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

PPS01-01 Room:A03 Time:May 26 12:00-12:15

Numerical Modeling of Moist Convection in Jovian Planets

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It is now widely accepted that moist convection is a common phenomenon in Jovian planets' atmosphere. The moist convection is thought to play an important role in determining the mean vertical structure of the atmosphere; the mean vertical profiles of temperature, condensed components, and condensible gases in the moist convection layer is thought to be maintained by the statistical contribution of a large number of clouds driven by internal and radiative heating/cooling over multiple cloud life cycles. However, the averaged structure of the Jovian planets' atmosphere and its relationship to moist convection remain unclear. For the purpose of investigating the above problem, we developed a cloud resolving model and investigated a possible structure of moist convection layer in Jupiter's atmosphere with using the model (Sugiyama et al., 2009, 2011, 2014). In this presentation, we perform two-dimensional calculations of moist convection and demonstrate a possible structure in the atmospheres of Saturn and Uranus.

The basic equation of the model is based on quasi-compressible system (Klemp and Wilhelmson, 1978). The cloud microphysics is implemented by using the terrestrial warm rain bulk parameterization that is used in Nakajima et al. (2000). We simplify the radiative process, instead of calculating it by the use of a radiative transfer model. The model atmosphere is subject to an externally given body cooling that is a substitute for radiative cooling. Because the vertical profile of net radiative heating is not observed in Saturn and Uranus, the layer between 2 bar level and the tropopause, which corresponds to the observed cooling layer in Jupiter, is cooled. The body cooling rate is set to be 100 times larger than that observed in Jupiter's atmosphere in order to save the CPU time required to achieve statistically steady states of the model atmosphere. The domain extends 7680 km in the horizontal direction. The vertical domains of the planets are 480 km for Saturn's case and 650 km for Uranus' case. The spatial resolution is 2 km in both the horizontal and the vertical directions. The temperature and pressure at the lower boundary are based on the one-dimensional thermodynamical calculation (Sugiyama et al., 2006). As the first step of the experiments, the abundance of each condensable gas is set to be solar abundance.

In Saturn and Uranus, the obtained characteristic of vertical motion is that many narrow and strong downdrafts are found in the upper moist convection layer, while strong updrafts are found near the bottom of the moist convection layer that is associated with the H_2O lifting condensation level. This characteristic is obviously different from that obtained in Jupiter. The vertical motion in the whole moist convection layer of Jupiter is characterized by narrow, strong, cloudy updrafts and wide, weak, dry downdrafts. In Saturn and Uranus, the velocity of downdrafts is over 50 m/s, which is comparable to the updrafts, and the skewness of vertical velocity is negative in the upper moist convection layer. The skewness obtained in Uranus' case is the smallest, which indicates the downdrafts are more dominant in Uranus than in Saturn. The existence of strong downdrafts is caused by the following two reasons. One of the reasons is that convective motion is driven by not a heating from the bottom of the moist convection layer but a cooling layer near the tropopause ($0.1 < p < 2$ bar). Another reason is that the atmospheric temperature in the upper moist convection layer is colder than that of Jupiter. H_2O condensation occurs at lower level (high pressure level). The value of H_2O mixing ratio is almost zero and the effect of latent heat is very small in the upper part of the layer.

Keywords: atmosphere of Jovian planets, moist convection, numerical modeling, cloud resolution model

PPS01-02 Room:A03 Time:May 26 12:15-12:30

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

PPS01-03 Room:A03 Time:May 26 12:30-12:45

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.

Keywords: Jupiter, Stratosphere, Atmospheric radiation, Atmospheric dynamics, Gas giants, JUICE

PPS01-04 Room:A03 Time:May 26 14:15-14:35

Cassini-Huygens Mission Highlights: Discoveries in the Saturn System

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Cassini-Huygens exploration of the Saturn system has yielded 11 years of unprecedented discoveries, and answers to many scientific mysteries. Cassini's findings have revolutionized our understanding of Saturn, its complex rings, its amazing assortment of moons and the planet's dynamic magnetic environment. The robotic spacecraft arrived in 2004 after a 7-year flight from Earth, dropped a parachuted probe named Huygens to study the atmosphere and surface of Saturn's big moon Titan, and commenced making astonishing discoveries that continue today.

Among its many firsts, Cassini discovered cryovolcanic jets shooting from the south pole of the tiny moon Enceladus; found hydrocarbon lakes and seas on Titan that are dominated by liquid ethane and methane as well as complex pre-biotic chemicals form in the atmosphere and rain to the surface; provided multi-wavelength coverage of a giant northern storm, the first of its kind on Saturn since 1990; demonstrated that the Saturn Kilometric Radiation period does not reflect the planet's internal rotation; proved that Enceladus is the source of Saturn's E Ring and that its water dominates the magnetosphere; and constrained and complicated our understanding of the 3-dimensional structure and dynamics of multi-particle ring systems. Cassini's findings at Saturn have also fundamentally altered many of our concepts of how planets form around stars.

In just the last two years, Cassini discovered that: the majority of Titan's lakes and seas are located near the north pole and measured the depths of some of the seas; Enceladus harbors a subsurface ocean; a huge hurricane rages at Saturn's north pole; tidal stresses control Enceladus' particulate jets; plume activity is greatest near apoapse; the depth of Titan's Ligeia Mare is 150-200 meters; meteorite impacts, embedded propellers migrating inwards and outwards, and the effects of Saturn internal oscillations can be witnessed in the rings; Titan has a subsurface water ocean; interactions between a strong solar wind and Saturn's magnetosphere can help us understand supernovae shockwaves; and Titan's south polar haze is a seasonal phenomenon.

The Solstice Mission continues to provide fundamental new science as Cassini observes seasonal and temporal changes, and addresses new questions that have arisen during the mission thus far. The mission's grand finale occurs in 2017, with 22 inclined orbits between the innermost D ring and the upper portions of Saturn's atmosphere, enabling unique gravity and magnetic field measurements of the planet, unprecedented determination of the ring mass, some of the highest resolution measurements of the rings and Saturn, and in situ observations in a completely new region around the planet. Highlights from 11 years of Cassini's ambitious inquiry at Saturn will be presented along with the remarkable science that will be collected in the next three years.

Cassini-Huygens is a cooperative undertaking by NASA, the European Space Agency (ESA), and the Italian space agency (Agenzia Spaziale Italiana, ASI).

This work was carried out in part at the Jet Propulsion Laboratory, California Institute of Technology, under contract with NASA. Government sponsorship is acknowledged.

Keywords: Cassini, Saturn, Huygens, Rings, Titan

PPS01-05 Room:A03 Time:May 26 14:35-14:50

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.

Keywords: Planetary Science, Jovian Planet, Saturn, Cassini Mission, Atmosphere, International Cooperation

PPS01-06 Room:A03 Time:May 26 14:50-15:05

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.

Keywords: Titan, Hydrocarbons, Oceanography, Exploration Vehicles, Radar

PPS01-07 Room:A03 Time:May 26 15:05-15:25

JUICE: A EUROPEAN MISSION TO JUPITER AND ITS ICY MOONS

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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.

Keywords: Jupiter, Ganymede, Europa, Callisto, Magnetosphere

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Jupiter Icy Moons Explorer: JUICE

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JUICE is an ESA's L-class mission to Explore Jupiter Icy Moons. JUICE was mission adopted in November 2014. It will be launched in 2022, arrive at Jupiter in 2030 and be inserted into Ganymede orbit in 2032. The science objectives of JUICE is to understand (1) emergence of habitable worlds around gas giants and (2) Jupiter system as an archetype for gas giants. Three Japanese groups were selected to provide part of the three science instruments RPWI, GALA, and PEP/JNA. Two Japanese groups were also selected as science Co-I of two instrument groups JANUS and J-MAG. JUICE is the first mission for ISAS/JAXA to participate to foreign large science mission as a junior partner who will provide part of the science instruments. JUICE will observe Jupiter system from Jupiter orbit in order to understand Jupiter system as an archetype for gas giants. JUICE will make observation of 3 of the 4 Galilean satellites, Europa, Ganymede, and Callisto in order to understand the emergence of habitable worlds around gas giants. JUICE will be launched by Arian-5. The Dry mass of JUICE is about 1800kg and the fuel is about 2900kg. The required Delta-V is about 2700m/s. JUICE is a three-axis stabilized spacecraft with solar cell paddle of about 70m2 that will generate approximately 700W power. The mass and power allocated to science instrument is 104kg and 150W, respectively. X band and Ka band are used for satellite-ground communications. After 7.5 years of interplanetary transfer and Earth-Venus-Earth-Earth gravity assists JUICE will be inserted into an orbit around Jupiter in January 2030. JUICE will make observation of all the three Jupiter icy Moons that potentially have subsurface ocean under the icy crust. After inserted into Ganymede orbit in 2032, JUICE will make detailed observation of the largest Icy Moon in the solar system. Taking into account all the data to be obtained by 5 instruments that JUICE-JAPAN will participate, Japanese team will be able to contribute to most of the major science objectives relating with planet Jupiter (JANUS), Jupiter magnetosphere (PEP/JNA, RPWI, and J-MAG), and Icy Moons (GALA, J-MAG, and JANUS). JUICE-JAPAN Working Group (WG) was established in September 2013. JUICE-JAPAN WG submitted a proposal for ISAS/JAXA small project in February 2014. JUICE-JAPAN WG passed the MDR in September 2014. JUICE-JAPAN is now preparing for the SRR. After SRR, SDR is scheduled in the end of 2015, PDR is scheduled in 2016 and CDR is scheduled in 2017.

Keywords: Jupiter, Ganymede, Satellite Exploration

PPS01-09 Room:A03 Time:May 26 15:40-15:55

Outer Planet Exploration by the Solar Power Sail: Cruising Observation and In-situ Investigation of Jupiter Trojans

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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.

Keywords: Solar Power Sail, Cruising Observation, Jupiter Trojan Asteroids, Surface Exploration, In-situ Mass Spectrometry, Sample Return

PPS01-10 Room:A03 Time:May 26 16:15-16:30

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

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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.

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

PPS01-12 Room:A03 Time:May 26 16:45-17:00

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.

Keywords: Europa, Icy Worlds, Astrobiology, Habitability, Outer Planets, Microfracturing

Japan Geoscience Union Meeting 2015
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PPS01-13 Room:A03 Time:May 26 17:00-17:15

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.

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PPS01-14 Room:A03 Time:May 26 17:15-17:30

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

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[1]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA

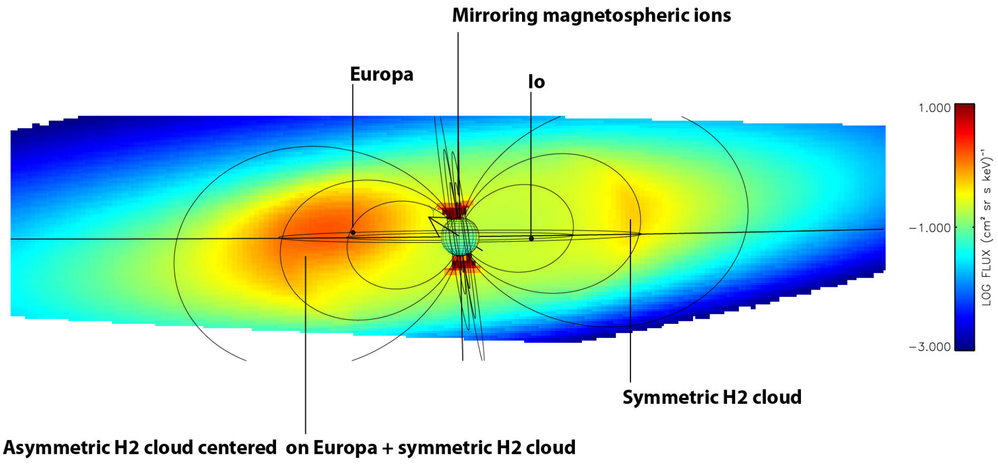
The Jupiter Energetic Neutrals and Ions (JENI) Camera is one out of six sensors of the Particle Environment Package (PEP) suite that was selected for flight on the ESA Jupiter Icy Moon Explorer (JUICE). JENI is a combined imaging energetic ion spectrometer and an ENA camera that operates in the ~0.5 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 $\leq 2^{o}$ 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.

Keywords: Europa, Jupiter, Torus, Magnetosphere



Japan Geoscience Union Meeting 2015
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PPS01-15 Room:A03 Time:May 27 09:00-09:20

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.

Keywords: Planet, Satellites, Formation

PPS01-16 Room:A03 Time:May 27 09:20-09:40

The Juno Mission and the Role of Earth-Based Supporting Observations

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The Juno spacecraft was launched in 2011 and passed close to the Earth for a gravity assist in 2013. It will reach Jupiter in July of 2016 and enter orbit around Jupiter, with the first of over thirty highly elliptical polar orbits whose periapsis distances are inside the radiation belts. The purpose of the mission is to determine the abundance and distribution of water in the deep atmosphere of Jupiter, map the close-in gravity field, and map the electromagnetic environment over all longitudes. These investigations will determine the structure, composition and dynamics of the interior of Jupiter. It will relate features that are easily detectable in the exterior of Jupiter to movement in the deep interior. Understanding these processes will provide clues to formation and evolution of Jupiter, providing insight into the formation of giant planets in general. The complement of scientific instruments on board Juno consists of in-situ instruments that measure the electromagnetic environment of Jupiter and remote-sensing instruments that cover a broad, but incomplete, spectral range. The Ultraviolet Spectrometer (UVS) will cover 70-205 nm, the Juno IR Auroral Mapper (JIRAM) will cover 2-5 μm, and the Microwave Radiometer (MWR) will cover 1.3-50 cm. In addition, a public-outreach camera, JunoCam, will produce images in broad-band red, green and blue filters, together with a narrow-band 890-nm filter centered on a CH_4 gaseous absorption feature. Juno will make over thirty orbits of Jupiter, but remote sensing will only be a priority on orbits 1 and 3 through 8, although the instruments will remain functioning during the remaining gravity-sensing orbits. The mission will benefit from substantial levels of Earth-based support. Spectral ranges not covered by remote-sensing instruments contain valuable information. JunoCam will not produce calibrated imaging, and so a broad range of narrow-band and spectroscopic information at wavelengths of 0.3-2.0-μm would provide information on cloud properties in the troposphere. Near-infrared high-resolution spectroscopy will supplement JIRAM by providing sensitivity to lines of minor constituents that serve as tracers of vertical winds. No Juno instrumentation will cover infrared wavelengths greater than 5 μm (the mid-infrared), which provide direct information on temperature structure and the distribution of trace gases in both the troposphere and stratosphere, as well as cloud properties in the upper troposphere (pressures of 1 bar or less). Another key element of support will be the need to supply the spatial context for remote sensing instruments that will have pole-to-pole latitudinal coverage but only in strips that are 5 to 10 degrees in longitude. Equally important during this period will be observations of changes in time, both to monitor the history and evolution of features that fall into the remote-sensing coverage of Juno as well as to determine velocity fields around features. Prior to solar conjunction in mid-2016, it will be important to assess the extent and lifetime of features that might be captured in the coverage of the atmosphere, e.g. the Great Red Spot, Oval BA, brown barges or other cyclonic features, and blue-gray regions that are associated with clear and dry atmospheric conditions. This assessment will inform the precise timing of the orbit-reduction maneuver in order to increase the probability of measuring any of these features of interest around close passes with Jupiter. We are soliciting both professional and amateur observations, with the author serving as the point of contact for input. Support for this work was provided by the Juno Project through an award from the National Aeronautics and Space Administration.

Keywords: Juno, Jupiter, imaging, spectroscopy, astronomy

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PPS01-17 Room:A03 Time:May 27 09:40-09:55

Solar UV/EUV response on Jovian thermosphere and radiation belt

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

[1]Tohoku Univ., [2]Research Institute in Astrophysics and Planetology

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.

Keywords: Jovian radiation belt, Jovian thermosphere, Infrared spectroscopic observation, Radio interferometric observation, Solar UV/EUV response

Japan Geoscience Union Meeting 2015
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PPS01-18 Room:A03 Time:May 27 09:55-10:10

Summary of Hisaki observation during one-year and the next

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

[1]University of Tokyo, [2]EXCEED Mission team

The Sprint-A satellite with the EUV spectrometer (Extreme Ultraviolet Spectroscope for Exospheric Dynamics: EXCEED) was launched in September 2013 by Epsilon rocket.

Now it is orbiting around the Earth (954.05 km x 1156.87 km orbit, the period is 104 minutes) and has performed a broad and varied observation program for 1-year.

With an effective area of more than 1cm2 and well-calibrated sensitivity in space, the EUV spectrometer produces spectral images (520-1480 A) of the atmospheres/magnetospheres of solar planets (Mercury, Venus, Mars, Jupiter, and Saturn) from the earth-orbit.

Continuous 3-month measurement for Io plasma torus and aurora of Jupiter was conducted with HST to witness the sporadic and sudden brightening events occurring on one or both regions.

For Venus, Fourth Positive system of CO and some yet known emissions of the atmosphere were identified.

Mercury, Saturn,and Mars were also observed. Summary of 1-year observation will be presented.

Keywords: HIsaki, EUV, Planetary airglow, Solar planets

Japan Geoscience Union Meeting 2015
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PPS01-19 Room:A03 Time:May 27 10:10-10:25

Dynamics of Jupiter's auroral acceleration investigated by multi-wavelength plasma remote sensing with space telescopes

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] ; HST, Cycle 20 go 13035 team[1] ; CXO, Cycle 15 go 15100276 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 Room:A03 Time:May 27 10:25-10:40

Solar wind influence on Jupiter's inner magnetosphere found by HISAKI/EXCEED

MURAKAMI, Go[1*] ; YOSHIOKA, Kazuo[1] ; KIMURA, Tomoki[1] ; YAMAZAKI, Atsushi[1] ; TSUCHIYA, Fuminori[2] ; KAGITANI, Masato[2] ; TAO, Chihiro[3] ; YOSHIKAWA, Ichiro[4] ; FUJIMOTO, Masaki[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 Room:A03 Time:May 27 11:00-11:15

EUV observation for Jovian inner magnetosphere

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.

Keywords: EUV, Jupiter, magnetosphere

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PPS01-22 Room:A03 Time:May 27 11:15-11:30

Local electron heating around Io observed by the HISAKI satellite

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.

Keywords: Jovian magnetosphere

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PPS01-23 Room:A03 Time:May 27 11:30-11:45

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.

Keywords: Radioastronomy, Saturn, Aurora, Magnetosphere, Cassini

PPS01-P01 Room:Convention Hall Time:May 26 18:15-19:30

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.

Keywords: Jovian System, Subsurface Ocean, Habitable zone, Icy satellites

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PPS01-P02 Room:Convention Hall Time:May 26 18:15-19:30

Development of JUICE/Ganymede Laser Altimeter (GALA)

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"Is there a life elsewhere in the universe?" It is a fundamental question deeply rooted on intelligence of human beings. And a clue of this question may be found on Ganymede. After magnificent achievements of Galileo and Voyager missions, an existence of thick liquid water layer, namely subsurface oceans under icy crust, has been implied for three icy satellites of Jupiter, Ganymede, Europa, and Callisto. And water in liquid state is thought to be a necessary condition for emergence of life in the field of astrobiology. The evidence of ocean, however, is not widely accepted, because it depends on an inferences of electromagnetic observation and surface morphology. Looking for new evidences and clues for these important issues, a new mission to Jupiter system is planned by European Space Agency. It is the Jupiter Icy Moon Explorer (JUICE). 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.

Ganymede Laser Altimeter, GALA, is one of model payloads and measures distance between the spacecraft and the surface of the satellite from time of flight of laser pulse. By taking positions of the spacecraft and mass center of the satellite, surface topography of the satellite is calculated from measured distances. The GALA data are particularly important for finding of internal ocean. First, if the ocean exists beneath icy crust, tidal deformation of the satellite is so large that temporal variation of the topography as great as several meters is expected. Second, small eccentricity of orbit of Ganymede causes libration that will be observed as lateral shifts of footprint of laser beam at the surface. And third, improved determination of spacecraft orbits by cross over analysis results in precise estimate of low degree harmonics of gravity field. Thus accurate Love number will be calculated to infer internal density structure of the satellite.

Global topographic data derived by GALA are also important for the study of tectonic history at the surface, elastic and viscous structure of ice crust, and thermal evolution of interior of the icy satellite. For example, linear structures such as ridges and grabens reveal extension stresses due to past variation of thermal states. As well, flat surface and thin crust may indicate partial melting of the crust and consequent subsurface lake. These observations on various geologic activities lead to new understanding of transport of heat and materials from inside to the surface of the satellite. Further, a comparison of styles of tectonics of ice crust and that of silicate lithosphere will likely shed a new light on theory of plate tectonics of the Earth.

GALA is developed by international collaboration of scientists and engineers in Germany, Switzerland, Spain, and Japan. The conceptual design is based on the laser altimeter on board of BepiColombo consisting of transceiver unit (TRU) with laser optics and appropriate electronics, electronic unit (ELU) with digital range finder module, digital processing module and power converter module, and laser electronic unit (LEU) with laser control electronics. Japanese team takes receiver telescope, its back-end optics, detector, and analogue electronics of TRU. The transmission optics of TRU and LEU are developed at DLR in Germany, and ELU is developed at Bern University in Switzerland. Assembly and integration are conducted at DLR.

The initial designs of analogue electronics and receiver telescope including back-end optics have been examined. A main mirror of the telescope will be 300 mm in diameter and be made of aluminum with gold coat. The same detector as those of BELA, Hayabusa, and Kaguya will be taken. Structural and thermal analyses are currently undertaken.

Keywords: Ganymede, Icy satellite, Planetary exploration, Laser altimeter

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

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Ganymede Laser Altimeter (GALA) is scheduled on board JUICE mission by ESA to be launched in 2022. GALA will be developed and manufactured jointly by teams of Germany, Japan, Switzerland, and Spain. Japanese team is responsible for a receiver unit out of GALA instrument; a receiver telescope, a backend optics (BEO), a focal plane assembly (FPA) accommodating an APD sensor module and an analog electronic module (AEM).

Return laser pulse from the target body is collected by the receiver telescope and is fed into the following BEO. The BEO focuses the return light on the surface of an APD sensor contained in an APD module. For APD as optical sensor, we adopted a product of Excelitas Technologies Corporation that has a lot of experiences in space laser altimeter. The APD sensor is mounted on a hybrid IC of the APD module including a trans-impedance amplifier (TIA) for signal readout in a wide band width as 120MHz, a thermos-sensor for measurement of the APD sensor temperature and a thermoelectric (TE) cooler for control of the APD sensor temperature to stabilize the temperature as 25 deg-C or so. The APD sensor has an enhanced quantum efficiency of up to 40% at 1060 nm. APD typically has a large temperature dependency of gain. The APD module is equipped with TE cooler and the TE cooler is capable to control the temperature of APD precisely. Two redundant optical fibers are attached to the FPA so that a part of transmitted laser pulse generated in Laser head Module (LHM) is introduced to the APD sensor.

The TIA in the APD module outputs voltage signals corresponding to the input light pulses. The voltage signals are fed into the AEM. The transmitted pulses introduced from LHM are attained not to overshoot by a programmable amplifier in the AEM because the following part of analogue signal processing circuit in AEM is to be tuned for signals returned from the target body which are much smaller than the introduced laser pulses. Signal waveform from the introduced laser pulse to the received return pulse is converted to digital data by analogue-to-digital conversion (ADC) circuit and digitized waveform are transmitted to a range finder module (RFM). In RFM, the digital waveform with the transmitted pulse and the received pulse are filtered to optimize signal-to-noise ratio by "matched filter" and the timings of both pulse are detected for ranging and also the width and height of the received pulse can be identified more precisely.

In our poster presentation, the current development status of the optical sensor and analogue module of GALA will be reported.

Keywords: JUICE, GALA, Laser altimeter, APD, Ganymede, analogue signal processing circuit

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JUICE-GALA : Design of receiver telescope and related optics

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Ganymede Laser Altimeter (GALA) is scheduled on board JUICE mission by ESA to be launched in 2022. GALA will be developed and manufactured jointly by teams of Germany, Japan, Switzerland, and Spain. Japanese team is responsible for receiver telescope, backend optics (BEO), APD detector, and analog electronic unit.

Receiver telescope is Cassegrain type reflector whose aperture is 250mm or 300mm, which collects laser echo pulses from Ganymede's surface and guides to APD detector through backend optics (BEO). Telescope's field of view is 450μrad which covers laser beam expansion angle (100μrad.) and reduces noise signal to APD as small as possible. We have designed 300 mm aperture model in which distance between primary and secondary mirror is less than 160mm using Code V software. In parallel we compared two types of BEO using Code V again and confirmed both types satisfy GALA specification; one type of BEO is comprised of 1 folding mirror and 2 convex lenses and the other is comprised of 2 concave mirrors. The narrow band filter for laser echo (wavelength 1064nm; band width 8nm) is also confirmed available from a Japanese optics manufacturer. Primary and secondary mirrors and supporting structures will be fabricated of aluminum to realize athermal property and surfaces of two mirrors will be sputtered of gold to enhance total throughput of telescope. Thermal vacuum and radiation tolerance test of gold sputtered aluminum samples, filter material, and BEO elements is an important issue and will be conducted within 2015. It is also a critical issue how to establish the way to realize accurate alignment between laser transmitting telescope (German side) and receiver telescope (Japanese side).

Practically, GALA optical system cannot be determined by only optical design itself because it is closely related or depending on weight resource management and results of thermal or structural investigation of GALA. In our poster presentation the newest development status of GALA optical system will be reported.

Keywords: JUICE, GALA, telescope, BEO, Ganymede, athermal

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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.

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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.

Keywords: Oxygen isotope, Submillimeter-wave, SWI

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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

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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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Keywords: Icy Satellites, The Mixing Length Theory, The Thermal Stress, Phase Transition, surface feature

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Horizontal and vertical structures of Jovian IR aurora emission observed by SUBARU / IRCS

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We will report the horizontal and vertical structures of Jovian infrared (IR) aurora observed by SUBARU 8.2m telescope in Feb. 2014 and Jan. 2015. In these observations, we used Adaptive Optics (AO) and achieved high spatial resolution (~170km). This makes it possible to analyze not only horizontal profile but also vertical one (scale height: ~200-400km) of Jovian IR aurora. These observations were held in a framework of Jupiter observation campaign simultaneous with Hisaki/EXCEED.

Jovian magnetosphere, ionosphere and thermosphere are coupled (MIT coupling system) by electric current that generated by fast Jovian rotation. Upper atmosphere extracts the dynamical energy to the magnetosphere through the collisions of neutral and plasma atmospheres and it drives magnetospheric plasma. Such magnetospheric energy is back to the upper atmosphere as electrical current and aurora electrons that causes UV aurora. By these interactions, upper atmosphere is heated and thermally excited H3+ and H2 emit IR aurora. Past K-band spectroscopy showed the different horizontal distributions of H3+ and H2 aurora [Raynaud et al., 2004; Uno, 2013]. In previous emission models of H3+ and H2 lines, it could be originated from the different source altitudes (H3+ from higher and H2 from lower). But our SUBARU/IRCS observation on Dec. 2011, the first Jovian IR spectroscopy with AO, found that H3+ and H2 emissions have similar altitude profile (H2 peaks at 590-720km, H3+ peaks at 680-900km)[Uno et al., 2014]. This is not agreed with past explanations by the altitude difference.

For further pursuit, we performed Jovian IR aurora observation on 13-14 Feb. 2014 and on 30-31 Jan. 2015 by the SUBARU/IRCS (R~10,000) with AO. The former, we observed southern hemisphere and the latter, we observed both hemispheres. While AO was active, we set the slit along the rotational axis to cross the aurora oval vertically. While AO was not active (when Galilean satellites were not at suitable positions), we set the slit along and over the aurora oval to avoid the effect of sliding off of the FOV. At the same time, we took the image of the H3+ in fundamental (v=1-0) line. We acquired the emission lines of H3+ fundamental in L-band (3.2-4.0 um) and H3+ overtone (v=2-0), hot overtone (v=3-1) and H2 (S1) in K-band (2.0-2.4 um) at the same time each in good weather condition. Those enable us to discuss compare spatial distribution, relative intensity and spatial-temporal variations with high accuracy. During this observation, Hisaki/EXCEED tracked Jovian UV aurora emission from the north pole and acquires the information of the flux and energy of precipitating electrons. We try to analyze considering this information.

We have been analyzing the observation data in Feb. 2014 and get follow results (1) H2 emission has lower contrast than H3+ emission at the main oval, (2) the peaks of H2 and H3+ exist similar altitudes. Recently, we try to find out the cause of structures problems by comparison of the horizontal and vertical temperature profiles derived from H2 and H3+ emission.

And we try to H3+ L-band / K-band comparisons about the emission structures and intensities of those for the first time using the fine datasets in Jan. 2015. H3+ is generated through the collisions of precipitating electrons and H2. Since the highly energetic electron can penetrate deeper into the atmosphere, H3+ density and emission intensity may include the information of precipitating electron energy. A theory says that the L-band lines from lower energy states come from lower altitude at lower temperature region than K-band lines from higher altitude at higher temperature region. Using our observation data and Hisaki/EXCEED data, we examine the L-band / K-band emission intensity ratio and response to the precipitating electron energy.

Keywords: Jupiter, aurora, Infrared, spectroscopy

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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.

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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.

Keywords: Hisaki, Saturn, neutral oxygen, Enceladus neutral torus