PPS01-01　　会場:201B　　時間:5 月 21 日 14:15-14:30

Formation, Evolution, and Future Exploration of the Giant Planets
Formation, Evolution, and Future Exploration of the Giant Planets

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The giant planets are key to the mystery of the origin and evolution of the solar system and, by extension, extrasolar systems. Prevailing hypotheses of the giant planet formation include the core accretion model and the gravitational instability model, while the former is conventionally favored. At the heart of the classic core accretion model is the formation of a solid core of a critical mass of 10-15 Earth masses, followed by gravitational collapse of surrounding protoplanetary nebula that completes the formation of the planet. The core forms from agglomeration of grains of dust, refractory material, metals and ices and the volatiles they trap. The most volatile of the gases, hydrogen, helium and neon are captured last, gravitationally during the collapse phase. The atmosphere results from these gases and the volatiles initially trapped in and subsequently released from the core during accretional heating, and presumably mixed uniformly. The above formation scenario demonstrates that the core is critical to the formation of the giant planets, and that the well-mixed atmosphere is expected to reflect the composition of original elements. Since heavy elements (>4He) comprise much of the core mass, their determination is crucial to any model of the giant planet formation. The core accretion model predicts solar abundances of heavy elements, all relative to H. The Galileo probe measurements at Jupiter in 1995 changed all that. The probe revealed that the heavy noble gases, argon, krypton and xenon, were each enriched relative to solar by roughly a factor of two, whereas the enrichment factor was 4-6 for carbon and nitrogen and about 2.5 for sulfur. Thus, these heavy elements were found to be enriched relative to solar by a factor of 4(+/-2), and the enrichment factor is non-uniform. One missing element is oxygen, which is crucial since water ? the principal reservoir of oxygen in Jupiter ? was presumably the original carrier of the core-forming heavy elements and could make half of the core mass, or greater. The Galileo probe entered a five-micron hotspot ? the Sahara Desert of Jupiter ? where water vapor was severely depleted. O/H was measured to be 0.4x solar in this site. It is unknown whether water is depleted everywhere on Jupiter or enriched like the other heavy elements. The Juno microwave radiometers will measure and map water to deep tropospheric levels in Jupiter in July 2016. It is only then one could assess whether Jupiter is indeed carbon rich and oxygen poor like the exoplanet hot Jupiter WASP-12b, or not. Even after the inventory of key heavy elements has been completed for Jupiter, comparison with the other gas giant, Saturn, is essential. However, with the exception of carbon, no reliable data exist on other heavy elements for this planet or, for that matter, the icy giant planets, Uranus and Neptune. Considering the fundamental importance of this science, which only entry probes can deliver, the US NRC Planetary Decadal Survey (Visions and Voyages, NRC, 2011) has recommended a Saturn probe as one of four candidate missions in the New Frontiers class and a Uranus orbiter and probe as one of four candidate missions in the flagship class for the 2013-2023 decade. Relevant publications may be downloaded from www.umich.edu/~atreya for personal use.

キーワード: Giant Planets, Jupiter, Saturn, Juno, Entry Probes, Extrasolar Planets
Keywords: Giant Planets, Jupiter, Saturn, Juno, Entry Probes, Extrasolar Planets

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木星系探査ミッションESA-JUICE：日本チームの参加
Exploration of Jovian System by ESA-JUICE Mission: Participation of Japanese Team

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木星は地球の 300 倍の質量をもつ巨大ガス惑星で、強い磁場と磁気圏を持つ。ヨーロッパ宇宙機構 (ESA) の木星系探査ミッション JUICE が今年５月に選定された．エウロパ、カリストのフライバイ観測、木星観測の後、ガニメデ周回観測を行う．ガニメデは、太陽系最大の衛星で、氷を主成分とする天体でありながら自励磁場を保有する．中心部には溶融した金属コアがあり、さらには氷マントルの中に地下海が存在すると考えられている．太陽系外惑星で存在が議論されている氷惑星のモデルとしても、重要な存在である．

当初は、ヨーロッパと日本のコミュニティから開始した国際共同計画 LAPLACE にはじまり、アメリカが加わり EJSM という形を経て、木星系探査計画の議論を続けてきた．アメリカはエウロパ周回機、日本は磁気圏探査機を提供する計画であったが、実現にいたらず、ESA のガニメデ周回機が、エウロパフライバイ、高緯度観測のシナリオを加える形で、プロジェクトとして承認された．これが JUICE である．

ESA 側の機器開発候補グループからの誘いがあり、モデルペイロードに含まれる、以下の６機器の開発への参加が、ESA の機器応募 (10/15 〆切) に含まれた．結果は 2013 年 2 月に発表される予定である。機器が選定された場合は、ISAS/JAXA 理学委員会の審査を経ることで、ISAS/JAXA が開発資金支援を含めた主導的な枠組を作り、日本チームとして、木星系探査計画に参加する予定である．さらに新たな機器の提案、モデルペイロード以外の提案機器への参加、機器開発を伴わないサイエンス Co-I 参加を含めた、大きなチームの構成も視野に入れる．

＜固体惑星科学分野＞
〇レーザー高度計 Ganymede Laser Altimeter (GALA)
潮汐変形、回転変動計測によるガニメデ地下海検出、表層地形の生成機構
＜惑星大気科学分野＞
〇紫外線観測器 EUV/UV Grating Spectrometer (UVIS)
木星、衛星大気と周辺プラズマのダイナミクス解明
〇サブミリ波観測器 Submillimetre Wave Instrument (SWI)
氷衛星希薄大気の生成機構、直接風速観測による木星大気大循環構造の解明
＜磁気圏科学分野＞
〇プラズマ粒子観測器 CEPAGE HEP（高エネルギー電子・イオン）, ISATIS（低エネルギーイオン質量分析）
回転する巨大磁気圏である木星磁気圏（粒子）と衛星・衛星磁気圏の相互作用
〇中性粒子観測器 PEP/JNA
木星磁気圏内の物質輸送において衛星が果たす役割、ガニメデ磁気圏構造
〇プラズマ波動観測器 RPWI
木星磁気圏の高エネルギー粒子加速機構、磁気圏へのエネルギー供給

キーワード: 木星探査, 磁気圏, ガニメデ, エウロパ, 地下海, 氷衛星
Keywords: Jupiter exploration, magnetosphere, Ganymede, Europa, interior ocean, icy satellites

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Radio and Plasma Wave Investigation around Jupiter
Radio and Plasma Wave Investigation around Jupiter

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Future Jovian mission is now planned for 2020s.
One of its major objectives is the investigation of electromagnetic system connected and driven by Jupiter. Under the international collaborations, we have started the development for the small-sized radio sensor for this mission from 2011, by the aid of the Grant-in-aid of JAXA Payload Development etc.
We succeeded to establish the base technical elements for (1) light-weight rigid antenna with simple and reliable extension capability and (2) small-sized radiation-hard preamp with the highest sensitivity.

In any missions related to plasmas, electric field from DC to several 10s MHz has contributed to the remote-sensing and in-situ studies of dynamics and energetic interactions in the electromagnetic system, associated with remote optical measurements and in-situ particle and magnetic field sensors.
For the Jovian project, an Europe-USA-Japan joint team is formed for the plasma and radio wave studies. Especially in Jupiter, its radio wave is important as a remote sensing tool for the direct measurement of Jovian radio source regions distributing around the Jovian system, i.e., polar region, radiation belts, Io torus system, and Galilean satellites with thin atmospheres. We are involved for this team based on the high reputation of Plasma Wave Investigation (PWI) aboard the BepiColombo/MMO, and have developed the small-sized radio sensor package with antenna and preamp within the tightest resource limitations.

We investigated base technologies for (1) a 3-axial antenna with 2m length, extracting at the Earth orbit and can be kept during the long travel till the end of the mission on the orbit around Galilean satellite, and (2) a 3-axial preamp covering 10kHz-100 MHz with the highest sensitivity, enough radiation tolerance in Jovian environment, the hardest in the solar system, within the mass limit less than 200g. For the former, we established a simple extension mechanism based on the self-extracting thin BeCu and CFRP element, which is based on the combination of the key technologies in the SCOPE Z-axis antenna (STEM-type extension mechanism but with a complex motor system) and the sounding rocket antenna (self-extraction but with limited length, only 1 m). For the latter, under the collaboration with the IRF-Uppsala (Sweden) team, we established the key parts of the radiation-hard analogue custom IC technologies, in which the most difficult part was a relay in the package with high-impedance, small-sized, and high-reliability. In parallel, we also tested the high-sensitivity preamp BBM under the radiation hard condition, and proved that even in 200 krad the degradation of the noise level is only the twice, without critical linearity and sensitivity damages. In 2012, we are proceeding to the next phase, including the design of a backend receiver with direct sampling scheme with fast (100-125MHz) rad-hard A/D.

Since the small but reliable extension mechanism and electronics are not so much expensive, we can also consider the implementation to sounding rocket experiments. After the full establishment of this technology, we will be able to adopt it to any space radio and planetary missions in which the resource is very tight.

キーワード: 木星, 電波, 受信機, アンテナ
Keywords: Jupiter, Radio, Receiver, Antenna

PPS01-04 会場:201B 時間:5月21日 15:00-15:15

非熱的中性粒子観測器による木星探査
Measurement low-energy energetic neutral atoms around Jupiter's satellite

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We are proposing a measurement of low-energy (10eV-3keV) energetic neutral atoms around Jupiter's satellite especially Ganymede. 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. JNA is a part of PEP (Particle Environment Package) led by Swedish Institute of Space Physics, which was proposed as potential instruments onboard JUICE mission.

We will discuss current status of JNA.
Keywords: low-energy energetic neutral atoms, Ganymede, magnetosphere, remote observation

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EXCEED 計画と木星探査 (JUICE 計画）
The EXCEED mission and the next

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小型科学衛星 EXCEED が２０１３年夏に打ち上がります。１２月には、ハッブル宇宙望遠鏡と地上の大型望遠鏡との木星の共同観測も計画されている。この発表では、EXCEED 計画の全容、木星観測キャンペーン、今後の木星探査計画への参画について話をする。

キーワード: 極端紫外光, 木星, 木星探査計画 JUICE, 小型科学衛星 EXCEED, 惑星大気光
Keywords: EUV, Jupiter, JUICE, EXCEED, planetary airglow

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PPS01-06 会場:201B 時間:5 月 21 日 15:30-15:45

JUICE/SWI ミッション
The Submillimetre Wave Instrument (SWI) for JUpiter ICy moons Explorer (JUICE)

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The Submillimetre Wave Instrument (SWI) is an instrument proposed to form part of the scientific payload instruments for the JUpiter Icy Moons Explorer (JUICE) mission of the ESA's Cosmic Vision 2015-2025 program.

SWI is a very high spectral resolution (up to R=107), dual band (600 and 1200 GHz), sub-millimeter heterodyne instrument on the JUICE spacecraft, achieving 1000-2000 km spatial resolution on Jupiter's disk and 0.5-1 km on icy satellites. SWI will determine the composition, structure and dynamics of Io's atmosphere. On Europa, Ganymede and Callisto, SWI measurements will detect active regions, generally determine sources and sinks of the atmospheres, their interaction with magnetospheric plasma; the interaction of Ganymede's magnetosphere with the Jovian magnetosphere will be derived.

SWI has four scientific targets as fellow: 1) the Jovian system with particular emphases on the chemistry, meteorology and structure of Jupiter's middle atmosphere, and atmospheric coupling processes, 2) Characterize the regoliths, icy-crusts, atmospheres, and exospheres of Ganymede, Europa and Callisto, thereby providing important inputs for the exploration of their habitable zones, 3) Study Ganymede as a planetary object and possible habitat; study and explore Europa's young icy crust in recently active zones, 4) Explore the Jovian system as an archetype for gas giants in characterizing the Jovian atmosphere and its satellite and ring systems.

SWI will measure Three-Dimensional of temperatures, winds (with accuracy of ~10 m/sec) and chemical species (e.g. CO, CS, HCN, H2O, CH4) in Jupiter's stratosphere. The Icy moon measurement will be performed with water vapor, its isotope ratio, and ortho/para ratio in their tenuous atmospheres/exospheres. It will measure thermophysical and electrical properties of satellite surface/subsurfaces and correlate them with atmospheric properties and geological features. SWI will determine key isotopic ratios in Jupiter's and satellite atmospheres, especially the deuterium-to-hydrogen ratio, diagnostic of the formation and evolution of Jupiter's satellite system.

SWI is a instrument with a passive, heterodyne receiver for simultaneous observation in two submillimetre spectral bands, 530-601 GHz and 1082-1271 GHz. In combination with two high-resolution Chirp Transform Spectrometers (CTS), SWI obtains a resolving power v/dv of up to 107. The local oscillator is tunable to observe at any frequency within the bandwidth of the two receivers. SWI is equipped with a movable 30 cm telescope to change its viewing direction independent of the spacecraft orientation. In this presentation, the overview of the SWI mission will be introduced.

キーワード: 木星, 氷衛星, JUICE, SWI, sub-millimeter sounder, atmospheric dynamics
Keywords: Jupiter, icey moon, JUICE, SWI, atmospheric dynamics, sub-millimeter sounder

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JUICE-SWI が観測ターゲットとする木星大気成層圏の力学と物質循環
Dynamics and material transport of Jupiter's stratosphere as scientific targets of JUICE-SWI

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木星成層圏の大気科学について、欧州の JUICE ミッションに提案されているサブミリ波測器 (JUICE-SWI) により期待される観測的な貢献と絡めつつ、その概要を紹介する。

木星を初めとする巨大ガス惑星の大気は、惑星大気環境の形成・進化というものを地球型惑星大気とは異なった視点でより普遍的に理解して行く上で、また個々の惑星に特有の物理パラメーターを明示する上で、重要不可欠な研究対象である。さらには惑星科学が太陽系内の範疇を超えて 系外も含めた惑星大気を取り扱う日が今まさに近づきつつあるが、その過程で最初に理解が要求されるのは木星型系外惑星である。これは我々にとって最も身近な存在である木星大気の徹底的な理解なくして達成できるものでは無い。

木星の成層圏は可視の雲頂より上方 350km 以上に渡り広がっており、その領域の気圧は大体 10^3～10^{-3}hPa である。木星の自転角速度は地球よりも高速で、その力学過程は成層圏の大気分子による放射過程と対流圏上部で励起され上方に伝播する波動の影響を受けていると考えられている。最大 140m s^{-1} にも及ぶ高速の西風ジェットが北緯 23 度付近と北緯 5 度付近に見られ、準 4 年振動 (QQO) と呼ばれる赤道東西風が約 4 年周期で変化する現象も確認されている。また CS, CO, HCN の各微量物質については、1994 年のシューメーカー・レビー第 9 彗星に代表される外部天体の衝突による供給が示唆されている。水の存在も観測されているが、その起源を定量的に断定するには至っていない。

JUICE-SWI は、CH_4, H_2O, HCN, CO, CS といった木星成層圏に存在する微量物質を非常に高い感度で観測することが可能である。また CH_4 の吸収線より鉛直温度分布やドップラー風速を求めることも可能である。CO と CS は化学的に安定なため、大気の流れを見るためのトレーサーとして用いることができる。これらの観測を通して、木星成層圏の力学過程・化学過程の理解が進むことが期待される。

キーワード: 木星, 大気力学, 大気化学, サブミリ波サウンダ, JUICE
Keywords: Jupiter, atmospheric dynamics, atmospheric chemistry, sub-millimeter sounder, JUICE

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Geophysics of Ganymede as revealed by orbiter missions: application to the JUICE mission
Geophysics of Ganymede as revealed by orbiter missions: application to the JUICE mission

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As indicated by the Voyager and Galileo missions, Ganymede is a very complex world:
(a) Ganymede is highly differentiated. With a dimensionless moment of inertia of 0.3115 [1] it is the most condensed solid-state body of the solar system. The moment-of-inertia value is consistent with interior structure models including an iron-rich core, a silicate layer, high-pressure ice layers, a liquid water layer, and an ice-I layer at the surface. Based on the Galileo gravity field measurements a set of models with different thicknesses of the layers can be constructed (e.g., [2]). The process of differentiation would be accompanied by global extension of the satellite because ice is more compressible than rock.
(b) Ganymede has a magnetic dipole field. Together with the Earth and Mercury, Ganymede is one of only three solid bodies in the solar system that generate a magnetic field in a liquid (outer) iron core [3]. Therefore present temperatures and heat flows of the core and/or compositional gradients must be sufficient to sustain a dynamo.
(c) The magnetic field data is consistent with induced fields generated in an electrically conducting salty global ocean beneath the ice-I layer [4]. This provides strong evidence for a present subsurface ocean on Ganymede. The latter would have strong implications on the tidal response of the satellite.
(d) Ganymede is locked in the three-body Laplace resonance with Io and Europa. Although the forcing of Ganymedes orbital eccentricity of ef = 0.0006 is weaker as compared to Io and Europa, scenarios of formation of the resonance and its implications for tidal heating must be consistent with the satellites orbital evolution (e.g. [5]) and present state.
(e) Ganymedes icy surface consists of two types of terrain exhibiting differences in albedo, surface age (through crater density), and surface morphology (e.g., [6]). Whereas the dark terrain is several Gyrs old the light terrain can be as young as about ~400 Myrs. The different types of geologic activity may be a consequence of different energy budgets available from the interior during different regimes of thermal evolution.
(f) Ganymedes bright terrain globally shows intense fracturing and tectonic resurfacing. In addition there is local evidence for cryovolcanic activity.
(g) Ganymede displays a great diversity of impact morphologies. Those are related to the thermal state of the icy crust at time of the impact and temperature dependent relaxation processes.

Starting from various scenarios of Ganymedes evolution that have been discussed in the literature to explain the unique features of the satellite we describe measurements by orbiting spacecraft that could constrain these theories. Application to ESAs JUICE mission will be shown. Emphasis is given on the geophysical aspects, i.e. interior structure and tidal deformation. The models are set into perspective by comparison with the neighboring satellites Europa and Callisto. Prospects to investigate the geophysics of Europa and Callisto with flybys are briefly discussed.

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木星探査計画 JUICE 搭載レーザ高度計の国際共同開発
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 の搭載候補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，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 の基本設計，探査機構体とのインターフェース，検証計画は BELA 実績に基づいているが，当然，水星と木星の環境の相違は慎重に取り扱われなければならない．特に，放射線環境と低温環境が設計フェーズでの重点課題である．また，日本チームは反射光受信部を設計・製造して DLR に引き渡すが，測距データ処理系とのインターフェース，即ち Analogue electric 部と RFM の設計要求，を明確化することがもう一つの重点課題である．さらに，ESA の検証計画・受け入れ基準に合致させる準備が第三の重点課題である．日本チームでは手始めに初期熱設計を実施し，TRU 内の熱歪みと温度環境の評価を開始している．さらに探査機構体の外部に露出する望遠鏡部の放射線環境評価を行い，主鏡材料の選定とその熱歪み評価へと進んでいく予定である．

キーワード: 木星, ガニメデ, レーザ高度計
Keywords: Jupiter, Ganymede, Laser altimeter

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巨大氷衛星の進化と多様性
Evolution and diversity of the large icy moons

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Large icy moons in the solar system, Ganymede, Callisto, and Titan, have a similar size of Mercury but smaller bulk density (~2.0 g/cc) than the terrestrial planets, which indicates that the bulk composition is half water ice and half rocky material. However, there are quite different state on its surface and interior at present among these moons. Ganymede has globally-tectonic surface and completely differentiated interior having the central metallic core which generates the intrinsic magnetic field, while Callisto's surface is saturated by the impact craters, suggestive of an old age, and its interior seems to be incompletely differentiated which is implied by a large value of the moment of inertia factor. Titan has an intermediate size, density, and moment of inertia between Ganymede and Callisto, and has experienced some internally driven geology. Although many studies have proposed hypotheses explaining this contrasting states between the two moons, none of these theories has been sufficiently convinced.

We construct a new model for the evolution of large icy moons, especially in order to explain the origin of surface tectonics and strongly differentiated interior on Ganymede and the different current state and history between Ganymede and Callisto. That is, "Dehydration model" of primordial hydrous silicate and metal-mixed core so that only Ganymede undergoes significant temperature rise inside allowing the separation of a conductive core and the global tectonics during its history. This model assumes that during the stage of accretion rocky component is possibly hydrated because of the chemical reaction with liquid water generated by accretional heating. The similarity in reflectance spectra among hydrated carbonaceous chondrites and asteroids near Jovian orbit also implies that the constituent material of the icy moons has already been hydrated prior than their incorporation into circum-Jovian nebula in which the regular satellites accreted. After the end of accretion, primordial core starts to warm due to only the decay heating of long-lived radioactive elements. Once the dehydration starts to occur, the temperature of rocky core would increase more rapidly and exceed the melting point of the metallic component, and thereby metal segregates from rocky material. The difference of radiogenic heat and moon's size between Ganymede and Callisto may have potential to create the dichotomy between two moons.

In addition, applicability of this model is not limited to Ganymede and Callisto but extends to other similar-sized icy moons, e.g., Europa and Titan, and an implication for the "Super-Ganymede" exoplanets will be addressed. If extrasolar planetary systems are analogous to our own, then icy moons could be the most common habitats in the universe, probably much more abundant than Earth-like environments which require highly specialized conditions that permit surface oceans.

Finally, we will propose a possible contribution to the JUICE (Jupiter Icy Moon Explorer) mission, which is planned by ESA (European Space Agency) to visit the Jovian system and will launch in June 2022 on an 11-year mission to explore the giant planet and three of Jupiter's moons; Ganymede, Callisto, and Europa.

キーワード: 衛星, 熱史, 内部構造, 地形, 進化, 探査
Keywords: satellite, thermal history, interior, tectonics, evolution, exploration

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Formation Processes of Regular Satellites around Giant Planets
Formation Processes of Regular Satellites around Giant Planets

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Satellite systems around the giant planets in our solar system are commonly seen. They are thought to have formed in circum-planetary disks, which are believed to have existed around giant planets during their gas capturing growing stage.

In earlier works, the formation process of satellite systems has been considered based on a minimum mass subnebula (MMSN) model, in which satellites form from a disk that contains sufficient solid mass with solar composition for reproducing the current satellite systems (e.g., Lunine and Stevenson 1982), as an analog of the minimum mass solar nebula model (Hayashi 1981). However, it was suggested that the MMSN model has difficulty in reproducing current satellite systems around Jupiter and Saturn (Canup and Ward 2002). One of the severe problems is that the model leads to much higher temperature than that of H2O ice sublimation at the current regular satellite region, which means that ice, which is the main component of the satellites, cannot be used as building material of the satellites.

In order to overcome the difficulties of the MMSN-type models which assume a closed and static disk, alternative models have been developed. Canup and Ward (2002) proposed a model in which an accretion disk with a continuous supply of gas and solid is considered as a proto-satellite disk. This model reproduces ratio of total satellite mass to the parent planets' mass for Jupiter, Saturn, and Uranus.

Recently, Crida and Charnoz (2012) showed that if a massive ring around a giant planet exists, it spreads outward by radial diffusion, which could produce regular satellites. This model can reproduce satellite masses and orbital radius simultaneously for Saturn, Uranus, and Neptune.

In this talk, satellite formation processes mainly of the two major hypotheses will be reviewed.

Keywords: satellite, moon, Jupiter, giant planets

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Planetary tectonics: A new tool to judge the presence or absence of life on planets

Planetary tectonics: A new tool to judge the presence or absence of life on planets

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Concept of habitable planet has been suggested around 1965 to discuss the possibility of presence of life on planets, because liquid water is major component of life, which has a tight stability field of T<100 degrees depending on pressure. Discovery of icy satellites of Jupiter, which may contain water under the icy surface, pointed to the possibility of presence of life there. Titan has a landmass, which is partly occupied by methane lakes, enveloped by CH4-rich atmosphere. If the landmass comprises rocky materials and an energy circulation system, such discoveries would certainly change the original definition of habitable planet.

Here, we propose a new tool of planetary tectonics as an index for the presence of life on planets. The phenomenon of life is possible only where there is a steady-state supply of nutrients, as well as water circulation and thermal energy. If these conditions are not satisfied, life will terminate. Considering these conditions, the Earth has only two life-sustaining places: (1) the surface of the Earth fed by a climate driven by the Sun, and (2) endogenic-influenced aqueous environments, best exemplified by both continental lake environments, which interact with basement structures such as rift systems and associated hydrothermal systems (the structures serve as conduits for the migration of volatiles and heat energy often related to magma), and deep-sea hydrothermal systems driven by MORB magma (though the biomass at mid-oceanic ridge is 10-6 times smaller than that of the surface of the Earth; negligibly small when compared to the continental lake environments). Understanding planetary tectonic systems that can generate such environments is significantly important in the search for life beyond Earth, including providing an index not only for finding life in our Solar System but also extrasolar planets.

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Planetary Tectonic System (#1) and the Search for Life
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For life to initiate, diversify, and flourish, it requires a continuous nutrient supply, metabolism with continuous reactions to gain energy, and self-duplication. These conditions can be optimally met through a planetary tectonic system (PTS) that is composed of a nutrient-enriched continental landmass, an ocean, tectonic structures such as rift systems that act as conduits for the migration of volatiles and heat energy, and a sunlit planetary surface. This is realized through the evolution of the Earth, particularly in the case of the Cambrian explosion [1; also see Shingenori Maruyama, this conference]. The Cambrian explosion included a dramatic increase in the supply of nutrients and oxygen and resultant organic matter, including macroscopic hard-shelled animals that reached dimensions 1 million times larger than the Precambrian Eukaryotes.

The PTS to explain the Cambrian explosion is as follows [1, also see Shigenori Maruyama, this conference]: (1) the appearance of a landmass of nurtrient-enriched materials resulting from a drop in sea-level related to plate tectonism including subduction of hydrated slabs into the mantle, (2) the global distribution of the nutrient-enriched continental materials into the ocean through wind (aeolian erosion and deposition) and water (e.g., fluvial erosion and transport along river systems); winds, for example, transported fine-grained materials from desert regions to the oceans, feeding the plankton life along the surface of the open oceans, and (3) the interaction among deep-seated basement structures, magma, and continental lakes which collectively yield life-thriving, hydrothermal systems (considered prime habitable environments on Earth and Mars; [1,2]).

The delivery of enormous amounts of nutrients drove the burst of photosynthesis which resulted in an increase of free oxygen in the atmosphere and a rapid increase of organic matter. Knowledge of PTS provides the road map for the search for life beyond Earth [also see Dohm and Maruyama?Planetary tectonic system #2, this conference].

References

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