Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

PCG38-01 Room:423 Time:May 1 09:00-09:15

Surface zonal flows induced by thermal convection in rapidly rotating thin spherical shells

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Surface flows of Jupiter and Saturn are characterized by the broad prograde zonal jets around the equator and the narrow alternating zonal jets in mid- and high-latitudes. It is not yet clear whether those surface jets are the result of fluid motions in the ”shallow” weather layer, or they are produced by convective motions in the ”deep” region. ”Shallow” models consider atmospheric motions driven by the solar differential heating and the intrinsic heat flow from the deeper region under the assumption of hydrostatic balance in the vertical direction as a result of the thin atmospheric layer compared with the radius of the planet. These models can produce narrow alternating jets in mid- and high-latitudes, while the equatorial jets are not necessarily prograde. On the other hand, ”deep” models, which describe thermal convection in rapidly rotating spherical shells whose thickness is comparable to the radius of the planet, can produce equatorial prograde flows easily, while it seems to be difficult to generate alternating jets in mid- and high-latitudes.

Recently, Heimpel and Aurnou (2007) proposed thin spherical shell models and show that the equatorial prograde zonal jets and alternating zonal jets in mid- and high-latitudes can be produced simultaneously when the Rayleigh number is sufficiently large and convection becomes active even inside the tangent cylinder. However, they assume eight-fold symmetry in the longitudinal direction and calculate fluid motion only in the one-eighth sector of the whole spherical shell. Such artificial limitation of the computational domain may influence on the structure of the global flow field. For example, zonal flows may not develop efficiently due to the insufficient upward cascade of two-dimensional turbulence, or stability of mean zonal flows may change with the domain size in the longitudinal direction. In the present study, we perform numerical simulations of thermal convection in the whole thin spherical shell domain while coarse spatial resolution and slow rotation rate compared to Heimpel and Aurnou (2007) are used due to the limit of computational resources.

We consider Boussinesq fluid in a spherical shell rotating with constant angular velocity. The non-dimensionalized governing equations consist of equations of continuity, motion, and temperature. The non-dimensional parameters appearing in the governing equations, the Prandtl number, the Ekman number, the modified Rayleigh number, and the radius ratio, are fixed to 0.1, 10^{-4}, 0.05, and 0.75, respectively. The initial condition of the velocity field is state of rest and that of the temperature field is conductive state with random temperature perturbations. After time integration for 35000 rotation period, kinetic energy is saturated and statistically steady state seems to establish. Obtained velocity field satisfies Taylor-Proudman theorem; it is almost uniform in the direction of the rotation axis. An equatorial prograde surface zonal jet emerges in the region outside the tangent cylinder. In the inside of the tangent cylinder, the surface zonal flows are retrograde, but eastward spike features appear near the tangent cylinder in low latitudes. Correspondingly, coherent small scale convective motions exist in these latitudinal zones. It is expected that these convective motions excite topographic Rossby waves which remove westward angular momentum from these zones, producing eastward spike features. This mechanism may explain the origin of the strong thin jet at about 25 degrees north observed on the surface of Jupiter.

Acknowledgement : Numerical computations were carried out on the Earth Simulator (ES2) at the Japan Agency for Marine Earth Science and Technology.

Reference : Heimpel, M., Aurnou, J. (2007) Icarus, 187, 540–557.

Keywords: atmospheres of the gas giant planets, banded structure, equatorial prograde jet, Rossby waves, Jupiter, Saturn

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PCG38-02 Room:423 Time:May 1 09:15-09:30

Numerical modeling of Cloud-level Convection in Venus Atmosphere

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Cellular convection has long been thought to occur in the cloud layer of Venus, because some evidences for convection are obtained from radio occultation and spacecrafts data. However, the convective structure in the cloud layer is still unclear. Some numerical studies are performed to examine convective structure of the cloud layer (Baker et al., 1998, 2000, Imamura et al., 2014), but the domain of the model atmosphere in their numerical experiment is two-dimensional. In this presentation, we perform three-dimensional numerical calculation of convection using the same settings of Baker et al. (1998) in order to investigate a possible three-dimensional structure of convection in the cloud layer in statistically steady state.

The numerical model used in this paper is a cloud resolving model that is mainly used to simulate moist convection in Jupiter's atmosphere (Sugiyama et al., 2009, 2011, 2014), but condensation and chemical reaction are not considered in this experiment. The same sub-grid turbulence and radiation processes of Baker et al. (1998) are included in our model. The settings of the experiment are also based on those of Baker et al. (1998). In these settings, the altitudes of the lower and upper boundaries are 40 km and 60 km levels, respectively, and the layer between 48 km level and 55 km level is almost neutral.

The vertical motion obtained in our numerical experiment is characterized by wide, weak, warm updrafts and narrow, strong, cold downdrafts. This qualitative characteristic of convective motion is consistent with that obtained in Baker et al. (1998). The maximum velocity of downdrafts is about 10 m/s, while the mean vertical velocity is about 3 m/s. The downdrafts are driven by the cooling caused by the turbulent diffusion above the neutral layer and thermal flux at the upper boundary. The horizontal cell size is about 20 km, which is somewhat smaller than that of observed typical cloud-top cells in ultraviolet images; the sizes of the observed cells are typically 100-200 km and in some cases a few tens of kilometers across.

Keywords: Venus atmosphere, convection, numerical modeling

PCG38-03 Room:423 Time:May 1 09:30-09:45

Convectively-generated gravity waves on Mars and their influence on the upper atmosphere

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Gravity waves in the Martian atmosphere have been identified through various observations. The sources of the waves are still unclear, although topographically-generated gravity waves have been studied using regional models and incorporated into Mars GCMs with parameterizations. Here we investigate convective generation of gravity waves on Mars using a two-dimensional regional model based on the non-hydrostatic meteorological model CReSS. The heating source of the convection model is considered a horizontally-uniform heating of the atmosphere near the surface by sunlight and a localized heating caused by absorption of sunlight by dust clouds. The results show that tntense convection is generated as a result of a thin atmosphere, leading to generation of short-period, large-phase velocity (both in horizontal and vertical) waves. Such waves can reach high altitudes without serious dissipation; the horizontal wavelengths and the amplitudes of the gravity waves reproduced in the lower thermosphere are consistent with the density fluctuations measured during aerobraking experiments. The waves attain saturation amplitudes above ~80 km altitude.

We further investigated the properties of vertical propagation and dissipation in the thermosphere using linear wave solutions based on the wave parameters observed in the convection experiment. Gravity waves reaching the thermosphere are damped by molecular diffusion and heat the atmosphere. The vertical profile of the heating rate shows two maxima: the lower one is located near the altitude where the amplitude peaks, and is generated by the sensible heat flux divergence, and the upper one is generated by the viscous dissipation of kinetic energy. These heating rates are comparable to other dominant processes such as EUV heating.

Keywords: Mars, gravity wave, convection

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PCG38-04 Room:423 Time:May 1 09:45-10:00

A proposal of Martian dust devil observation by combination with eletromagnetic and acoustic wave measurements

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Mars 2020 rover is planned to launch by NASA in 2020, as the almost same package of the Mars Science Laboratory (named Curiosity after its successful landing in August 2012). The announcement of opportunity (AO) for scientific/technology payloads to be onboard the NASA Mars 2020 rover was called for to the scientists community in world wide in September 2013. Here, we introduce our proposed instrument designed for electromagnetic (EM) and acoustic wave (AW) measurements that have never been operated on Mars.

Low-frequency EM and AW are important for monitoring atmospheric events because of their long-distant propagating characteristics more than 1000 km. Electrical discharges could be a hazard for instruments and future human activities on Mars, hence it should be treated as one of the strategic knowledge gaps (SKGs) for future missions. Our concept is that combining EM and AW measurements, precise distance information of dust storms and/or dust devils can be obtained by using two independent velocities of light (c) and sound (Cs) because discharges could be generated by electro-static processes in low-pressure dusty atmosphere and the process also generates shock waves in acoustic/infrasonic pressure wave range. Moreover, wind roaring sound, shock waves by meteors entries, and operational sounds by rover itself will be recorded as the world first "Martian sound."

Our EM and AW detection system consists of antennae, microphones, and common receiver circuits with on-board software. For E-field detection, a legacy monopole of 10 cm will be used as a vertical antenna. Two orthogonal loop antennae should be applied for B-field with direction-finding system. However, instead of pop-up devices, these 3 antennae will be compressed into a fixed 10 cm cubic antenna to be equipped on rover surface. Although a legacy receiver circuit can be used, we can minimize it into a postcard size by applying a newly-developed chip device. Analyses of EM and AW for monitoring discharges can be operated by on-board software to reduce data volume. Similar software is used in GLIMS operated on JEM-Kibo/ISS, where only the most significant events will be sent to the Earth in priority basis.

EM sensing in the Martian atmosphere is significant for the future human exploration on Mars. Although the environment on Martian surface is too severe to survive even in fair climate condition, human activities on Mars is obviously dangerous especially when it is under the storm-like condition. Thus, dust devils on Martian surface are significant for the future human exploration, especially, electrostatic discharge events could be serious hazards for astronauts as well as for Martian base facilities. However, the EM condition on the Martian surface has never been measured in detail. Hence, we consider the remote-sensing of the dust devils and discharge events from a single site on Mars with simple sensors could be a potential instrumentation.

Here, as a proposal to the NASA 2020 AO, we introduce one of the most promising remote-sensing methods for dust devils and discharge events by using a combination of EM and AW. According to its rarefied atmospheric pressure condition on Martian surface, about 1/100 of the Earth's surface, dust particles can easily be flown up by surface wind then could effectively produce charged particles by convection. Based on previous studies on the Earth, such charged particles possibly produce discharge events. Drastic changes in EM fields can be observed even at far-distant observatory, more than 1000 km away from the exact coordinates of discharges. AW also could be a remote-sensing method when there exists the atmosphere. Especially, low frequency AW less than 1 Hz can propagate for long distance more than 100 km even in the rarefied atmosphere. If we use two independent velocities of light (for EM) and sound (for AW), we can identify source coordinates of every discharge events within a few tenth km.

Keywords: Mars, electromagnetic wave, acoustic wave, discharge, dust devil, lander

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PCG38-05 Room:423 Time:May 1 10:00-10:15

Observation of a few months temporal variability of UV brightness in Venus with Pirka telescope

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The superrotation, which is a phenomenon that Venusian atmosphere moves westward at a velocity 60 times faster than the planetary rotation, is a unique atmospheric system of Venus. There are several theories to explain what drive the superrotation, but it is still unknown. Yamamoto and Tanaka (1997) suggested that the Kelvin wave in equator and the Rossby wave in mid-latitude, which propagating at an altitude of 70 km or higher, play an important role in the driving of the superrotation. They also suggested that the Kelvin and Rossby wave forms the Y-feature when they balanced. The Y-feature is the bright and dark pattern in UV range, and it has a planetary scale. From the Pioneer Venus spacecraft observation, it was revealed that the propagation and the distribution of UV features cause variation in several time scales [Del Genio and Rossow, 1982, 1990], but it has not been understood which dynamical processes determine these time scales. In our study, we focused on about 2-month brightness variation. That variation seems to be strongly associated with the Rossby wave because there is inverse correlation between low-latitude and mid-latitude, suggesting the existence of quasi-barotropic eddy. After the Pioneer Venus mission, there were no further observations to reveal the mechanism of the 2-month variation.

In this study, we observed the Venusian UV brightness variation as a function of latitude and time. We carried out the ground-based observations with Multi-Spectral Imager (MSI) onboard the Pirka telescope. The Pirka 1.6 m telescope, owned and operated by the graduate school of science in Hokkaido University, is primarily dedicated to the observations of solar planets. Using this system, we can monitor the planetary scale UV-features ($\sim$ 5,000 km) in Venus atmosphere over 8 hours in a day at 365 nm wavelength. In 2013, we carried out about 2 months total observations from mid-Aug. to mid-Nov.

There was a problem to estimate the absolute brightness variation because we observed Venus in the daytime and the correction of the extinction of the Earth's atmosphere had some difficulty. To investigate the brightness variation, we perform additional procedure for each image that we normalize the brightness in each latitudinal band with the mean brightness in 70^{o}N-70^{o}S area. Our results showed two types of UV feature. One showed the strong periodicity in both of equatorial region and mid-latitude and it also had the symmetric structure between northern and southern hemisphere. The other one did not show the strong periodicity and had the symmetric structure. We suppose that the Y-feature does not always exist and the balance of the Kelvin and Rossby wave might be lost when the periodicity and the symmetry disappear. From our observations, it seems to take more than 2 months to return from the asymmetric phase to symmetric phase. Additionally, we found that 2-month variation of brightness in each latitudinal band showed weak inverse correlation between both hemispheres like a seesaw. Such inverse correlation was not seen in the past Pioneer Venus observation. In this paper, we discuss the dynamical state of Venus during our observations and show further observation plans.

Keywords: Venus, Pirka telescope, superrotation, Y-feature

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PCG38-06 Room:423 Time:May 1 10:15-10:30

Spatiotemporal variations of brightness temperatures in the middle atmosphere of Venus revealed by Subaru/COMICS

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The middle atmosphere (60-100 km altitudes) of Venus plays an important role in determining its own environment. Venus is completely shrouded by a curtain of dense clouds (50-70 km) with total optical thickness of 20-40 at visible wavelengths. The upper sulfuric acid (H_2SO_4) clouds reflect ˜76% of the incident solar radiation back to space (Crisp and Titov, 1997). More than 70% of the solar energy absorbed by Venus is deposited at altitudes higher than 64 km mainly due to absorption of unknown UV absorbers mixed in the upper cloud (Tomasko et al., 1980, 1985). This horizontally and vertically unusual heating in the cloud layer excites the thermal tides, which are the key process to understand the atmospheric super-rotation. In order to elucidate this mysterious atmospheric phenomenon, it is fundamental to investigate horizontal and vertical thermal structure in the middle atmosphere.

We conducted Venus observations at three mid-infrared wavelengths (8.66, 11.34, and 12.84 micron) with the Cooled Mid-Infrared Camera and Spectrometer (COMICS), mounted on the 8.2-m Subaru Telescope, during the period of October 25-29, 2007 (UT). Thermal radiations at these wavelengths (brightness temperature: 230-240 K) are most sensitive to altitudes of ˜70 km. The angular diameter of Venus and the solar phase angle (Earth-Venus-Sun angle) at the observation period were ˜25 arcsec and ˜90 deg (i.e., both the dayside and nightside hemispheres were observed), respectively. The spatial resolution of the observed images, which was determined by astronomical seeing, was ˜200 km for the sub-observer point. This was the first time that such high spatially-resolved images had been obtained at mid-infrared wavelengths (Mitsuyama et al., 2008).

From images at 8.66 micron, we obtained three important findings. First, the brightness temperatures at cloud top altitudes (˜70 km) in north high-latitudes seemed to be synchronized with those in south ones during the period, which implies that the rotational speeds of them were nearly identical in both high-latitudes. Such atmospheric synchronization has not been reported by any previous mid-infrared ground-based (Diner et al., 1982; Orton et al., 1991) and spacecraft (Taylor et al., 1980; Zasova et al., 2007) observations mainly because of low spatial resolution and tilt of Venus' north pole toward the Earth, and of restricted distribution of sounding, respectively. Second, the center-to-limb curves (dayside and nightside) showed a day-night asymmetry across the morning terminator except that those on October 25 were nearly symmetric. The magnitude of this asymmetry was variable from one day to the next. Such day-night asymmetric features would result from the differences of temperature and/or cloud optical thickness. Finally, there were some streaky and patchy patterns in the whole disk after high-pass filtering. These patterns, typical amplitude of which was ˜0.5 K, varied from day to day. It is worth noting that streaky patterns obtained on October 28 were similar to a well-known horizontal Y-shape structure seen in UV. The above three findings were commonly seen at the other wavelengths.

In this talk, we show the observational results and discuss what kind of atmospheric parameters are responsible for the anomalous features of planetary scale center-to-limb curves through radiative transfer calculations.

Keywords: Venus, middle atmosphere, ground-based observation, atmospheric synchronization, center-to-limb curve, small-scale streaky and patchy patterns

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PCG38-07 Room:423 Time:May 1 10:30-10:45

Energy spectra of atmospheric motions simulated by a high-resolution general circulation model of Venus

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The dynamics of the Venus atmosphere is unclear because of the lack of observational data. Many researchers have developed General Circulation models (GCM) for the Venus atmosphere and have attempted to simulate atmospheric motions of Venus. Because the planetary rotation period of Venus is much longer than the Earth, long-term integrations are needed for the solution to achieve a statistically steady state. Therefore, the simulations have been performed by low-resolution ($\sim$ T21; i.e., about 5.6 deg x 5.6 deg grids) models. We have developed a simplified Venus version of the AFES (Atmospheric GCM for the Earth Simulator) (Sugimoto et al. 2012) and performed a very high-resolution simulation. In this paper, we report and discuss kinetic energy spectra obtained from the high-resolution simulation.

The dynamical core of AFES is descretized by the spectral method in horizontal. The model resolution is T159 (i.e., about 0.75 deg x 0.75 deg grids) and L120 (Δz is about 1 km). In the model, the atmosphere is dry and forced by the solar heating with the diurnal change and Newtonian cooling that relaxes the temperature to the zonally uniform basic temperature which has a virtual static stability of Venus with almost neutral layers. To prevent numerical instability, the biharmonic hyper-diffusion is included with 0.01 days of e-folding time for the truncation wavenumber. The coefficient of the vertical eddy diffusion is 0.15 $m^2\ s^{-1}$. A sponge layer is set above 80 km to prevent the reflection of waves. The dry convective adjustment scheme is used to avoid statically unstable state. A fast zonal wind in a solid-body rotation and the temperature field that balances (gradient wind balance) with the zonal wind are given as the initial state. Time-integrations are performed until the solution achieves a statistically steady state.

We calculate the horizontal kinetic energy per unit mass per unit wavenumber from the spectral coefficients of the vertical vorticity and horizontal diffusion (Koshyk & Hamilton 2001). The energy decreases by –5/3 power law in a range from wavenumber 4 to 45. Both in lower and higher wavenumber sides, the energy shows higher decreasing rate.

A feature of the energy spectral of aircraft observations (Nastrom & Gage 1985) and high-resolution GCM calculation of the Earth (Takahashi et al. 2006) is that the energy decreases by –3 power law in low-wavenumber range ($n < 80$) and by –5/3 power law in higher range. Terasaki et al. (2011) have reported that the –3 power law in synoptic scale is due to Rossby waves and the –5/3 power law in the mesoscales is due to gravity waves. The energy spectrum that we have obtained shows –5/3 power law in the wavenumber range lower than the Earth cases. This implies that the gravity waves may dominant even in scales of several thousand kilometers in the Venus atmosphere. A reason for the Rossby wave not being dominant in these scales may be the slow planetary rotation. The effect of the hyper-diffusion may appear in the range near the truncation wavenumber.

[Acknowledgement] This study was conducted under the joint research project of the Earth Simulator Center with title “Simulations of Atmospheric General Circulations of Earth-like Planets by AFES.”

Keywords: Venus atmosphere, general circulation model, high-resolution, kinetic energy spectra

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Microphysical properties of Venusian upper hazes observed with an Imaging-Polarimetry system " HOPS "

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The high albedo of Venus is due to optically very thick main cloud deck which covers the whole planet. The small particles (hazes) which were distributed above the main cloud deck were discovered by the observations from Pioneer Venus Orbiter (PVO) which arrived at Venus in December 1978. Kawabata et al. [1980] found, from the data of Orbiter Cloud Photopolarimeter (OCPP) onboard PVO, that abundant sub-micrometer sized particles " hazes " were distributed above the main cloud deck mostly in polar regions. The optical thickness of the haze layer was reported to reduce during the PVO mission period [Sato et al., 1996]. Coincidently, decrease of the SO_2 abundance was also reported [Esposito, 1985]. After the PVO mission, however, the variation of the optical depth of the hazes has not been studied, so it is not clear what this correlation means for the generation and maintenance of hazes and whether a similar correlation between them exist today. Our study provides the latest information about the microphysical properties of hazes by ground-based monitoring observations which have not been done since PVO.

To monitor the distribution of the Venusian upper hazes, we developed an imaging-polarimetry system " HOPS " (Hida Optical Polarimetry System) and performed observations by attaching it to the 65cm refracting telescope at Hida Observatory of Kyoto University. As HOPS provides spatially resolved polarization map, polarization in an arbitrary area can later be obtained just by summing up the corresponding pixels for comparison with previous measurements. This is the biggest advantage of imaging polarimetry against the aperture measurements. HOPS is a " two beam type " polarimetry instrument which enables high accurate measurements against variable atmospheric conditions. The effect of variable atmospheric transparency, non-uniformity of sensitivities over the CCD pixels and different throughputs of two beams can be corrected through arithmetic operations in image processing.

The observations were carried out at solar phase angles around 39deg. (Jul., 2013), 56deg. (Aug., 2013), 58deg. (Oct., 2012), 85deg. (Aug., 2012) and 129 deg. (May, 2012) at 4 selective wave lengths 438nm (B), 546nm (G), 650nm (R) and 930nm (IR); G and IR data can be compared with similar wavelength data of PVO/OCPP. We averaged observed degree of linear polarization over the polar regions (latitudes higher than 60 deg.) and compared with the report of PVO. A clear difference is seen in IR data. The neutral point of our data is found to be at around 75 deg. while the point of PVO/OCPP is around 40 deg. This difference may indicate the different situation of the distribution and size parameters of hazes.

To analyze the obtained polarization data, we developed a radiative transfer calculation code using Adding?Doubling method with the Stokes parameters fully treated [de Haan et al., 1987, Hovenier et al., 2004]. It is possible to analyze three wavelengths IR, R, and G neglecting the Rayleigh scattering effect because Rayleigh scattering cross-sections for IR, R G and B are about 0.21, 0.083, 0.041, 0.0096μm^2 while Mie scattering cross-sections for a main cloud particle are the order of 7μm^2. We treated haze particle effective radius r_{eff} and optical depth τ_h as free parameters, respectively. The effective variance of hazes was fixed to 0.18 and parameters for main cloud layer were taken from Hansen and Hovenier [1974]. Single scattering albedos were assumed to be 1 for both haze and cloud layers. The resultant parameters for northern and southern polar region are r_{eff} = 0.22, 0.20μm, τ_h = 0.09, 0.05 at IR, respectively. The optical depth is smaller compared with the initial observations of PVO τ_h = 0.25 but comparable with those observed during the declining phase. Such declination of the abundance of SO_2 is also observed by Venus Express orbiter [Marcq et al., 2012], so our results are consistent with the report of the correlation with it.

Keywords: Venus, Hazes, Imaging-Polarimetry, Radiative transfer analysis

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Estimation of wind at the cloud top of Venus

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A number of theories have been proposed to explain the formation of the super-rotation in the Venus atmosphere. Among them, we focused on the Gierasch mechanism. To validate the mechanism, it is required to investigate the horizontal momentum transport by eddies with an accuracy sufficient to resolve the eddies with scales smaller than several thousand kilometers. In this study, we used the ultraviolet images from Venus Monitoring Camera (VMC) onboard ESA's Venus Express. The VMC data have some random and coherent noises, so the simple cross-correlation methods used in previous studies do not necessarily provide an high accuracy. Here, we suggest a new and robust method to estimate wind velocity vectors accurately by using multiple images, thereby reducing the effect of noises. The accuracy of its results is estimated statistically. The results are also examined from the dynamical point of views. Contrary to conventional expectation, the magnitude of horizontal wind divergence has similar magnitude to its rotation on the horizontal scale of several thousand kilometers. It is discussed how the results are explained.

Keywords: Venus, super-rotation, estimation of wind

PCG38-10 Room:423 Time:May 1 11:30-11:45

Studying the Venusian atmosphere on the 2012 transit of Venus

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The solar satellite Hinode observed the transit of Venus on June 5-6th 2012. The solar optical telescope (SOT) observed the dark Venus disk against the bright solar surface. The images were acquired continuously for the wavelength of 396.8, 430.5 450.4, 555.0, 668.4 nm with unprecedented spatial scale (~0.3 arcsec).

The purpose is the derivation of the latitudinal and vertical distribution of the cloud particle, SO2 and SO from the transmittance for considering the global dynamics. We calculated the transmittance normalized by the unattenuated solar intensity after the data correction processes including the removal of the solar limn darkening and the calibration for the plate scale.

The altitude as the transmittance of 0.5 (~90 km) in the Venus atmosphere has the slant toward the equator. The difference is 9.1 km in the evening and 6.1 km in the morning. In the equatorial region (latitude $\leq$ 40 degree), the fluctuation of the altitude is observed. The amplitude for the wavelength shorter than 400 nm is a few times larger than that of 430.5 nm. We would show the consideration to explain the longitudinal distribution of the altitude of the Venus disk.

Keywords: planetary atmosphere, the transit of Venus

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Millimeter Wave Band Monitoring of Venusian and Martian Middle Atmosphere with SPART Telescope

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To understand the influences of the activities of the central star on the middle atmospheres of the surrounding terrestrial planets, we have performed millimeter-wave-band monitoring of the atmospheres of Venus and Mars by using a 10-m radio telescope called SPART (solar planetary atmosphere research telescope). The telescope employs highly sensitive superconducting SIS mixer receivers in the 100- and 200-GHz bands for the front-end and a commercially available FFT spectrometer (1-GHz bandwidth and 67-kHz resolution) for the back-end. Millimeter-wave-band heterodyne sensing is a powerful technique that can be utilized to trace the abundance and vertical distribution of minor constituents in a planetary middle atmosphere.

In 2011, we began observations of the middle atmospheres of Venus and Mars in the 100-GHz band. In 2012, the telescope had problems with the azimuth gear, motor, and synchro-to-digital converter unit, which resulted in a pause in telescope operation. In 2013, we repaired these problems and resumed the substantive operation test. We are currently restarting double-band full remote monitoring of the spectral lines of minor constituents such as ^{12}CO J=2-1 at 230 GHz, ^{13}CO J=2-1 at 220 GHz, and ^{12}CO J=1-0 at 115 GHz toward Venus and Mars. This season, the apparent diameter of Venus is greater than the beam size at the 200-GHz band (35 arcsec.). We adopted position switching and on-the-fly modes for 100- and 200-GHz-band observations, respectively. The latter two-dimensional mapping allows us to cover the entire disk of Venus. The retrieved CO abundance variation is compared with the data of high-energy particles, X-rays, solar wind velocity/density, and other measured parameters. The data are associated with flare, coronal mass ejection, and solar proton events.

In this conference, the current status of the SPART project and the millimeter-wave-band monitoring will be presented.

Keywords: planet, solar activity, radio telescope, heterodyne spectroscopy, middle atmosphere, remote sensing

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

PCG38-12 Room:423 Time:May 1 12:00-12:15

Observation of a wave structure of stratospheric haze in Jupiter's polar regions by the ground based telescope

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Stratospheric haze formed by aerosol particles covers both polar regions in Jupiter. It has been reported based on the imaging using a methane band filter at 889 nm that the stratospheric haze can be measured. They show bright cap structures covering polar regions and the edge of the cap shows a wave structure spreading in longitudinal direction. This structure can be seen more clearly in the Jupiter's south pole than the north pole, and wave is clear at a latitude of about 67 S [Sanchez-Lavega, 2008].

Jupiter's polar areas have been investigated by the Hubble Space Telescope (HST) from 1994 to 1999 and the Cassini ISS in 2000. This wave structure is known to exist for several years in Jupiter's both polar regions. These observations suggested that this wave structure is caused by planetary Rossby waves because this wave structure presents for a longer period and moves westward relative to the background flow. However, the origin and mechanism keeping to this wave structure, the vertical structure of the wave, change of the propagation velocity of the wave in the short time scale, and north-south asymmetry of the wave structure are unclear so far, because of lack of the observations in short time scale (monthly scale). We have carried out the monthly monitoring of Jupiter from 2011 to 2014 with the 1.6 m Pirka telescope of Hokkaido University.

In this paper, we show results of our observations of the wave structure in Jupiter's polar region. We found a north-south asymmetry of the wave structure in the polar areas. The wave structure at 67 N spread to 42 N in the northern hemisphere, however it does not so in the southern one. In addition, we found that the wave structure has varied in the vertical direction a bit between altitude of 361 mbar and 750 mbar.

Keywords: Jupiter, haze, ground-based observation, Rossby wave

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PCG38-13 Room:423 Time:May 1 12:15-12:30

Observing Jupiter with an infrared camera NIIHAMA

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An infrared camera, NIIHAMA (1024x1024 pixels, PtSi array sensor), is attached to the SOLAR-C telescope (45-cm diameter off-axis Gregorian reflector) atop Haleakara in December 2013 and is now observing Jupiter.

NIIHAMA's 6-position wheel houses Dark, J, H, K, 3.4-micron (for Jupiter's H_3^+ aurora) and 2.26-micron (for Venus night-side IR emission) filters. The primary target of this project is to monitor the brightness of Jupiter's aurora simultaneously with SPRINT-A/HISAKI and other telescopes. However, due to smaller aperture of telescope, rather low quantum efficiency of PtSi sensor, etc., Jupiter's aurora has not yet been imaged so far. On the other hand, the satellite Io while in Jupiter's shadow was observed in K band, and the night-side IR emission of Venus was successfully imaged in 2.26-micron filter. We report the result of first-light observations and also discuss improvement and observing plans in near future.

Keywords: Infrared camera, Jupiter, aurora, Io, Venus, Haleakala

PCG38-14 Room:423 Time:May 1 12:30-12:45

Self-driven auroral acceleration process at Jupiter captured by continuous monitoring of Hisaki satellite with HST

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Two possible drivers have been proposed for planetary auroral acceleration processes: magnetosphere-solar wind interaction referred to as an 'external driver' and shear flow of magnetospheric plasma around a planet referred to as an 'internal driver'. Recent observations of Jupiter's aurora indicated significant responses of auroral intensity and morphology to the solar wind. These results are suggestive of the 'external driver' for Jupiter. On the other hand, there have not been reported dynamics of the 'internal driver' for Jupiter yet which should be essential because of Jupiter's fast rotation and internal plasma source Io. Here we firstly report dynamics of the 'internal driver' based on long-term continuous observation of extreme ultraviolet (EUV) aurora by Hisaki satellite. The long-term variations in EUV aurora are compared with solar wind extrapolated from Earth's orbit by numerical simulation. We found dramatical brightening and decay of EUV aurora during the solar wind quiet period. The brightening occurs once every a few days followed by sudden decay with a timescale less than a half of rotation (~5 hours), which is significantly faster than the solar wind daily variations. Highly-resolved auroral imaging by Hubble Space Telescope captured expansion of diffuse aurora down to latitudes of Io's footprint aurora during the brightening. These observations are indicative of hot plasma deeply injected into the inner magnetosphere around Io's orbit independently from the solar wind, followed by rapid energy dissipation through auroral emissions and possibly other radiation and/or chemical processes.

Keywords: Hisaki satellite, Hubble Space Telescope, Jupiter, aurora

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PCG38-15 Room:423 Time:May 1 14:15-14:30

Characteristics of O+ velocity distributions at Venus and ion acceleration mechanisms: ASPERA-4 observations

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O^+ ion velocity distributions for high energy O^+ beams (>100 eV) around Venus are statistically studied. The study shows that O^+ acceleration is controlled by the local convection electric field produced by the local proton and local magnetic field. In the magnetosheath, velocity distributions show a trend that perpendicular velocity component shifts from initial phase of the ring distribution to the local proton velocity. This indicates that gyro motions of the pickup ion immediately collapse after pickup and the ions are incorporated into the local proton flow. The pickup ions only escape through the $+E_L$ hemisphere. In the dayside induced magnetosphere in the $+E_L$ hemisphere, measurements show a scattered velocity distribution of O^+. This velocity distribution has two ion components depending on whether their gyro radius is larger or not than the scale of the induced magnetosphere. For O^+ ions with small gyro radius (<500 km), the O^+ velocity distribution appears on the middle phase of the ring distribution. On the other hand for the O^+ ions with a large gyro radius (>500 km), the O^+ velocity distribution is similar to the one in the magnetosheath. This means that in the induced magnetosphere two types of ions are mixed up: pickup ions subject to the E x B drift and ions moving with the local proton bulk velocity. Since both ion components flow tailward, they are convected toward the nightside. In the nightside of the induced magneto- sphere, velocity distribution shows initial and last phase of the ring distributions and parallel beam (3D ring distribution). This suggests that ion pickup occurs at the center of the plasma sheet. There is no evidence of an electric potential in the plasma sheet because the O^+ parallel beam velocity is larger than the parallel velocity component of the local proton. Our result suggests that the local convection condition is rather important to discuss ion acceleration mechanisms at Venus than the solar wind condition.

Keywords: Venus, ion escape, ion acceleration, Venus Express, ASPERA

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PCG38-16 Room:423 Time:May 1 14:30-14:45

Characteristics of boundary layer between the magnetosheath and Martian ionosphere during solar wind penetration events

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Deceleration of the solar wind due to the mass loading by planetary heavy ions forms the magnetic pile-up region around unmagnetized planets such as Mars and Venus. The Martian magnetic pile-up region diverts shocked solar wind plasma around the planet at altitudes typically in excess of 800 km [e.g., Vignes et al., 2000]. Mars Global Surveyor (MGS) measurements have shown, on one hand, that shocked solar wind (magnetosheath) plasma occasionally penetrates into much lower altitudes (~400km) [e.g., Brain et al., 2005; Crider et al., 2005]. Our previous statistical study of these solar wind penetration events using MGS magnetic field and electron observations revealed that both solar wind dynamic pressure (Psw) and the orientation of the interplanetary magnetic field (IMF) control the occurrence of the events. However, MGS cannot observe the solar wind regions due to its orbital design.

In this study, we focused on the simultaneous observation of the penetration events by MGS and Mars Express (MEX). MEX possess the ion mass analyzer (IMA) and electron spectrometer (ELS), which are parts of plasma packages of ASPERA-3. MEX partly observed the solar wind region, since the orbit of MEX is elliptical orbit. We can thus obtain the solar wind density and velocity from MEX data. Among the simultaneous observation data by MEX and MGS, we identified 46 simultaneous observation events of the solar wind penetration. We divided the 46 events into the low Psw ($\leq\sim$4nPa) and high Psw ($\geq\sim$4nPa) events. The solar wind penetration event on January 20, 2005 is observed during the high Psw periods, while the event on February 20, 2005 is during the low Psw periods. We investigated characteristics of the boundary layers between the magnetosheath and the ionosphere. We found that the electron flux shows a gradual decrease in the boundary in the high Psw event. On the one hand, intermittent appearance of both the magnetosheath plasma and the ionosphere plasma in the boundary is during the low Psw event. The signature of the boundary layer resembles with the K-H instability signature seen in LLBL (low-latitude boundary layer) in the Earth's magnetotail [e.g., Hasegawa et al., 2006]. We also report the results of statistical analysis of 46 simultaneous observation events.

Keywords: Mars, Ionospheres, Induced magnetosphere, Solar wind, Unmagnetized planet

PCG38-17 Room:423 Time:May 1 14:45-15:00

Effects of ion-ion collisions on vertical distribution of CO2+ in Martian ionosphere based on multi-fluid MHD simulation

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Comparison of the mass fraction of CO2 and N2 with regard to the total mass of each terrestrial planet suggests importance of the atmospheric escape to space in Martian atmospheric evolution [Chassefiere et al., 2006]. It has been considered that heavy CO_2^+ ions are difficult to escape based on known atmospheric escape processes. Observations of a large amount of CO_2^+ ion escape by the Mars Express thus challenged the existing escape processes. Vertical distribution of CO_2^+ density in the ionosphere is one of important factors that determine the rate of CO_2^+ escape. Chemical reactions in ionosphere have been implemented in previous studies using multi-species MHD simulations [e.g., Ma et al., 2004; Terada et al., 2009]. The velocity difference between ion fluid cannot be reproduced by the multi-species MHD approximation. On one hand, the importance of vertical transport in the upper ionosphere (>300km altitude) was pointed out by some ionospheric models [Fox and Hac, 2009]. Multi-fluid MHD code [e.g., Najib et al., 2011] can solve such ion-species dependent velocity.

In this study, we developed a multi-fluid MHD simulation code. Our code includes ion-ion collisions in order to investigate their effects on the vertical distribution of CO_2^+ density in the Martian ionosphere. Three cases of the simulation runs are carried out: Multi-fluid MHD with ion-ion collision (Case1), multi-fluid MHD without ion-ion collision (Case2), and all ion species have the same vertical velocity corresponding to multi-species approximation (Case3). We compared the results after each simulation run reached to a quasi-steady state. The CO_2^+ density at altitude 460 km were turned out to be 82, 190, and 11 cm^{-3}, respectively for the Cases 1-3. The results suggest that inclusion of ion-ion collision is important to reproduce the realistic CO_2^+ transport from lower to upper ionosphere.

Keywords: Mars, ionosphere, Atmospheric escape, Multi-fluid MHD

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PCG38-18 Room:423 Time:May 1 15:00-15:15

Temporal variability of exospheric sodium density

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Mercury's atmosphere is very thin and it is also called "surface-bounded exosphere". In the detected species, e.g., H, He, O, Na, Mg, K, and Ca, Na emission (NaD) is the brightest and has been most frequently observed. Solar-photon-stimulated desorption, sputtering by impacting solar particles, and meteoroid vaporization are considered to be the source processes of Mercury's sodium. However, the primary process among these three processes is unclear as yet. The resonance scattering constitutes exospheric emission. The NaD emission is well suited for study by ground-based observations because of its high intensity. Past observations have shown that the temporal variation and north-south asymmetry of intensity of sodium emission.

We have observed Mercury sodium exosphere at the Haleakala Observatory in Hawaii since April 2011. The observations were performed using a 40 cm Schmidt-Cassegrain telescope, a high-dispersion spectrograph, and a CCD camera. We determined the temporal variation of the sodium density using the observational data. It is possible that the temporal variation of the sodium density is caused by variation of solar wind magnetic field if solar wind ion sputtering is the primary source process of Mercury exosphere. To verify this assumption, we checked the temporal variation of solar wind magnetic field observed by MESSENGER, and then we compared these variations with our observational result.

In this presentation, we show our observational results and discuss the dominant source process.

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PCG38-19 Room:423 Time:May 1 15:15-15:30

Study of heavy ion dynamics in the Mercury's magnetosphere with offset dipole

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From Mariner 10 and MESSENGER observations, Mercury's magnetosphere is thought to be a miniature of the Earth's magnetosphere. While these two magnetospheres have several characteristics in common, some critical differences are also evident. First, there is no atmospheric layer, but only tenuous exosphere. Second, the kinetic effects of heavy ions might not be negligible because Mercury's magnetosphere is relatively small compared to the large Larmor radii. Trajectory tracings is one of the dominant methods to estimate the kinetic effect of heavy ions which originate the exosphere, though the results of the simulation are quite sensitive to the electric and magnetic field. Hence, it is important to provide a realistic field model in the trajectory tracings. In order to construct a large scale structure, we developed a MHD simulation code, and adopted to the global simulation of Mercury's magnetosphere. We performed four solar wind conditions of the northward IMF, and the results showed that the global configurations such as the location of magnetopause depend heavily on the dynamic pressure, while the solar wind electric field contributes little to the magnetospheric configuration. On the other hand, the results of statistical trajectory tracings of exospheric sodium ions depend not only on the dynamic pressure but also on the solar wind electric field. In the results, we identified two efficient acceleration processes and formation of the 'sodium ring' which is formed by the accelerated ions drifting around the planet by magnetic gradient of the dipole field. When the solar wind dynamic pressure is low, acceleration by magnetospheric convection is efficient in the vicinity of Mercury. When the dynamic pressure is high, entry of the accelerated ions picked-up in the magnetosheath into the magnetosphere becomes dominant. The entry point of sodium ions changes due to the variation of the solar wind electric field, which causes a difference in the sodium ring's shape for the same solar wind dynamic pressure cases. Recent observation by MESSENGER revealed the weaker dipole field of Mercury than the past estimation based on Mariner 10 as well as large offset of dipole which could change the global configuration of Mercury's magnetosphere and behavior of sodium ions. In the presentation, we will also discuss the ongoing simulation including the above configuration of intrinsic magnetic field of Mercury especially focus on how will this affect the acceleration mechanisms.

Keywords: Mercury's magnetosphere, test particle simulation, MHD simulation

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PCG38-20 Room:423 Time:May 1 15:30-15:45

Structure and time variability of Io plasma torus observed by EXCEED onboard the HISAKI satellite

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Spatial distribution and time variability of emission lines of sulfur ions in Io plasma torus (IPT) measured by EUV spectrograph (EXCEED) onboard the HISAKI satellite are presented. The satellite has been launched on 14 Sep. 2013 and begun regular observation of IPT and Jupiter's UV aurora since middle of Dec. and it will continue until the end of Feb. A wide slit whose designed field of view (FOV) is 400 x 140 arcsec was chosen to measure both radial and latitudinal distributions of IPT. Jupiter's north aurora was guided at the center of FOV and its spectrum was simultaneously observed. Averaged spatial distribution of sulfur emission lines is consistent with previous observations. Looking at the time variability of IPT, new features were found from the EXCEED observation. The most surprising one is periodic variation synchronized with Io's orbital period. The variations in dawn and dusk sides were out-of-phase, suggesting the bright region is co-rotating with Io. The amplitude of the periodic variation is larger than those of well-known Jupiter's rotation periodicities in shorter wavelength and becomes smaller as increasing wavelength. The wavelength dependence suggests significant electron heating and/or hot electron production processes associated with Io. Another noticeable feature is long-term change in dawn-dusk asymmetry of the emission intensity which had not been reported so far. The asymmetry has been assumed to be a proxy of large scale dawn-to-dusk electric field generated in Jovian magnetotail and the origin of the variation observed will be discussed in detail. Sporadic change in the emission intensity of IPT associated with the aurora brightening event is expected to investigate in detail with the EXCEED observation to reveal energy transport process between inner and middle/outer magnetospheres. The expected event has not been detected so far and further continuous observation will be expected to resolve this issue.

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PCG38-21 Room:423 Time:May 1 15:45-16:00

Plasma dynamics of Io plasma torus seen from the EXCEED

YOSHIOKA, Kazuo[1*] ; MURAKAMI, Go[1] ; KIMURA, Tomoki[1] ; YAMAZAKI, Atsushi[1] ; TSUCHIYA, Fuminori[2] ; KAGITANI, Masato[2] ; YOSHIKAWA, Ichiro[3]

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Major ions in Io plasma torus have many allowed transition lines in the EUV and their radiation easily escapes to become observable from outside the region. In other words, Jovian inner magnetosphere is able to be monitored by the EUV spectral observation remotely. Moreover, with the atomic database which provides the cross sections to the ambient electron, transition probabilities, and these temperature dependence, EUV observations can be a very important diagnostic of ion densities, electron density, and its temperature.

The EUV spectroscope EXCEED on the Hisaki spacecraft has started to observe the Jovian magnetosphere from the Earth orbit since the end of 2013. The spacecraft is dedicated for the solar system planets so that all the observation window is spared for planetary science. The spectral range is from 52 to 148 nm and its resolution is 0.3 nm with one of the narrowest slit. The field of view is 400 arc-seconds which corresponds to around 18 RJ. Therefore, it can observe whole region of Io plasma torus at one time. Moreover, it can achieve better spatial resolution than 1 RJ. It is the first time to get a whole spectral images of Io plasma torus in the EUV with such a high performance instrument. In this presentation, we will show the first results of EXCEED observation with its high spectral resolution slit for Io plasma torus.

Keywords: EUV, Io plasma torus, Jovian magnetosphere, Hisaki, EXCEED

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PCG38-22 Room:423 Time:May 1 16:15-16:30

Dust-plasma interaction in Saturn's inner magnetosphere and its magnetosphere-ionosphere coupling

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We investigated the magnetosphere-ionosphere coupling with a dust-plasma interaction in Saturn's inner magnetosphere by using a modeling of ionosphere and inner magnetosphere. From our previous model, it was revealed that the magnetospheric ion velocity was significantly reduced by the electric fields generated by the ion-dust collisions when the dust density is high and the thickness of dust distribution is large. It was consistent with observations when the dust density is larger than ~10^5 m^{-3} for ionospheric conductivity of 1 S. An average electron density of Saturn's ionosphere obtained from radio occultations by Cassini spacecraft was ~10^{10} m^{-3} at 2000 km where density had a peak and gradually decreased with the increasing altitude. The density was ~10^8 m^{-3} at 10000 km. Plasma densities calculated by models also were similar to the observations and the topside temperature is ~650 K. However, electron densities from those models were calculated at the altitudes below 4000 km.

We estimated the ionospheric Pedersen conductivity from the plasma densities, and the plasma temperatures and velocities by using a magnetohydrodynamics model. We used the magnetospheric plasma temperature, which was 2 eV, as a boundary condition to investigate the magnetospheric influences. The plasma density was about 10^9 m^{-3} at the altitude of 1200 km, and it decreased to about 10^7 m^{-3} at the altitude of 10000 km. Below 10000 km altitudes the light ion has the upward velocity, while heavy ions have zero or downward velocity at low altitudes. This might be due to the difference of mass. The electron temperature increased to 20000 K at the altitude of 10000 km due to the heat flow from the inner magnetosphere. The electron temperature was about 2000 K at the altitude of 1000 km, and the collision and joule heating were contributing to the temperature below 2000 km. The peak density changed between about 10^8 and 10^{10} m^{-3} during one Saturn's day, and the electron density decreased with increasing the altitude. On the other hand, the electron temperature didn't depend on the local time. The Pedersen conductivity was the maximum 0.77 S on day time and the minimum 0.30 S on dawn time. The Pedersen conductivity strongly depends on the ionospheric plasma density.

We estimated the magnetospheric ion velocity by using the calculated conductivity. The Pedersen conductivity was the largest value at L = 3 and it decreased with the increase of the distance from Saturn. The conductivity changed in local time. The maximum was on the day time and the minimum was on the dawn time. The calculated ion velocity decreases from the co-rotation speed outside 3.5 R_S. The ion velocity was 60-80% of the co-rotation speed in the inner magnetosphere. The ion velocity was smaller than the co-rotation speed since the magnetospheric electric field is smaller than the co-rotational electric field when the current due to the ion-dust collision flows in the inner magnetosphere. The ion velocity strongly depended on the local time since the conductivity also depended on the local time. It is suggested that the dispersion of the observed speeds could show the dependence of local time. The ion velocity is fast during the solar irradiation since the Pedersen conductivity is large, while it becomes slow after the sunset because of the small conductivity.

The magnetosphere-ionosphere coupling is significantly important for the dust-plasma interaction. It is impossible to understand the dust-plasma interaction in Saturn's inner magnetosphere without understanding of the Saturn's ionosphere, since the magnetosphere and ionosphere is intimately-connected.

Keywords: Saturn, Dust-plasma interaction, Magnetosphere-ionosphere coupling, Dusty plasma

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PCG38-23 Room:423 Time:May 1 16:30-16:45

Relation between Kronian magnetospheric convection and auroral emission from MHD simulation with solar wind data observe

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In a series of our simulation studies we have reported that vortices formed at Saturn's dawn magnetopause in simulations when IMF was northward. We interpreted these vortices as resulting from the Kelvin Helmholtz (K-H) instability. In addition, thanks to the recent developments of computer performance, we have been able to perform the high resolution global MHD simulations of the Kronian magnetosphere. In these simulations we obtained the signature of the field-aligned currents from the K-H vortices in Saturn's auroral ionosphere and found small patchy regions of upward field-aligned current which may be related to auroral emissions. These patchy aurorae resembling our results have been reported from Cassini observations.

In our previous simulations we used the constant and simple solar wind conditions to understand the basic behavior of Kronian magnetosphere. In this study we have used Cassini observations of the solar wind upstream of Saturn to drive a simulation. Using these solar wind data we simulated the Kronian magnetosphere from 2008-02-12/14:00:31 to 2008-02-13/01:59:31 when the Hubble Space Telescope (HST) observed the Kronian UV auroral emissions. In these solar wind conditions there are several enhancement of the solar wind dynamic pressure (shock) and polarity reversal in the IMF components.

From these simulation the shape and convection of Kronian magnetosphere dynamically changed according to the variation of dynamic pressure and IMF directions. As the results, layered convection formed between the corotation region and magnetopause. Furthermore these convection interacted each other, then the large vortex configurations appeared. The calculated configuration of field aligned currents from the simulation also showed the layered and patchy distributions. In addition the upward field aligned current appeared in the dawn side mainly which resembles the configuration of auroral emission by HST.

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PCG38-24 Room:423 Time:May 1 16:45-17:00

Study of dynamics of the Jovian magnetosphere-II: energy transportation process to the inner magnetosphere

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We have researched response of the Jovian inner magnetosphere to the substorm-like event which occurred in the night side of the middle/outer magnetosphere. The transport of magnetic flux tube is one of important issues in the global dynamics of the Jovian magnetosphere [Kivelson et al., 2005]. The magnetic flux tubes are carried outward from the Io plasma torus with the slowly outflowing plasma. As they move outward, alternative flux tubes should be returned to the torus through rapid inflow of lower-dense flux tubes. Goal of this study is to reveal the role of the substorm-like event in the transport of magnetic flux tube in the Jovian magnetosphere.

In this study, substorm-like events were identified by using the in-situ observation data obtained by the Plasma Wave Subsystems (PWS), Energetic Particle Detector (EPD) and Magnetometer (MAG) onboard the Galileo orbiter. X-lines where the substorm-like events are thought to start were located at around 60-80 RJ [Woch et al., 2002]. Narrowband KilOMetric radiation (nKOM) which was remotely observed by PWS was used to find response of the inner magnetosphere to the substorm-like event. The source of nKOM is suggested to be located at the outer edge of the Io torus (8-10 RJ) (Reiner et al., 1993).

In the preceding studies, Louarn et al. (2001) reported nKOM correlated with inward flow burst during Jovian substorm-like event reported by Woch et al.(1998) and Krupp et al.(1998). The report implies that the generation mechanism of nKOM relate with the return of magnetic flux tube to inner magnetosphere. However, it has not been revealed well yet how inner and outer magnetospheres couple each other during substorm-like event.

On the other hand, Dubyagin et al.(2011) reported about deeply penetrating flow burst at the terrestrial magnetosphere. They reported that an inward flow burst penetrated into the inner magnetosphere when its entropy was less than that of the inner magnetosphere, while flow burst did not penetrated when its entropy was larger than that of the inner magnetosphere.

We have analyzed Jupiter's several inward flow events which are expected to relate with tail reconnection and nKOM radiation by using the data obtained by Galileo. We also have applied Dubyagin's entropy analysis method to Jupiter's cases in order to reveal that how reconnection event at the outer magnetosphere couple with the inner magnetosphere.

In this presentation, we will show preliminary results on relations of Jovian substorm-like event and phenomena of inner magnetosphere.

Keywords: Jovian magnetosphere, magnetospheric dynamics, substorm, plasma density, Galileo, nKOM

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Jupiter's decametric Io-C modulation lanes observed by LWA1 (2)

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The Long Wavelength Array (LWA) is a low-frequency radio telescope designed to produce high-sensitivity, high-resolution images in the frequency range of 10-88 MHz. The Long Wavelength Array Station 1 (LWA1) is the first LWA station completed in April 2011, and is located near the VLA site in New Mexico, USA. LWA1 consists of a 256 element array, operating as a single-station telescope. Each LWA1 beam provides dual orthogonal linear polarizations such that it is possible to reconstruct the full Stokes parameters for each tuning. The first Jupiter radio observation using LWA1 was made by Tracy Clarke (PI) from December, 2011. The initial analyses of Io-A/C, Io-B, and Io-D event, show many spectral features such as S-bursts, narrow-band events (N-bursts), as well as modulation lanes and Faraday lanes.

The modulation lanes in Jupiter's decametric radiation, which were discovered by Riihimaa [1968], are groups of sloping parallel strips of alternately increased and decreased intensity in the dynamic spectral plots. We present LWA1 observations of modulations lanes detected across a Jovian decametric Io-C burst that contains both right hand circular and left hand circular emission. The modulation lanes cross both handedness of polarization, suggesting that the emissions may be coming from the same hemisphere. These results add important information regarding the emission mechanism of Jupiter's decametric emissions.

Keywords: Jupiter radio, decametric wave, modulation lane, radio source, radio emission mechanism, LWA1

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Observations of Polarization of Auroral Kilometric Radiation by KAGUYA and its Lunar Occultations

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In KAGUYA (SELENE) LRS[1], WFC-H[2] observes wave spectra in 1kHz-1,000kHz and various plasma waves like Auroral Kilometric Radiation (AKR), electron plasma waves, and broadband electrostatic waves have been observed. This system can observe wave polarizations by two pairs of dipole antennas. We have analyzed the AKR polarizations.

Kaguya moves behind the Moon every rotation. The occultations of AKR radiated from the Earth occur. Such occultation observation by the 32 channel burst receiver of lunar orbiter RAE2 was reported in [3,4]. The polarizations were not measured then. The polarization of AKR is defined with respect to the magnetic field from a view point of plasma waves. On the other hand, the polarization is observed with respect to the propagation direction. Both polarizations depend on the source hemisphere. When only one hemisphere can be seen due to the occultation, the source hemisphere is identified and the polarization can be measured correctly. This result is also useful when both hemispheres are seen after the occultation. We show the results and their interpretations.

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Keywords: AKR, Polarization, Occultation, KAGUYA, Moon