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 H2O 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. H2O condensation occurs at lower level (high pressure level). The value of H2O 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

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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 ($\sim10^8$ 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

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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

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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

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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

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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.

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
(May 24th - 28th at Makuhari, Chiba, Japan)

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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(May 24th - 28th at Makuhari, Chiba, Japan)

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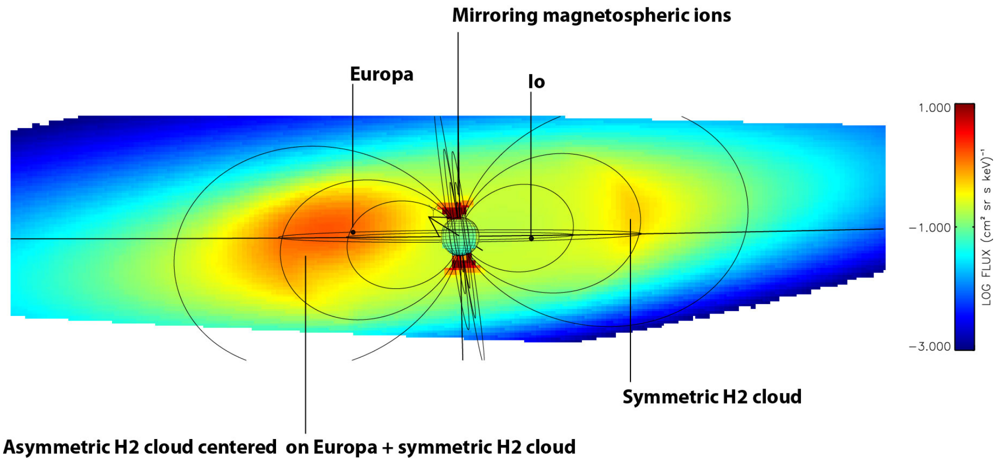
The Jupiter Energetic Neutrals and Ions (JENI) Camera is one out of six sensors of the Particle Environment Package (PEP) suite that was selected for flight on the ESA Jupiter Icy Moon Explorer (JUICE). JENI is a combined imaging energetic ion spectrometer and an ENA camera that operates in the ~0.5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

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

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

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

Keywords: Europa, Jupiter, Torus, Magnetosphere



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]

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

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

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

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

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

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

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 specical 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

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]

[1]Planetary Plasma and Atmospheric Research Center, Tohoku Univ., [2]ISAS/JAXA, [3]National Institute of Technology, Kagoshima College, [4]Graduate school of Science, Tohoku University, [5]Department of Complexity Science and Engineering, Univ. of Tokyo

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

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