yasumasa[1] ; MORIOKA, Akira[1]

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In order to evaluate the solar UV/EUV heating effect on the Jovian radiation belt, we made coordinated observations for both temperature of the Jovian thermosphere using an infrared telescope and synchrotron radiation from the radiation belt (JSR) using a radio interferometer.

Jupiter's synchrotron radiation (JSR) is the emission from relativistic electrons in the strong magnetic field of the inner magnetosphere, and it is the most effective probe for remote sensing of Jupiter's radiation belt from the Earth. Although JSR has been thought to be stable for a long time, recent intensive observations for JSR reveal short term variations of JSR with the time scale of days to weeks. It is theoretically expected that the short term variations are caused by the solar UV/EUV heating (hereafter the B-M scenario): the solar UV/EUV heating for Jupiter's upper atmosphere drives neutral wind perturbations and then the induced dynamo electric field leads to enhancement of radial diffusion. If such a process occurs at Jupiter, brightness distribution of JSR is also expected to change. Previous studies have confirmed the existence of the short term variations in total flux density and its variation corresponds to the solar UV/EUV variations. However, confirmation of the scenario is limited. The purpose of this study is to examine the B-M scenario based on radio interferometer and infrared observations, and reveal precise physical processes of the inner magnetosphere.

We made simultaneous observations of the Giant Metrewave Radio Telescope (GMRT) and the NASA InfraRed Telescope Facility (IRTF) in January 2014, in order to reveal whether the Jovian thermosphere responses to the solar UV/EUV and whether this actually causes variations of the total radio density and brightness distribution of JSR. The total radio flux density, rotational temperature of H_3^+, and solar EUV flux showed a similar decreasing trend until Jan. 10. These results support the B-M scenario. On the other hand, the total flux density and the temperature increased after Jan. 12 even when the solar EUV flux decreasing almost monotonically. The enhancement of the temperature and the total flux density after Jan. 12 might be caused by the high latitude heating. A numerical simulation study of the Jovian upper atmosphere suggests that the high latitude Joule heating is induced by solar EUV radiation and it affects the mid-low latitude thermosphere. It is shown that the high-latitude heating produces an atmospheric convection cell which propagates from the heat source region at both high and low latitudes. In addition to that, if high latitude heating is caused by some processes other than the solar UV/EUV, it is expected that this also affects the mid-low latitude temperature and the radiation belt: one of such effects might be brought by enhancement of field aligned currents flowing into the high latitude region, which is driven by some global magnetospheric variations.

Thus, we found that the solar UV/EUV enhancement causes the variations in thermospheric temperature and intensity of JSR had correlation from the combined simultaneous observations, which is consistent with the B-M scenario. It is also suggested that one point should be taken into account in addition to the original B-M scenario, i.e., the high latitude heating effect on the mid-low latitude thermosphere.

キーワード: 木星放射線帯, 木星熱圏, 赤外分光観測, 電波干渉計観測, 太陽紫外線応答
Keywords: Jovian radiation belt, Jovian thermosphere, Infrared spectroscopic observation, Radio interferometric observation, Solar UV/EUV response

PPS01-18 会場:A03 時間:5 月 27 日 09:55-10:10

ひさき衛星の観測 1 年間のまとめ、今後
Summary of Hisaki observation during one-year and the next

吉川 一朗[1*] ; EXCEED Mission team[2]
YOSHIKAWA, Ichiro[1*] ; EXCEED, Mission team[2]

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EUV 分光器（EXCEED) を搭載したスプリント衛星 A（ひさき）はイプシロンロケットで 2013 年 9 月に打ち上げられ、観測を開始しました。 現在も、地球の周回（954.05km × 1156.87km、周期１０４分）を飛翔しています。この 1 年の間に太陽系惑星の水星、金星、（地球）、火星、木星と土星を一通り、観測した。EUV 波長域に 1cm2 以上の有効面積を持ち、520-1480A の波長範囲でよく較正されています。
この測器を用いて、木星を約３ヶ月間にわたり連続的に観測した。
その結果、イオプラズマトーラスとオーロラの双方に起こる突発的な増光のイベントから高エネルギー粒子の内部磁気圏への流入を確認した。
また金星の観測からは、一酸化炭素の Fourth Positive バンドと窒素分子の輝線をはじめて同定することができた。水星、火星、土星も含め、1 年間の観察の概要を紹介します。

キーワード: ひさき, 極端紫外光, 惑星大気光, 太陽系惑星
Keywords: HIsaki, EUV, Planetary airglow, Solar planets

PPS01-19 会場:A03 時間:5 月 27 日 10:10-10:25

宇宙望遠鏡群を用いた多波長プラズマ遠隔観測が明らかにする木星オーロラ加速のダイナミクス
Dynamics of Jupiter's auroral acceleration investigated by multi-wavelength plasma remote sensing with space telescopes

木村 智樹 [1*] ; Badman Sarah[2] ; 垰 千尋 [3] ; 吉岡 和夫 [1] ; 村上 豪 [1] ; 山崎 敦 [1] ; 土屋 史紀 [4] ;
Bonfond Bertrand[5] ; Kraft Ralph[6] ; Elsner Ronald[8] ; Branduardi-Raymont Graziella[7] ; Gladstone Randy[9] ;
藤本 正樹 [1] ; ひさき サイエンスチーム [1] ; HST Cycle 20 GO 13035 team[1] ; CXO Cycle 15 GO 15100276 team[1]
KIMURA, Tomoki[1*] ; BADMAN, Sarah[2] ; TAO, Chihiro[3] ; YOSHIOKA, Kazuo[1] ; MURAKAMI, Go[1] ;
YAMAZAKI, Atsushi[1] ; TSUCHIYA, Fuminori[4] ; BONFOND, Bertrand[5] ; KRAFT, Ralph[6] ; ELSNER, Ronald[8] ;
BRANDUARDI-RAYMONT, Graziella[7] ; GLADSTONE, Randy[9] ; FUJIMOTO, Masaki[1] ; HISAKI, Science team[1] ;
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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.

PPS01-20 会場:A03 時間:5 月 27 日 10:25-10:40

ひさき搭載 EXCEED が捉えた木星内部磁気圏における太陽風の影響
Solar wind influence on Jupiter’s inner magnetosphere found by HISAKI/EXCEED

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藤本 正樹 [1]
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The dawn-dusk asymmetry of the Io plasma torus has been seen by several observations. One possible cause of this asymmetry is a dawn-to-dusk electric field in 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 for more than several months. 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. This result agrees with the scenario that a dawn-to-dusk electric field is imposed in the inner-magnetosphere by a field-aligned current.

PPS01-21 会場:A03 時間:5 月 27 日 11:00-11:15

木星内部磁気圏の極端紫外光観測
EUV observation for Jovian inner magnetosphere

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YOSHIOKA, Kazuo[1*] ; MURAKAMI, Go[2] ; KIMURA, Tomoki[3] ; YAMAZAKI, Atsushi[2] ; TSUCHIYA, Fuminori[4] ; KAGITANI, Masato[4] ; SAKANOI, Takeshi[4] ; KASABA, Yasumasa[5] ; YOSHIKAWA, Ichiro[6] ; FUJIMOTO, Masaki[7]

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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.

キーワード: 極端紫外光, 木星, 磁気圏
Keywords: EUV, Jupiter, magnetosphere

PPS01-22 会場:A03 時間:5 月 27 日 11:15-11:30

衛星イオープラズマトーラス相互作用による電子加熱
Local electron heating around Io observed by the HISAKI satellite

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坂野井 健 [1] ; 吉川 一朗 [5]
TSUCHIYA, Fuminori[1*] ; KAGITANI, Masato[1] ; YOSHIOKA, Kazuo[3] ; NOZAWA, Hiromasa[3] ; KIMURA, Tomoki[2] ; MURAKAMI, Go[3] ; YAMAZAKI, Atsushi[3] ; KASABA, Yasumasa[4] ; SAKANOI, Takeshi[1] ; YOSHIKAWA, Ichiro[5]

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Io-correlated brightness change in Io plasma torus (IPT) has been discovered by the Voyager spacecraft and show an evidence of local electron heating around Io. However, the observation data is still limited to investigate its detail properties and cause of the electron heating around Io is still open issue. EUV spectrograph onboard the HISAKI satellite carried out continuous observation of IPT and Jovian aurora for 2.5 months since the end of Dec. 2013. It covers wavelength range from 55 to 145 nm, a wide slit which had a field of view of 400 x 140 arc-second was chosen to measure radial distribution and time variation of IPT. Observation of IPT with HISAKI found clear periodic variation in the IPT brightness associated with Io's orbital period. The Io phase dependence shows that bright region is located just downstream of Io. The amplitude was larger in the short wavelength than in long wavelength. These are evidence of local electron heating around/downstream of Io and consistent with the Voyager result. In addition, it is found that the brightness also depends on the system-III longitude of Jupiter 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 IPT density at Io. Total radiated power from IPT on Jan. 2014 was 1.1 TW, which was about a half of the power measured by the Cassini UVIS instrument on Oct. 2000. Io-correlated component has about 10 % of the total radiated power, showing that about 100 GW of power was converted to heat thermal electron in IPT immediately after the generation of source energy around Io.

キーワード: 木星磁気圏
Keywords: Jovian magnetosphere

PPS01-23　会場:A03　時間:5 月 27 日 11:30-11:45

Cassini/RPWS: A low frequency radio imager at Saturn
Cassini/RPWS: A low frequency radio imager at Saturn

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The High Frequency Receiver (HFR) of the Radio and Plasma Waves Science experiment (RPWS) onboard Cassini is a sensitive, and versatile radio instrument. Although the radio antenna connected to this instrument have no intrinsic directivity, the HFR measurements can provide instantaneous direction of arrival, flux density and polarization degree of the observed radio waves. Hence, the HFR can be described as an full-sky radio imager. As the instrument provides direction of arrival, radio sources can be located with some assumption on the propagation between the source and the observer. Hence, it is possible to produce radio source maps and correlate them with observations at other wavelengths, such as UV or IR observations of the auroral regions of Saturn. The flux and polarization measurements together with the time-frequency shape of the radio emissions can also be used to identify the radio emission processes.

We present a review of the results of the Cassini/RPWS/HFR observations since its arrival at Saturn in 2004: interpretation of the radio arc shapes and equatorial shadow zones; in-situ observations in the radio source region; comparison with other wavelengths and particle measurements; confirmation of the Cyclotron Maser Instability (CMI) as the main emission mechanism for auroral radio emissions; monitoring of the radio emission variability in time and location, etc. We will also show how the future JUICE mission will benefit from these techniques.

キーワード: Radioastronomy, Saturn, Aurora, Magnetosphere, Cassini
Keywords: Radioastronomy, Saturn, Aurora, Magnetosphere, Cassini

PPS01-P01 会場:コンベンションホール 時間:5 月 26 日 18:15-19:30

JUICE による木星系科学探査：日本チームの参加
Scientific exploration of Jovian System by JUICE Mission: Participation of Japanese team

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The largest planet in the solar system, Jupiter, is a rapidly rotating hydrogen-helium gaseous body with strong magnetic field and associated magnetosphere. Recent discoveries of exoplanets suggest that Jupiter should represent a body not only in the solar system but also in the universe. Jupiter has various satellites: four large satellites, Io, Europa, Ganymede, and Callisto, were discovered by Galileo 400 years ago. Three of them except Io are icy moons.

The Jupiter system was observed by several flyby missions such as Pioneer 10 and 11, Voyager 1 and 2, Cassini, New Horizons and investigated by Galileo orbiter and its atmospheric entry probe. Galileo spacecraft data was very limited without capability of its high-gain antenna. So far we knew about Jovian system much less than the Saturnian System, where Cassini spacecraft has been continuously observing. JUNO mission will start observation of Jupiter in 2016. But since the main target of JUNO taking polar orbits is structure and composition of Jupiter, observation of satellites would be limited.

JUICE (Jupiter Icy Moon Explorer) is the ESA first Large-class mission of Cosmic Vision 2015-2025 program. The emergence of habitable worlds around gas giants, and the focus is to characterise the conditions of habitable environments among the Jovian icy satellites, with special emphasis on the Ganymede, Europa, and Callisto. JUICE will be launched in 2022, and will arrive at Jupiter in 2030. After several fly-bys to Europa and Callisto, JUICE will be inserted into an orbit around Ganymede in 2032 and will continue scientific observations for eight months until the end of nominal mission in 2033.

The discussion for the international collaboration for Jupiter mission between ESA and Japan (JAXA) started in 2006. Initially JAXA proposed a magnetospheric orbiter whereas ESA and NASA proposed Ganymede and Europa orbiters, respectively. After the selection of JUICE by ESA in May 2012, six Japanese groups were invited to participate in the mission as Co-Is with instrument development for model payloads. Finally through the selection process of instrument development teams, four of Japanese team partners were selected for the official JUICE instruments. These are GALA (Laser altimeter), SWI (Sub-millimeter wave instrument), PEP (Particle environment package), and RPWI (Radio & Plasma Wave Investigation). Moreover three Japanese scientists are invited to participate in the initial scientific analysis as Co-Is of JANUS (Optical cameras) and J-MAG (Magnetometer). And it is proposed that a longer Mast (for J-MAG) could be supplied from Japan.

キーワード: 木星系, 地下海, 生命存在領域, 氷衛星
Keywords: Jovian System, Subsurface Ocean, Habitable zone, Icy satellites

PPS01-P02 会場:コンベンションホール 時間:5 月 26 日 18:15-19:30

JUICE-GALA レーザ高度計
Development of JUICE/Ganymede Laser Altimeter (GALA)

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“地球以外に生命を宿す天体は存在するのか”という問いは，人類の知的好奇心の究極に位置する科学的命題である．木星系の大氷衛星であるガニメデやエウロパ，カリストでは，H_2O 主体の氷に覆われた表層の下に全球的な液体層，いわゆる“地下海”の存在が示唆されている．液体水の存在はすなわち生命生存の可能性に直結し，地球生物学の他天体への拡がりは「アストロバイオロジー」としてその重要性がこれまでも広く認識されている．しかし，地下海の存在は電磁気的観測や表面地形の解釈から導き出された“可能性”に過ぎない．ESA が主導する木星系探査計画 JUICE ではこの存否を確認することが最重要課題である．

JUICE の搭載機器であるレーザ高度計 GALA はレーザ光の往復飛行時間を測定することによって探査機と天体表面までの距離を測定する．探査機と天体重心の位置情報をもとに，測定距離から地形が求められる．これにより地形の平均場としての全球地形モデルが得られるのと同時に，木星からの潮汐力により生じる固体潮汐の振幅（地形の時間変化）の大きさを測定することで，地下海の存否が推定できる．また，地下海の存在によって引き起こされると予測される回転変動（秤動）も，レーザのフットプリント位置のずれとして条件さえ整えば観測可能であろう．さらに，クロスオーバー解析によって，高度計データは探査機の軌道改良にも役に立ち，その結果，天体の重力場係数，慣性能率比，潮汐ラブ数の精度向上につながり，内部構造が制約できる．

一方，レーザ高度計によって全球的に得られる地形情報は，氷衛星の構造変動履歴をうかがう窓となり，様々な地形の形態とその分布の把握を通して氷地殻構造と内部進化の理解に大きな寄与をもたらす．具体的には，過去に発生した伸張応力が作り出したと考えられる溝構造や，氷地殻が局所的に融解している，あるいは薄くなっている場所に存在すると予想される内部湖などを検出しその形態を解明することが期待できる．こうした情報は氷衛星が示す多様な地質活動（熱・物質輸送様式）の理解につながるだけでなく，氷という揮発性（低融点）物質主体のテクトニクス様式をケイ酸塩鉱物でのそれと対比することによって他の固体惑星の地質活動や地球のプレート・テクトニクスを再考察することにも寄与する．

太陽系固体惑星の主要構成成分は岩石と氷であり，固体惑星のサブカテゴリのひとつである地球型惑星は，雪線の内側で形成したために岩石主体となった．一方で木星系以遠に存在する固体天体は，主構成成分のひとつに氷を持っている．その中でもガニメデは岩石と氷をほぼ等量の割合で保持し水星以上のサイズを持っていることから，地球型惑星と並ぶ固体惑星のもうひとつのサブカテゴリというべき存在である．近年発見が続いている多様な太陽系外惑星の中で，ガニメデのように岩石と氷からなる天体は現在発見されてはいないが存在が十分に予想されることからも，ガニメデの理解は重要である．

GALA は，ドイツ，スイス，スペイン，日本の国際共同チームにより開発される．基本設計は水星探査機 BepiColombo 搭載のレーザ高度計 BELA をベースにしており，トランシーバユニット（TRU），制御（制御・時間計測・インターフェース）ユニット（ELU），レーザ電子回路ユニット（LEU）の 3 つのユニットで構成されている．このうち，日本チームは TRU の中の反射光受信部（受信光学系および検出器）を担当する．検出器バックエンドのエレクトロニクスは，測距データ処理系を担当するスイスのベルン大学が担当する．また，レーザ発振・送信部と全体のインテグレーションは，PI である Hauke Hussmann の所属する DLR（ドイツ航空宇宙センター）が担当する．

GALA は現在は概念検討段階にあり，電気系，光学系については概念検討を終えて，構造設計と熱設計を進めている．2015 年 3 月のプロジェクト準備審査後に概念設計を開始する予定である．受光望遠鏡は有効直径 300 mm の金属鏡で，主鏡と副鏡合わせての反射率は 0.85 以上，受光視野は 450 μrad を要求している．鏡材料はアルミを用い，金メッキを施す．後段光学系は屈折系と反射系のいずれかを熱解析結果をふまえて選択する．バンドパスフィルタは BELA の実績を元に，Nd-YAG レーザの波長 1064 nm を中心に 8 nm の幅を持ち，透過率 0.8 以上，400~1200 nm の阻止率は OD 0.4 以上が求められている．検出器は「はやぶさ」シリーズや「かぐや」で実績のある Si-APD を採用する．プリアンプ，TE

クーラー，温度センサを内蔵した HIC (Hybrid IC) としてパッケージ化することが可能である．

キーワード: ガニメデ, 氷衛星, 惑星探査, レーザ高度計
Keywords: Ganymede, Icy satellite, Planetary exploration, Laser altimeter

PPS01-P03 会場:コンベンションホール 時間:5 月 26 日 18:15-19:30

JUICE-GALA : Focal Plane Assembly と Analog Electronics Module の検討
JUICE-GALA : Concept of Focal Plane Assembly and Analog Electronics Module

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2022 年打ち上げ予定の ESA 木星探査計画 (JUICE; JUpiter ICy moons Exploler) でレーザ高度計 (GALA, Ganymede Laser Altimeter) の搭載が予定されている。GALA はドイツ、日本、スイス、スペインの 4 国で共同開発され、日本チームはレーザ反射光受信望遠鏡、バックエンド光学系 (BEO)、APD センサモジュールが収められる焦点面アセンブリ (FPA) およびアナログの電子モジュール (AEM) の開発を担当している。
GALA の受光系では、観測対象の固体表面からの反射パルス信号を受信望遠鏡で集光して、続く BEO に導入する。BEO は反射光を APD センサの表面に焦点を合わせるように設計される。GALA で使用する APD は、宇宙搭載のレーザ高度計で多くの経験を持っている Excelitas Technologies 社の製品を採用した。
採用する APD モジュールは、APD、プレアンプ（トランスインピーダンスアンプ、TIA)、温度センサ、ペルチエ素子を含むハイブリッド IC で構成されている。TIA の出力信号の帯域は 120MHz とする。この APD センサは 1060nm で約 40%まで高められた量子効率を持っていて、1064nm の YAG レーザを利用する装置には有利な仕様となっている。FPA には二重冗長になっている光ファイバが、レーザヘッドモジュール (LHM) で発生するレーザーパルスの一部を APD センサに導入するように、FPA に取り付けられる。APD モジュールによる TIA は入力光パルスに対応する電圧信号は AEM に送られる。導入されたレーザーパルスから容認されたリターンパルスまでの波形がアナログ・デジタル変換 (ADC) 回路によってディジタルデータに変換され、デジタルサンプリングされた波形信号は距離測定モジュール (RFM) に送信される。RFM では、「整合フィルタ matched filter」によって S/N 比を最適化し、送信および受信パルスのタイミングの検出および受信パルスの幅、波高値を測定することで、正確な距離測定をしたり、送信パルスが反射した地形を調べたりすることができる。
本講演では、JUICE-GALA の FPA および AEM の開発状況について報告する。

キーワード: JUICE, GALA, レーザー高度計, APD, ガニメデ, アナログ回路
Keywords: JUICE, GALA, Laser altimeter, APD, Ganymede, analogue signal processing circuit

PPS01-P04 会場:コンベンションホール 時間:5 月 26 日 18:15-19:30

JUICE-GALA : 受光望遠鏡の光学設計
JUICE-GALA : Design of receiver telescope and related optics

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2022 年打ち上げ予定の ESA 木星探査計画 (JUICE; JUpiter ICy moons Exploler) でレーザ高度計 (GALA, GAnymede Laser Altimeter) の搭載が予定されている。GALA はドイツ、日本、スイス、スペインの 4 国で共同開発され、日本チームはレーザ反射光受信望遠鏡、バックエンド光学系 (BEO)、APD 検出器、アナログエレキ部の開発を担当している。

受信望遠鏡は口径 250mm〜300mm のカセグレン型（反射式）で、集光した光束は BEO を通して APD 受光面に導かれる。受光視野は 450 μ rad. で出射レーザの広がり角 100 μ rad. をカバーしつつ APD に対するノイズの影響を小さくする。この仕様に対し口径 300mm、主鏡-副鏡間隔が 160mm 以下のモデルを設計した。同時に BEO について平面ミラー 1 枚と屈折レンズ 2 枚を用いる方式と曲面ミラー 2 枚を用いる方式も設計し、いずれも成り立つことを確認した。また BEO 中の狭帯域フィルター（1064nm を中心に帯域 8nm）もメーカー供給可能との見通しを得ている。望遠鏡の主鏡、副鏡、支持機構はアルミ素材を用いてアサーマル構造とし、鏡面には金蒸着を施す予定である。2015 年度中に金蒸着アルミ材、フィルター等の熱真空・放射線の耐性試験を予定している。またレーザ送信光学系（ドイツ側担当）と受信望遠鏡（日本側担当）の光軸合わせの方法確立も重要課題である。

GALA 受信光学系は光学系だけの検討では決まらず、現在進行中の重量リソース調整及び熱、構造設計の結果に依存するところも大きい。本講演では GALA 受信光学系について最新の検討・開発状況を報告する。

キーワード: JUICE, GALA, 望遠鏡, バックエンド光学系, ガニメデ, アサーマル
Keywords: JUICE, GALA, telescope, BEO, Ganymede, athermal

PPS01-P05 会場:コンベンションホール 時間:5 月 26 日 18:15-19:30

The Radio & Plasma Wave Investigation (RPWI) for JUICE: Contribution plan from Japan

The Radio & Plasma Wave Investigation (RPWI) for JUICE: Contribution plan from Japan

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We present the current status of Radio & Plasma Waves Investigation (RPWI) [PI: J.-E. Wahlund (IRF-Uppsala, Sweden)] on the ESA JUICE mission to Jupiter (launch: 2022). RPWI consists of a highly integrated instrument package that provides a whole set of Langmuir probe and electromagnetic wave measurements, and will study the electro-dynamics of the Jovian magnetosphere and the affected exospheres, surfaces, and conducting subsurface oceans of Ganymede, Europa and Callisto.

RPWI first focuses on cold plasma around Jupiter and its satellites by 4-axis Langmuir probe combined with 3-axis search coil sensor, for the understanding of how the momentum and energy transfer occurs through electro-dynamic and electromagnetic coupling in Jovian environments with icy moons. Exhaust plumes from cracks on icy moons will also be studied, as well as micron sized dust and related dust-plasma surface interaction processes.

RPWI also first provides the spatially resolved information of radio sources in auroral regions of Ganymede and Jupiter and possibly lightning activity of Jovian clouds, by the first 3-axis measurement in radio frequency. As a byproduct, reflected Jovian emission can be expected from the boundary of crust (ice) and subsurface ocean (conductive water), which could observed as the Lunar surface reflection in terrestrial auroral kilometric radiation seen by Kaguya Lunar Radar Sounder.

For these objectives, RPWI sensors consist of 4 Langmuir probes (LP-PWI) for determination of the vector electric field up to 1.6 MHz and cold plasma properties (including active measurements by LP sweeps and mutual impedance sounding) up to 1.6 MHz, a tri-axial search coil magnetometer (SCM) for determination of the vector magnetic field up to 20 kHz, and a tri-dipole antenna system (RWI) for monitoring of radio emissions (80 kHz - 45 MHz). From Japan, we will provide the RWI preamp and its High Frequency receiver with the onboard software, modifying from the BepiColombo PWI and ERG PWE developments. We will also provide Software Wave-Particle Interaction Analyzer (SWPIA) function to RPWI DPU, for the onboard quantitative detection of electromagnetic field - ion interactions, modifying from the ERG SWPIA developments.

The RPWI consortium covers all the best international scientists and engineers in this field who have provided a long heritage record in ESA/NASA/JAXA missions and a track record of collaboration with each other. The team also includes the expert members in numerical modeling of all relevant sciences related to RPWI, in order to maximize the science return from the investigation. Followings are the participating organizations: [Sweden] Swedish Inst. Space Physics (IRF); Royal Inst. Technology (KTH). [France] Lab. de Physique des Plasmas (LPP); LESIA - Obs. de Paris; CNRS-LPC2E, Univ. d'Orleans; CNRS-IRAP, Univ. Paul Sabatier 9; Univ. de Versailles Saint-Quentin (LATMOS). [Poland] Space Research Centre of the Polish Academy of Sciences. [Czech] Inst. Atmospheric Physics; Astronomical Inst. [UK] Imperial College London; Univ. Sheffield [Austria] Space Research Inst. [Germany] Univ. Cologne. [Japan] Tohoku Univ.; Toyama Pref. Univ.; Kyoto Univ.; Kanazawa Univ.; ISAS/JAXA; Nagoya Univ. [USA] Space Science Lab., UC Berkeley; Univ. Iowa; Johns Hopkins Univ.; NASA/GSFC; Boston Univ.; Univ. Michigan.

PPS01-P06 会場:コンベンションホール 時間:5 月 26 日 18:15-19:30

JUICE-SWI サブミリ波分光計
JUICE-SWI Submillimeter-wave instrument

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In the JUICE mission, we are developing the Submillimetre Wave Instrument(SWI) which is a spectrometer with two frequency bands in 600 GHz and 1.2 THz region to observe submillimeter-wave emission from molecular species in atmospehre such as CH4, H2O, 17-0, 18-O, D/H ratio, CS, HCN and CO, as well as surface emission of satellites and the planet. Japanese contribution is the main- and sub- reflector of the antenna, and moters.

The chemical and isotopic compositions of volatiles on geologically non-active Callisto may preserve information of the composition of icy planetesimals formed in the Jupiter-forming region. Based on the observations of Callisto's atmosphere, the SWI Japan will try to constrain dynamics and chemistry of both the outer solar nebula and circum-Jovian subnebula, using their chemical model of protoplanetary disks and N-body simulations.

Also, the compositions of the atmospheres (and plumes) of Europa and Ganymede would provide information on particular geochemical processes in their subsurface oceans. Using results of the observations, the SWI Japan team will be able to investigate the availability of biogenic elements, conditions of geochemical reactions, and habitability, based on their high-pressure hydrothermal experiments and chemical models of subsurface oceans.

キーワード: SWI, Submillimeter-wave, Oxygen isotope
Keywords: Oxygen isotope, Submillimeter-wave, SWI

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PPS01-P07 会場:コンベンションホール 時間:5 月 26 日 18:15-19:30

ギャップはガス惑星の成長を止められるのか？
Can gap suppress gas capturing growth of giant planets?

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We study the final masses of giant planets growing in a protoplanetary disk by using a toy model, which employs simulation-based two empirical formulae for gap depth and accretion rate of area of protoplanetary disks. This model enables us to calculate time evolution of mass of giant planets. We find that gap opening is not effective to suppress gas capturing growth of giant planets: a Jupiter-mass planet is easily formed in a disk with small viscosity (alpha is 10^{-3}) and a small disk surface density (~1/10 of the minimum mass solar nebula model). Hot jupiters, which are thought to be formed outer region and then move inward by type II migration, could be formed in-situ (at 0.1 AU for example).
Keywords: gap, protoplanetary disk, giant planet

PPS01-P08 会場:コンベンションホール 時間:5 月 26 日 18:15-19:30

氷衛星表層地形における応力の起源
Origins of stresses in the lithosphere of icy satellites

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Surface geological features on the Moon, terrestrial planets and icy satellites reflect past interior activity which effects surface stress.

Most geologic features on icy satellites suggest a possibility that the surface have fractured and extended due to tensional stress. In case of large icy satellites such as Europa and Ganymede, it also well-recognized that the surface stresses were directly generated from the past interior activity. On these surfaces, elastic lithosphere is divided from asthenosphere due to the large viscosity contrast between the base of icy shell and the surface. Therefore we assume that surface features have been formed by the stress of elastic lithosphere that directly affected by the current and past interior activity.

We will discuss origins of stresses of elastic lithosphere of icy satellites. On surfaces of Europa and Ganymede, we can see many extensional features, stripes, bands and ridges, which have been interpreted as a sign of past interior activity, especially global volume expansion (Greenberg *et al*., 1998). In previous studies, various origins of such extensional features have been suggested.

In case of Europa, stress associated with icy convection (McKinnon (1998)) and tidal deformation (Greenberg *et al.*, 1998) discussed but the resultant of amplitude of surface stress is too small to create the observed extensional features. Therefore we thus focus on global expansion as important source of surface feature. The growth of the surface Ice-I layer is proposed for the expansion quantitatively (Kimura et al., 2007). Hillier and Squyres (1991) discussed thermal stress on small satellites of Saturn and Uranus including contribution of the phase transition of water ice, and they suggested that thermal stress is another source of surface features. Although they included an effect of temperature change due to phase transition, they neglected a contribution of volume change due to the phase transition and thermal history. Kimura *et al*. (2007) discussed surface stress on surface of Europa, and they considered stress due to temperature change and volume change of phase transition. Furthermore they also simulated interior thermal history coupling with stress calculation. Surface stress due to temperature change associated with the temperature evolution in the lithosphere and the stress raised by the excess pressure in the asthenosphere are coupled. Therefore this method is consistent with the physical process of phase transition.

In the case of Ganymede though the amount of the expansion seems significant the origin is still enigmatic. Therefore in this report we try to formulate a kind of Stefan problem which takes into account of the self-consistent adaptation of pressure build-up by phase change of Ganymede. We consider the heat transfer in the lithosphere by temperature-dependent rheology in the scheme of MLT(Kimura *et al*., 2009) and the elastic lithosphere which accumulate stress is estimated by estimated the thermal history of Ganymede.

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キーワード: 氷衛星, 混合距離理論, 熱応力, 相変化, 表層地形
Keywords: Icy Satellites, The Mixing Length Theory, The Thermal Stress, Phase Transition, surface feature

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PPS01-P09 会場:コンベンションホール 時間:5 月 26 日 18:15-19:30

SUBARU/IRCS 観測による木星赤外オーロラの水平・鉛直構造
Horizontal and vertical structures of Jovian IR aurora emission observed by SUBARU / IRCS

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2014 年 2 月・2015 年 1 月に行った SUBARU 8.2m 望遠鏡による木星赤外オーロラの水平・鉛直構造観測の結果速報を行う。本観測では、Adaptive Optics（AO）を活用して 170km 程度の空間分解能を実現した。これにより、赤外オーロラの水平分布だけでなく鉛直分布（スケール高は 200-400km 程度）の解析も可能となった。この観測は Hisaki/EXCEED の 1-3 月の 2015 年木星観測キャンペーンに連動して行っている。

木星磁気圏では、高速自転により生成される電流系によって「磁気圏-電離圏-熱圏（MIT）結合システム」が形成されている。このシステムでは、熱圏での粒子間衝突を介して中性大気から電離大気へ自転角運動量が輸送され、さらにこれが沿磁力線電流を介して磁気圏へ運ばれ、磁気圏プラズマを駆動する。これにより供給された磁気圏活動のエネルギーは、極域電流・降下電子の形で電離圏・熱圏の中性大気-電離大気結合域へと戻ってくる。降下電子は木星上層大気と衝突し、紫外（UV）オーロラを光らせまた大気を加熱する。この加熱により、電離大気（H3+）・中性大気（H2）の熱励起発光が生成され、赤外オーロラとして観測される。この H3+と H2 の水平発光強度分布が一致していない事が過去の K-band 分光観測で報告されてきた [Raynaud et al., 2004; Uno, 2013]。これは、両者の発光高度の違い、H3+発光はより電子降込の影響が大きい高温・高高度、H2 発光域は電離圏電流による Joule 加熱の影響が大きい低温・低高度との解釈であった。しかし、我々が 2011 年 12 月に行った SUBARU 赤外分光による初の AO 観測では、北半球赤外線オーロラの鉛直発光分布において、H2 は 590-720km、H3+は 680-900km の高度に発光強度のピークを持ち、予想された明確な高度差は見られなかった [Uno et al., 2014]。

この追跡のため、2014 年 2 月 13-14 日と 2015 年 1 月 30-31 日に SUBARU/IRCS（波長分解能約 10,000）を用いた木星赤外オーロラ観測を行った。前者の観測では AO を効かせ南半球の赤外線オーロラの水平・鉛直構造の取得を行い、後者の観測では南北両半球で AO を効かせた赤外線オーロラの水平・鉛直構造の取得を行った。Slit（5arcsec 長）は、AO が有効な時間帯には水平・鉛直分布の導出を目的として木星 limb に垂直（自転軸平行）に当て、AO が無効な時間帯（Galileo 衛星が適切な場所にない時間帯）には、木星自転による slit 視野移動の影響を小さくすべくオーロラオーバル上で木星自転方向に平行にあてた。また、同時に H3+ Fundamental line（v=1-0）の空間分布をフィルターイメージで取得している。特に、後者のデータセットは好条件下で、L-band（3.2-4.0 μ m）において H3+ Fundamental、K-band（2.0-2.4 μ m）において H3+ Overtone（v=2-0）・Hot overtone（v=3-1）および H2（S1）の輝線をそれぞれ多数同時取得しており、相互の相対的空間分布・強度比とその時空間変動を初めて高精度で議論可能なものとなる。この観測の前後には Hisaki/EXCEED が北半球 UV オーロラの全発光量を観測しており、全発光量およびそこから演繹される降下電子の総量とエネルギー分布との比較も行う予定である。

現在 2014 年 2 月の南半球観測データの解析を行い Uno et al., 2014 と同様に（1）水平分布では、メインオーバル域において H2 の発光が H3+の発光よりもコントラストが弱いこと、（2）鉛直分布では、H2・H3+の発光高度ピークに大きな違いを見出せないことを追確認した。今後 H3+、H2 発光の line 強度比から導出される電離・中性大気温度の水平・鉛直分布を比較し、この原因を探ろうとしている。

また、2015 年 1 月の両半球に跨るデータセットで H3+の L-band と K-band の発光分布・強度比較を初めて行う。H3+分子は降下電子と H2 分子との衝突で生成され、高エネルギーの電子ほどより低高度まで侵入できることから、その密度・発光強度は降下電子エネルギーの情報を包含しうる。エネルギー準位のより高い K-band 輝線はより高温の高高度域、エネルギー準位の低い L-band 輝線は低温度の低高度域に対応することが理論的に予測されるが、両者の準同時観測による発光・強度の比較は報告がない。本観測では Hisaki/EXCEED からもたらされる平均的降下電子エネルギー分布情報も用いて、L・K-band 間発光強度比と振込電子エネルギーとの対応を初検討する。

キーワード: 木星, オーロラ, 赤外線, 分光
Keywords: Jupiter, aurora, Infrared, spectroscopy

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PPS01-P10 会場:コンベンションホール 時間:5 月 26 日 18:15-19:30

地上望遠鏡とひさき衛星とによるイオプラズマトーラスの協調観測
Coordinated observation of Io plasma torus using Hisaki/EXCEED and gourd-based telescopes

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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. An intense campaign observations of Jovian aurora and Io plasma torus were made using Hisaki/EXCEED and ground-based telescopes from December 2014 through February 2015. We will present results from [SII] 671.6/673.1nm observation of Io plasma torus using a 60-cm telescope at the Haleakala observatory feeding to a monochromatic imager.

The monochromatic imager consists of a coronagraph and a narrow-band filter (FWHM=0.9nm). The coronagraph has an occulting mask and a Lyot stop to reduce contamination by diffraction from Jupiter. Field-of-view, 8 arc minutes, is wide enough to cover both sides of the plasma torus. A platescale and integration time are 1arcsecond/pixel and 20 minutes respectively. We could get 280 images from the observation during December 2014 through January 2015.

Based on a preliminary analysis of the Haleakala 60-cm, we have found variability of dawn-dusk shift of plasma torus which is believed to be related to dawn-dusk asymmetry in EUV brightness as well as sudden brightening of plasma torus. Latest result will be presented at the meeting.

PPS01-P11 会場:コンベンションホール 時間:5 月 26 日 18:15-19:30

ひさき衛星により観測された土星内部磁気圏中の中性酸素原子トーラス
Observations of neutral oxygen torus in the inner magnetosphere of Saturn by Hisaki

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Water group neutrals in Saturn's inner magnetosphere play the dominant role in loss of energetic electrons and ions because of abundance of the neutral particles Enceladus [e.g., Paranicas et al., 2007; Sittler et al., 2008]. Understanding of the temporal and spatial distribution of the neutrals is required to understand the plasma-neutral dynamics in the inner magnetosphere of Saturn. Water molecules mainly originating from Enceladus lead to the productions of hydroxyl radicals and oxygen atoms through dissociation reactions. In this study, we focus on oxygen dynamics in the inner magnetosphere of Saturn. The atomic oxygen in the magnetosphere of Saturn was discovered by UVIS/Cassini [Esposito et al., 2005]. Melin et al., [2009] reported the spatial distribution of oxygen and the variation of the total number of oxygen with time scale of several days — several tens of days. In this study, we examine the time and spatial distributions of neutral oxygen in the inner magnetosphere of Saturn observed by Hisaki. The daily variation of oxygen is first detected by the EXCEED onboard Japanease Earth orbiting satellite Hisaki. We also show the daily variation of spatial distribution such as dawn-dusk distribution and Enceladus phase angle observed by Hisaki.

キーワード: ひさき衛星, 土星, 中性酸素, Enceladus 中性トーラス
Keywords: Hisaki, Saturn, neutral oxygen, Enceladus neutral torus