Elucidation, this is the engine of Super-Rotation caught by Venus Express/ESA

*Hirofumi Mase[1]

1.none

Only At this line, hot body - cold body - hot body, the hot body pulls each other(1). I call this hypothesis "2-temp.-rotating-disk"(Rotating-Disk). It's revealed that it can be observed easily every time at one period of Candle Oscillator(2). I'd like to explain this time the mechanism of the atmosphere's superrotation of Venus(SR) that the knowledge which Venus Express(VEX)/ESA got doesn't contradict.

I enumerate the matter(a-e) which can be confirmed when seeing image sequence of vortex in about 2000km radius from the South Pole at an altitude of about 65km(Fig.01-13)(4). (a)It's general that the vortex and the circumference(Territory) do the left rotation overall(Precession, angle 14deg./2h). (b)By skid or excessive rotation or both of them, in a body, Territory is moving(max 2000km) in a short time(4h) once per 2 days(Great Movement)(Fig.01,04,07,10,13). (c)By the movement that Territory was grasped at a specific place and was driven, all Great Movement advanced towards the direction where 150deg.W is made the center. (d)By changing the shade while maintaining the size-shaped mostly, the huge vortex occurs and disappears. But the shape of every vortex is various. (e)By Great Movement, the center of gravity of the vortex comes away big from the rotation center. And the new vortex of a state that both of them agree occurs. It changes from the previous one and meets next Great Movement.

I got (f)(g)(h) from the above. (f)Fact of (a)(b) shows that the structure(probably, flywheel and gyro) that Territory rotation doesn't collapse by Great Movement is equipped. (g)Fact of (b)(c) shows that a specific place in Territory is pulled to the point of almost fixing outside Territory. (h)Fact of (d)(e) shows that the vortex maintains, by flows along its structure, the rotational energy to the extent of that the Territory-rotation is influenced. And shows that, when the vortex rotation becomes unjust by external force(Great Movement), the vortex changes and adapts itself to the environment.

I'd like to build the model that fills (f)(g)(h) at the same time(Fig.17). At Layer2 where the high 65km is made the center, cold parts coexist with hot parts and polar dipole(6) is formed. This vortex produces flows in self-controlled way by using temperature structure and maintains the rotational energy by becoming rotational flow overall. This is main drive force of SR(Rotating-Disk1). Layer3, where the high 80km is made the center, is mounted on Layer2, and the same movement is done. When Hot Block near the edge of Layer3 is close to the point of polar collar, Hot Block is pulled each other between Hot Belt(turned by Rotating-Disk1)(Rotating-Disk2). SR is promoted temporarily at this time, so this must also be drive force of SR. (The part of Hot Belt is attracted to the pole direction)

Through "caster", Layer2 and Layer3 get on the turn-table-Layer1 that has the function of the flywheel and the gyro. Drive force is transmitted to Layer1 from Layer2 and Layer3. Stability is transmitted to Layer2 and Layer3 from Layer1.

(1)MASE/JpGU2008/E108-P007 (2)MASE/http://homepage3.nifty.com/hmase/upload110120web.pdf (3)MASE/J-GLOBAL ID:201302212255521162 (4)ESA/released 07 April 2011/The shape-shifting southern vortex of Venus/Reconstruction of the motion of Venus's polar atmosphere.(Credit: ESA/VIRTIS-VenusX/INAF-IASF/LESIA-Obs. Paris/ Univ. Lisbon/Univ. Evora (D. Luz, Univ. Lisbon & D. Berry, Univ. Evora)

(this continuation is indicated on the drawing)

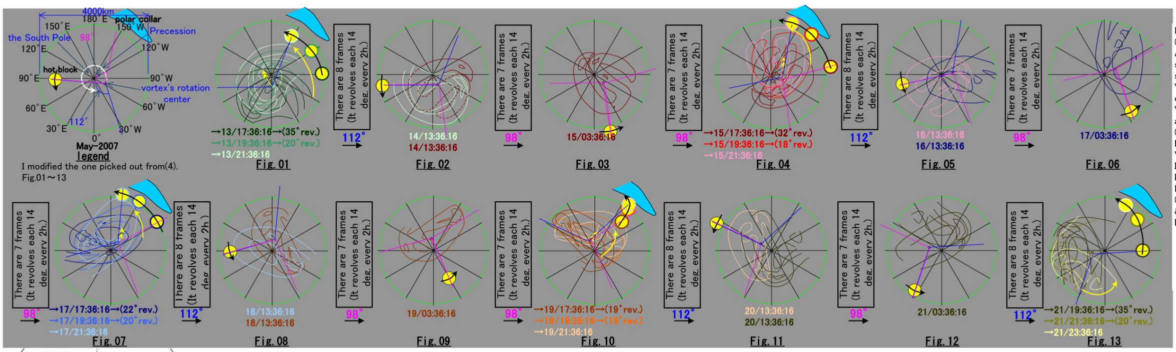

Fig. 01 Fig. 02 Fig. 03 Fig. 04 Fig. 05 Fig. 06 Fig. 07 Fig. 08 Fig. 09 Fig. 10 Fig. 11 Fig. 12 Fig. 13

Reference literature
(4)ESA/released 07 April 2011/The shape-shifting southern vortex of Venus/Reconstruction of the motion of Venus's polar atmosphere.
(Credit: ESA/VIRTIS-VenusX/INAF-IASF/LESIA-Obs. Paris/ Univ. Lisbon/Univ. Evora (D. Luz, Univ. Lisbon & D. Berry, Univ. Evora)

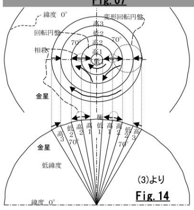

Fig. 14

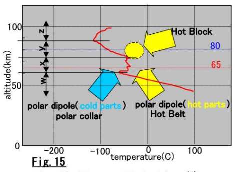

Fig. 15
I modified the one picked out from (5).

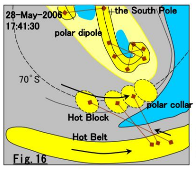

Fig. 16
I modified the one picked out from (7).

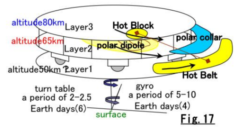

Fig. 17

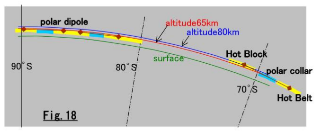

Fig. 18

Reference literature
(5)ESA/released 28 November 2007/金星北極の大気の高度による温度変化 (From http://kouda.asablo.jp/blog/2015/01/11/)
(6)佐藤(東北大)他/Venus Expressによる紫外/赤外画像を用いた金星中高緯度の風速分布の研究
http://www.isas.jaxa.jp/j/researchers/symp/2012/image/0301_proc/P-16.pdf(Piccioni et al.,2007)
(7)Venus Express/VIRTIS(piccioni et al.2007)/金星南極の輝度温度 (From http://www.jamstec.go.jp/esc/projects/fy2013/4-hayashi.pdf)

A plan to study the Venus’ haze based on SOIR/Venus Express and AKATSUKI

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The Venus cloud consists of a main cloud deck at 47 -70 km, with thinner hazes above and below. The upper haze on Venus lies above the main cloud surrounding the planet, ranging from the top of the cloud (70 km) up to as high as 90 km.
The Solar Occultation in the InfraRed (SOIR) instrument onboard Venus Express (ESA) was designed to measure the Venusian atmospheric transmission at high altitudes (65 -165 km) in the infrared (2.2 -4.3 μm) with high spectral resolution. We investigated the optical properties of the Venus’s haze above 90 km using the SOIR solar occultation observations. Vertical and latitudinal profiles of extinction, optical thickness, and mixing ratios of haze were retrieved. We find that haze extinction and optical thickness at low latitudes are two times higher than those at high latitudes. One of the noticeable results is that haze mixing ratio increases with altitude above 90 km at high and low latitudes. Therefore we speculate that haze could be produced at such high altitudes.
On December 7, 2015, AKATSUKI (JAXA) arrived at Venus after orbit insertion. Some instruments onboard AKATSUKI will observe characteristics of cloud and haze particles. In this presentation, a plan to elucidate Venus’s cloud including haze layer creation and maintain process in using observation data of SOIR/Venus Express and AKATSUKI will be proposed.

Keywords: Venus, AKATSUKI, Venus Express, cloud

Near-Infrared spectro-polarimetry of Venusian upper cloud structuer

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In estimating structures of planetary atmosphere by means of remote sensing, simultaneous determination of various parameters is required. The problem doesn't get easier even for simple structure such as thin haze layer above thick cloud layer. In case that the size of cloud and haze particles is distinctively different, however, parameters of both layers should be determined by considering the wavelength dependence of the characteristics. In this paper, we propose such a technique and report a result obtained by adapting to Venusian atmosphere.
Spectro-polarimetry in near-infrared region is specific technique. Venusian main cloud consists of the cloud and haze particles, of which the radii are on the order of 1μm and sub-micron, respectively (Mie theory can be adopted). The advantages in near-infrared region (0.9μm<λ<2.5μm) are
(1) characteristics of the cloud is dominant because of rapid decrease of scattering cross-section of hazes, and
(2) a neutral point (point where the sign of polarization changes) exists and is easy to detect.
Using such characteristics, we can determine the parameters of the main cloud independently from hazes.
We calculated radiative transfer including polarization in semi-infinite cloud (cloud particle size is standard: r=1.05μm) in near-infrared region. The sign of polarization turned negative to positive with an increase of wavelength (hereafter we use λ_n as the transition wavelength). Additionally, when particle sizes were changed as r=0.8μm (small), 1.05μm, 1.5μm (large), λ_n were found at 1.81μm for standard particle, at 1.46μm for small particles, at 2.28μm for large particles. Therefore, the particle size within the range of 0.8μm< r <1.5μm can be determined by obtaining λ_n from spectro-polarimetric observations in J, H and K band (central wavelength is 1.25μm, 165μm and 2,2μm, respectively) range.
In order to validate this technique and to study the cloud properties of Venusian cloud, which we have recently detected rapid decrease of hazes on, we performed observations at Higashi-Hiroshima observatory / Hiroshima University from May 19 through 25, 2015. We used "HONIR"(Hiroshima Optical and Near-Infrared) instrument attached to "Kanata" telescope. Observing wavelengths are J, H and K bands. We observed Procyon (unpolarized standard star) for calibrations of mechanical polarizations caused in its optical system, and we verified that we don't need to do such calibrations. There are variations of 0.2% in the polarization degrees (P[%]), which means that measurement error is of such degree.
The inclination of obtained polarization spectra P(λ) of low latitude of Venus is dP/dλ~4.5%/μm. With the combination of dP/dλ and measurement error (±0.2%), we obtained determination accuracy ± 0.05μm for λ_n. Since $d\lambda_n/dr$ is ~1.16, which is deduced by r dependence of λ_n obtained from model calculations described above, we finally have ±0.04μm in average for the determination accuracy of particle size. Obtained λ_n of Venus are λ_n=2.1μm for May 21, and λ_n=2.2μm for May 22, 24, 25. Those λ_n obtained on May 21 and the other days are similar to the results of model calculations for r=1.2μm and r=1.35μm, respectively. This result indicates the existence of larger particles compared with the particle size (1.05μm) of standard model (Esposito et al., 1983).
Rossi et al. (2014) reported some cases that model calculations for cloud particle size r=1.2μm is consistent with the near-infrared (λ~1.1μm, 1.27μm) polarimetric data of low latitude of Venus obtained in Apr. and May 2010 by SPICAV onboard Venus Express, we possibly detected such variations

in Venusian cloud.

Keywords: Venusian Upper Cloud, Spectro-polarimetry

Development of Fiber IFU for Venus Cloud Tops

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Venus cloud absorbs solar radiation at wavelength between 200nm and 500nm. The absorption of wavelength between 200nm and 320nm is well explained by SO_2 at the cloud tops, but the absorption at longer wavelength has not been identified yet. The comparison between the spatial features of different wavelength may clarify number of unknown-absorbers, but only one bandpass filter or one wideband filter with transmittance around 365nm has been used by telescopes and instruments of previous observation.
We are developing a spectrum imaging instrument using fiber array. Spectrum imaging can take several images of different wavelength at same time, and it is suitable for studying the UV-blue absorber of Venus. We thought a new manufacturing method of a fiber array with several hundred of fiber with diameter of ~100μm, and improvement has been added to the method for practical use. Optics using the fiber array are designed for Haleakala 60-cm. We will report performance of our instrument and plan to observation of Venus.

Keywords: Fiber integral field units, Ultraviolet observation, Venus atmosphere

Venus upper atmosphere as observed by Hisaki: Dayglow and ion tail

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Hisaki was launched on September 14, 2013. Since then, we have conducted quasi-continuous observations of the upper atmosphere of Venus by using the Extreme Ultraviolet Spectroscope for Exospheric Dynamics (EXCEED) [*Yoshioka et al*., 2013; *Yoshikawa et al*., 2014] on-board Hisaki. Our observation aims to see variations of the EUV dayglow of Venus and to detect ions, such as O^+ and C^+, escaping from Venus.
From three quasi-continuous observations in 2014, we found characteristic periodic variations of oxygen EUV dayglow [*Masunaga et al*., 2015]. In 2015, we conducted new observations of Venus upper atmosphere covering different local times or different latitude from those in 2014. Our result shows that the ~4 day periodicity is observed on the dawn side of Venus. We suggest that gravity waves may propagate from the middle atmosphere of Venus, where the atmosphere is super-rotating with a 4-day period, to the upper atmosphere of Venus. The local time difference of the ~4-day periodicity of the dayglow suggests that there is a local time difference in wave propagation altitudes or wave filtering structures.
Using the 10″ slit of EXCEED, we also observed Venus tail region to detect ion tail escaping from Venus. The 10″ slit has a better pointing accuracy than that of the 60″ slit. The result shows that C^+ ion tail (CII 133.5 nm) is detected with SNR > 1. We discuss the escape rate of C^+ ions from Venus by assuming cold C^+ ions are escaping from Venus.

Keywords: Hisaki, EXCEED, Venus, Dayglow, Ion escape

Monitoring Observations of Millimeter-Wave Band Spectral Lines of Carbon Monoxide in the Middle Atmospheres of Venus with the SPART Telescope

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For understanding of influences of solar activities and space weather on the middle and lower atmospheres of the terrestrial planets in the solar system, we have been carrying out the monitoring observations of the millimeter-wave band spectral lines of carbon monoxide (^{12}CO J=1-0 115.2712018 GHz, J=2-1 230.538 GHz, ^{13}CO J=2-1 220.3986765 GHz) of the middle atmospheres of Mars and Venus with a 10m-telescope, SPART (Solar Planetary Atmosphere Research Telescope) since it was launched in 2011. The SPART employed highly sensitive 100 and 200 GHz double band superconducting SIS heterodyne detectors and 1 GHz band digital fast Fourier transfer spectrometer with the frequency resolution of 67 kHz. This highly frequency-resolved heterodyne spectroscopy is powerful tool to trace the weak and narrow spectral lines of minor constituents in planetary middle atmosphere.
The results observed with SPART showed the disk averaged mixing ratios of CO derived at the altitude of around 80 km in case of Venus were around 60 ppmv during 2011 to 2015. This observing period corresponds to the solar cycle 24 maximum phase according to the 1 GHz band flux data observed with the Nobeyama Radio Polarimeters (NoRP). The mixing ratios of CO seem to be lower than those observed during the solar cycle 22 maximum phase. These suggest that solar activities might have no small effect on the abundance variations of CO.

Keywords: Venus, Ground-based Radio Telescope, Solar Activity

Development of 1.9-THz-band Waveguide-type Hot-electron Bolometer Mixer Employing Superconducting NbTiN Microbridge

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Many spectral lines for rotational, rotation-vibration, and fine-structure transitions of gas species in the interstellar medium and planetary atmospheres lie in the millimeter to terahertz waveband. In this frequency band, heterodyne spectroscopy with high frequency resolution is a powerful tool for understanding of the basic physical and chemical properties of planetary atmospheres and interstellar media. Despite its scientific and observational importance, 1–10-THz-band radio astronomy and remote sensing have long been unexplored because of the lack of good observing sites and the unavailability of sensitive heterodyne detectors in this frequency range.
We are currently developing a 1.9 THz band waveguide/diagonal-horn type HEB mixer employing a superconducting NbTiN micro-bridge fabricated using *in situ* sputtering techniques. The crucial observational targets for this frequency band are OH radicals, H_2O, and [OI], which are important oxidants in the chemical-reaction network in the atmosphere of Earth and other planets; [OI] and [CII] lines, which are the basic coolants of the interstellar medium; and other complex and high-*J* molecules.
The optical system and waveguide probe of the HEB mixer receiver that couple the input signal were newly designed with 3D electromagnetic-field simulators, GRASP and HFSS(TM). The fabrication of the waveguide chip slot of which the dimensions are 50 μm width and 40 μm depth were successfully realized by recent high- precision micromachining techniques. The performances of the diagonal horn such as beam pattern (axial symmetry and side-lobe levels) were newly optimized re-designing the length and truncated structures of the horn. The cold head of the 4 K mechanical refrigerator for the HEB mixer receiver has the temperature fluctuation of 0.2 K. By inserting the new optics as a buffer material between the cold head and the mixer we succeeded to reduce the fluctuation at the position of the HEB mixer to 1.6 mK, which is much smaller than the transition width of temperature between superconducting state and resistive state of the NbTiN microbridge. Therefore the reduced temperature fluctuation does not affect the performance of the HEB mixer.
In this conference, we will present the current developmental status of the newly fabricated 1.9-THz-band waveguide/horn-type HEB mixer detectors.

Keywords: Terahertz, heterodyne remote sensing, Superconducting detector

Measurements of the Venusian mesospheric wind and temperature profiles using mid-IR heterodyne spectrometer MILAHI

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Mesospheres of terrestrial planets are the transition region between the lower and the upper atmosphere. Their altitudes are 50-90 km on Mars and 60-100 km on Venus, respectively. In Venus, It is also the transition region from the super-rotated upper cloud layer (altitude: 65-90 km, observed by JAXA Venus orbiter Akatsuki) to the thermospheric SS-AS (subsolar-antisolar) flow layer (altitude: 100-120 km). The observations of this region are not enough and disagree with the results of Venus International Reference Atmosphere (VIRA) [Sonnabend et al., 2010].
We have promoted the study of the wind velocity and temperature profiles in the Venusian mesosphere using MILAHI (Mid-Infrared LAser Heterodyne Instrument). It was developed in Tohoku University and installed to the Tohoku Univ. 60 cm telescope (T60) at Mt. Haleakala, Hawaii, and can achieve ~3.5 arcsec of spatial resolution and >~10^6 of spectral resolution. This talk mainly shows the result observed by this system, and compares the derived wind velocity and temperature profiles with the early observational results of Akatsuki, in order to investigate of the effects of the dynamics in the Venusian cloud layer to the mesosphere.
We observe CO_2 non-local thermodynamic equilibrium (non-LTE) emissions at a wavelength of 10 μm from the altitude of 100-120 km. Temperature and wind velocity along the line of sight can directly be derived from the Doppler width and shift of emission line, respectively. Although similar measurement can be accomplished by CO line in mm and submm from the altitude of 80-110 km [e.g., Clancy et al., 2008], its spatial resolution is up to ~14 arcsec in single dish observation. We can resolve the Venusian disk with higher resolution and get their constant and long-term variations.
In nightside, wind velocity and temperature profiles in the altitude region 70-95 km also be observed by CO_2 absorption lines at 10μm. Those retrieval is done by Advanced Model for Atmospheric TeraHertz Radiation Analaysis and SimUlation (AMATERASU) [Baron et al., 2008] which performs forward (line-by-line radiative transfer and numerical modeling of instrumental characteristics) and inversion calculations.
We are now preparing the observation campaign in March 2016. Akatsuki will observe the atmospheric dynamics in the region between the surface and the altitude of 90 km. Our observation by MILAHI obtains the information at the region above them, and extend the vertical profiles above the cloud top toward the mesosphere. Akatsuki has several remote sensing instruments for those objectives; two imagers, LIR (wavelength range: 8-12μm) and UVI (wavelength: 283nm), with the radio occultation using USO. They will provide the temperature distribution near the cloud top (altitude: ~70 km) at nightside, the altitude of the cloud top and wind distribution near the cloud top (altitude: ~70 km) at dayside, and the vertical temperature profile at limb (altitude range: 35-90 km) twice in every orbital period, respectively. We will try to provide simultaneous and continuous ground-based observations.
In this study, we evaluate the vertically resolved profiles of Venusian atmosphere by the comparison between the temperature profile by MILAHI and the Akatsuki radio occultation. We also derive the daily variation of wind velocity profiles from cloud top to the mesosphere by UVI and

MLAHI in dayside, and evaluate the transition features between super-rotation and SS-AS flows. We also derive the daily variation of temperature profiles from the cloud top to the mesosphere by LIR and MILAHI in nightside.

Keywords: Venus, mesosphere, heterodyne, Akatsuki

Radiative transfer model combined with multiple scattering in planetary atmosphere: implication for a potential biomarker

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The transit method is one of the main ways to detect extrasolar planets. Analyzing transit transmission spectra of the planets gives us the information on planetary atmospheres, since absorption and scattering by atmospheric molecules have wavelength dependence. As current data points in observed transit spectra are not enough to characterize planets, atmospheric compositions are estimated by comparing with theoretical models. It has been expected to characterize Earth-like planets in future observations. Oxygen and ozone are considered as potential biomarkers which originate from life in an Earth-like atmosphere. Therefore, it will be a good benchmark to find life outside the Earth that we discuss the detectability of these molecules in a variety of conditions.

Our study aims to estimate quantitatively how biomarker molecules are detected in observations. We develop a spherical radiative transfer model based on the TAU code by Hollis et al 2013, and perform mock observations for transmission spectra of Earth-like planets. We deal with multiple scattering in planets by assuming spherical atmosphere. We estimated how Rayleigh scattering and surface reflection affect the detection of biomarkers.

In a clear-sky condition, we evaluate if O_2 and O_3 are detectable from an Earth-like planet. The shape of the transmission spectrum changes when the planet is covered with the ocean. It indicates that we can identify the reflection from the ocean due to the Rayleigh scattering. In the corresponding wavelength region, absorption of O_2 and O_3 are too weak to be detected (at 1.27 and 2.47 μm, respectively).

Keywords: extrasolar planet, transmission spectra, mock observation

Ion acceleration by magnetic reconnection in the dayside ionospheres of unmagnetized planets

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We have examined magnetic reconnection in the dayside ionosphere of Venus and its application to other unmagnetized planets using a 2-D multi-species magnetohydrodynamic (MHD) model. Main object is to investigate the ionospheric ion acceleration and the escape processes associated with magnetic reconnection after an interplanetary magnetic field (IMF) reversal.
Magnetic reconnection is an efficient energy conversion process that converts the energy of magnetic field in an anti-parallel configuration into plasma kinetic and thermal energy. Thus, it is potentially important to accelerate and remove the ionospheric ions from unmagnetized planets and to understand the evolution of planetary atmospheres. Recently, magnetic reconnection has been observed around unmagnetized planets such as Venus and Mars [Eastwood et al., 2008; Halekas et al., 2009; Zhang et al., 2012; Hara et al., 2014; Harada et al., 2015]. However, there remain unsolved problems about magnetic reconnection after an IMF reversal; its spatiotemporal evolution and resulting atmospheric loss rate.
In this study, we performed three runs with different initial conditions. In order to examine the altitude where magnetic reconnection develops, different initial heights of the current sheet are given; 450 km (Run A), 360 km (Run B) and 260 km (Run C) altitudes. Our simulations showed that the fast magnetic reconnection called the plasmoid instability [Loureiro et al., 2007] occurs in Run A and Run B. On the other hand, the instability evolves slowly in Run C. From three runs, it is shown that the growth rate of the plasmoid instability is suppressed in the lower region of the ionosphere. For all cases, ionospheric plasmas are accelerated and ejected from the current sheet by magnetic reconnection. The averaged outflow velocities are 2.3 km/s for Run A, 2.8 km/s for Run B, and 0.4 km/s for Run C, respectively. It is indicated that the plasma is accelerated efficiently (up to 0.7-0.8 times the local Alfven velocity) in the upper ionosphere of Venus.
We also examined the O^+ loss rates due to magnetic reconnection after an IMF reversal in three runs. The transient O^+ loss rates are about 2.8×10^{25} ions/s for Run A, 2.3×10^{25} ions/s for Run B, and 5.5×10^{24} ions/s for Run C. This difference is attributed to the difference in the outflow velocity. It is suggested that the escape rate due to the reconnection decreases with a decreasing initial altitude. We have compared the O^+ loss rate due to magnetic reconnection with other escape processes, and concluded that the reconnection after an IMF reversal potentially contribute to oxygen loss if an IMF reversal frequently occurs.
Based on the simulation results and the theory of magnetic reconnection, we investigated the possible atmospheric loss by the magnetic reconnection after an IMF reversal at other unmagnetized planets. From an analytical estimation of the loss rate due to the reconnection after an IMF reversal, it is shown that the loss rate is proportional to local Alfven velocity and the number density of ionospheric ions. Using the parameter of the Martian ionosphere, we have estimated the O^+ loss rates as 8×10^{24} ions/s at the maximum. The estimated maximum loss rate is several ten times larger than that obtained from the Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft [Hara et al., 2015].

Keywords: Venus, Mars, Magnetic reconnection

Solar wind conditions on the escape of oxygen from Mars

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The Martian atmosphere was warm and high pressure several billions of years ago[Carr, 1999]. The Martian atmosphere is dry and low pressure (636 Pa)[McKay and Stoker, 1989; Kerr, 2000; Baker, 2001]. Although about 95% of Martian atmosphere is CO2, about 90% of escaping atmosphere is oxygen (O, O+) from the observation by Mars Express[Lundin et al., 2009].Oxygen escape may be important for the evolution of the water of Mars. Mars does not have a significant internal magnetic field. The solar wind can penetrate to the Martian ionosphere altitude and interact with the Martian ionosphere [Acunã et al., 1998; Lundin et al., 2004]. Then, ionopause and bow shock are formed, and oxygen ion escape is strongly affected by the solar wind. The structures of ionopause and bow shock are important for oxygen ion escape.The important escape mechanisms of Martian atmosphere are Dissociative Recombination, Solar Wind pick up and Sputtering. The previous models do not include the effect of the collision of the escaping particles with the atmospheric particles and the escape of the collided secondary particles. Then, We constructed a model including dissociative recombination, solar wind pick up and spattering processes, and investigated the amount of the atmospheric escape from Mars.We calculated the solar wind interaction with the Mars ionosphere with Magnetohydrodynamics equations and particle model of Oxygen, and we found that the solar wind conditions around Mars control the escape flux of Oxygen in Mars.

Keywords: Mars, Solar wind, Escape, Oxygen

Study of the solar wind influence on the Jovian inner magnetosphere using an ionospheric potential solver

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The solar wind hardly influences the convection in the Jovian inner magnetosphere, because the corotation of magnetospheric plasma dominates the convection there. However, the extreme ultraviolet spectroscope (EXCEED) aboard the Hisaki satellite observed change in a dawn-to-dusk asymmetry in the brightness distribution of the Io plasma torus. This asymmetry can be explained by assuming the existence of a dawn-to-dusk electric field of ~3-7 [mV/m] around Io's orbit. The influence of the solar wind is suggested as its cause: First, the solar wind compresses the Jovian magnetosphere. Then, the magnetosphere-ionosphere current system is modified, and the field-aligned current into the high-latitude ionosphere increases. As a result, the ionospheric electric field increases and penetrates to low-latitude regions. It is mapped to the equatorial plane of the magnetosphere along the magnetic field line, and the dawn-to-dusk electric field is created at Io's orbit in the inner magnetosphere.
An ionospheric potential solver is one of the best tools to test this scenario quantitatively. The ionospheric potential solver is a simulation code by which we can investigate how the global ionospheric potential gets distributed responding to the input of the field-aligned current. We constructed an ionospheric potential solver and investigated whether the dawn-to-dusk electric field generated by the solar wind interaction could penetrate into the Jovian inner magnetosphere. We validated this potential solver by applying it to the Earth's ionosphere and comparing with an established code [Nakamizo et al., 2012]. Our code succeeded to reproduce a similar potential distribution, however there remain minor differences caused by minor differences in the assumption of the ionospheric conductivities, i.e., their spatial distributions including relative positions to the field-aligned current. Then, we applied this code to the Jovian magnetosphere-ionosphere current system. As a peak intensity of the field-aligned current, we used a value based on the observation of FUV aurora by HST [Gustin et al., 2004] and adopted the Earth's empirical model for its distribution [Hori et al., 2009]. We assumed the Jovian ionospheric conductivities as 10 percent of the Earth's values [Tao et al., 2009]. The electric field mapped to Io's orbit appears to be on the same order as or smaller than the value suggested by the Hisaki satellite observation. In this paper, we will present a result using more realistic spatial distributions of the ionospheric conductivities and the field-aligned current obtained from the Galileo spacecraft observation and a Jovian upper atmospheric model.

Keywords: Jupiter, Io plasma torus, dawn-to-dusk electric field

Study on dynamics of Jovian atmosphere by a colorimetric observation of surface structures

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Stripe patterns called belts or zones with various colors persist on Jovian surface. Anticyclonic vortices called an oval with various scales and colors are maintained and drifted in the boundary between zones and belts. Some ovals have different colors despite they are formed simultaneously in same latitude region. Color changes of ovals after an interaction with other ovals were also reported. Such results suggest a strong relationship between dynamics of Jovian atmosphere and colors of local structures. However, detailed mechanisms for such color variations are still unknown. In this study, colors of remarkable Jovian structures like the great red spot (GRS), bands, and zones are focused on as a tracer of the Jovian atmospheric dynamics. It is essential to monitor the Jovian surface continuously to quantify color variations with various temporal scales. However, it is difficult to make a continuous monitoring of Jupiter with large telescopes due to limited machine time. Instead, large amounts of image data reported by amateur astronomers in the world have potential to achieve the continuous monitoring by combining them (e.g. Archive by Association of Lunar and Planetary Observers of Japan: http://zetta.jpn.ph/Alpo/latest/index.html). However, quantitative color comparison between color images acquired by different optics and sensors are basically difficult. It is necessary to have standard spectra to correct a white balance of these color images. Thus, a simple device which can observe visible spectra of Jovian surface with resolving spatial structures was developed. Since this device is compact and portable, an observation by combining it with established telescopes managed by public astronomical observatories is immediately possible. On a night of Dec 15 2015, a spectroscopic observation of Jovian surface atmosphere using the device and a 40cm diameter telescope in Kawasaki municipal science museum have been conducted. In this talk, results of the spectroscopic observation of Jovian surface on Dec 15, 2015 and an analysis method to quantify the colors of the surface structures using a chromaticity diagram are presented.

Keywords: Jupiter, atmosphere, colorimetry, GRS, spectroscopy, chromaticity diagram

Derivation of the vertical distribution of Jovian decametric S-burst sources based on ground-based observations for verification of the Jovian ionospheric Alfven resonator model

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Vertical distribution of Jovian decametric (DAM) S-burst was studied based on the analysis of S-burst events simultaneously found in multiple frequency range in the ground-based observation. Using the determined repetition frequencies of the S-burst elements, scale height of the Jovian ionosphere has been estimated from Jovian ionospheric Alfven resonator (JIAR) model.

JIAR hypothesis was proposed by Ergun et al. [2006] and Su et al. [2006]. According to these studies, eigen-frequencies of JIAR are expected to determine the repetition frequency of S-burst elements. The ionospheric Alfven resonator (IAR) model has been investigated through the theoretical studies and observations of the Earth's ionosphere. In the IAR model, the fundamental and higher harmonic eigen-frequencies were analytically derived from parameters such as the Alfven speed at the plasma density peak of the ionosphere, and the scale height of the topside ionosphere [Lysak, 1991; 1993].

In this study, we have observed Jovian decametric S-burst in a frequency range from 20 MHz to 40 MHz with a logperiodic antenna and a wideband receiversince 2012 at Yoneyama observatory of Tohoku University. These observations were performed mainly in Io-B source condition, in which Previous studies reported high occurrence probability of intense S-burst events.

We especially focus on a simultaneous S-burst event in two different frequency bands (~23.5 MHz, hereafter DAM1, and ~27.0 MHz, hereafter DAM2) found at 15:56 on 24 November 2014. With assumption that emissions are radiated at the local electron cyclotron frequency, the geometric distance of the DAM1 and DAM2 sources are respectively estimated to be ~1.085 Rj and ~1.040 Rj based on the VIPAL magnetic field model [Hess et al., 2011] and the location of Io UV footprint [Bonfond et al., 2009]. The determined repetition frequencies of DAM1 and DAM2 were 22.3 Hz and 28.5 Hz, respectively.

The two emission sources are considered to be in the same magnetic field line or in the different magnetic field lines which are close to each other. In the both cases, we can assume that the repetition frequencies are equal to the fundamental and high harmonic eigen-frequency of JIAR, and that the ionospheric scale heights for DAM1 and DAM2 are common or quite similar. Therefore the Jovian ionospheric scale height is estimated to be ~1400 km and ~1800 km.

In the presentation, we will discuss the comparison results of the S-burst source altitude derived from the emission frequency and vertical distribution of the standing Alfven waves in JIAR estimated from the eigen-frequencies of JIAR, also.

Observation of Jupiter's synchrotron radiation in the magnetospheric variation period

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Rapid variation of relativistic electrons in Jupiter's radiation has been inferred with the time scale of a day or less from the observation of Jupiter's synchrotron radiation (JSR) at 327MHz. The Galileo Jupiter orbiter data showed this rapid variation has some relation with the (recurrent) magnetic reconfiguration events (MRE) in the outer magnetosphere, however, the causality of the rapid variation of JSR and MRE have not been known yet. One plausible causality for MRE is proposed to be enhancement of mass loading originally brought by enhancement of plasma originated from Io. In the middle of Jan. to May, 2015, obvious Io plasma enhancement has been identified by the ground-based optical observation (Yoneda et al., 2015) and also the Hisaki spacecfarft observation. This phenomena gives us a good opportunity to directly confirm the relation between the occurrence of rapid variation of Jupiter's radiation belt and enhancement of the Iogenic plasma. We have made a quasi regular JSR observation at 2.3GHz for about three weeks in March, 2015 using the Kashima 34m radio telescope with a new observation method to eliminate artificial radio noises. We will report the result of this JSR observation and discuss variation characteristics.

Keywords: Jupiter, synchrotron radiation, radiation belt, magnetospheric variation

Estimation of dawn-to-dusk electric field in the Jovian inner magnetosphere from emission asymmetry in the Io plasma torus

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Past ground-based and probe observations show existence of dawn dusk asymmetry (DDA) in brightness distribution of the Io plasma torus (IPT) and suggest that it is caused by the dawn-to-dusk electric field (DDEF) of about 4 mV/m. Recent observation of IPT with the HISAKI satellite reveals that the DDA of emission intensity shows temporal changes in response to solar wind dynamic pressure, indicating the solar wind influence on the Jovian inner magnetosphere. Purpose of this study is to derive DDEF quantitatively from DDA of emission intensity from HISAKI observations and find which processes cause to make DDA in the emission intensity.
Because DDEF causes to shift a drift orbit of plasma to dawnward, electron temperature becomes higher in the dusk side than the dawn side due to the conservation of first adiabatic invariant. As an efficiency of electron impact excitation of ion depends on electron temperature, the emission intensity in the dusk side becomes higher than that in the dawn side. To estimate DDEF from the brightness asymmetry quantitatively, we considered following procedures. (1)Orbit of plasma is calculated by solving an equation of motion with the Runge-Kutta method under corotational and dawn-to-dusk electric fields. Two temperature electron distributions, thermal(5eV) and hot(50eV) components are considered and the adiabatic heating and cooling of electron are calculated for each component. (2)Assuming a conservation of total amount of plasma in a unit flux tube electron density changes by magnetic field intensity changes are also calculated at both the dawn and dusk sides. (3)Applying typical values of thermal and hot electron density of 2000/cc and 20/cc, respectively, and changes in electron temperature and density evaluated in (1) and (2). The ion volume emissivity is calculated by using the atomic data base (CHIANTI) for ion species : S++(68nm). (4)The change in the plasma distribution due to DDEF also changes line-of-sight lengths of IPT between the dawn and dusk sides seen from the earth. This effect is also taken into account. We carried out the procedure from (1) to (4) in the range of DDEF intensity from 0 to 10mV/m and derived the relation between electric field and the DDA of emission intensity.
To investigate contributions of the five factors described above (thermal and hot electron temperatures, thermal and hot electron densities, and the line-of-sight length) on the asymmetry in the emission intensity, we evaluated dependence of the asymmetry on each factor, where other four factors were fixed. From the result, it was found that the thermal electron temperature change dominated the asymmetry of emission intensity while hot electron has very minor contribution to it. This is responsible for electron temperature dependence of ion volume emissivity. The ion volume emissivity has weak dependence on electron temperature above 20eV in the wave length range of EUV. By using the relation between DDEF and the asymmetry of emission intensity in the IPT derived in our study, we estimated DDEF intensity from HISAKI observations. The ratios of emission intensity at the dusk side to that at the dawn side on January 1 and 14, 2014 were 1.49 and 1.13, respectively. From these ratios we estimated DDEF intensity is 3.4mV/m and 1.0mV/m. To estimate DDEF intensity from HISAKI observations quantitatively, a more realistic model which includes radial plasma distribution in IPT and electron cooling effect due to radiation is needed.

Keywords: Io plasma torus, Dawn dusk electric field, Dawn dusk asymmetry

North-south asymmetry of Saturn's auroral radio emissions: The seasonal variation of their fluxes

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Saturn emits intense radio emissions, Saturn Kilometric Radiation (SKR), from the northern and southern polar region in 3-1200kHz. SKR is generated by field-aligned energetic auroral electrons via Cyclotron Maser Instability (CMI) at local cyclotron frequency. Saturn’s rotation period has been evaluated based on occurrence period of SKR because SKR source is fixed in the planetary magnetic field with highly anisotropic beaming, thus forming a corotating searchlight of radio emission. In the Saturn’s magnetic field directions, the right-handed circularly polarization (RH) emissions are from the northern region and the left-handed (LH) ones from the southern region, respectively. Cassini observations in the southern summer (2004-2009) showed that the period of SKR daily variation is variable [Kurth et al., 2008]. It was slightly longer in the southern (summer) hemisphere [Gurnett et al., 2009], but close to each other near the equinox (September in 2009) [Gurnett et al., 2010]. Related to this trend, we also studied the flux ratio between northern and southern SKR in 2004-2010, and showed that the LH (summer, south) is stronger than the RH (winter, north) in average [Kimura et al., 2013]. Those characteristics could be explained by the north-south asymmetry in the polar ionospheric conductivities, which are related to the seasonal variations of the solar EUV flux illuminating to the polar region. However, the clear scenario has not been yet established. For example, in the observations in the Northern summer after 2010, northern and southern SKR periods merged together and are not clearly separated [Provan et al., 2014; Fischer et al., 2015]. This fact could not be explained by the simple idea based on the polar ionospheric conductivities.
In this study, we extend the study in Kimura et al. (2013) to 2015 covering the northern summer. We note that the simple extension of the analysis period is hard because of the Cassini orbit bias. Since the SKR is stronger in the dawn side, Kimura et al. (2013) adopted the detection criteria that Cassini is at the dawn side (2h - 10h LT). And in order to avoid the visibility effect of SKR caused by its propagation, other selection criteria were also set in the latitude (-5 to +30deg (RH), +5 to -30 (LH)) and the distance from Saturn (10 - 100 Rs). However, because of Cassini’s apokrone after 2010 was gradually shifted from dawn to dusk, it becomes hard to get a large number of observations under the same criteria.
In this study, we kept the same latitude and distance criteria but used the all LT data set. But, at former we could see the different LT between the both SKR, so we couldn’t avoid the LT dependence. In parallel, at latter we selected +-5deg in the latitude and verified the result about the data observed simultaneously for the north and south. In this revised result, the intensity of LH component in 2004-2009 (south, summer) was stronger ~+40 than RH (north, winter). In 2010-2012, the both SKR intensities got close to each other. After 2013, RH (north, summer) was stronger by ~+20 than LH (south, winter). These results support the result in Kimura et al. (2013) that the summer hemisphere is more enhanced. The variation of SKR peak intensity by a running median with a window of +-35 days to avoid visibility effect also showed same trend. However, it is not well explained that the flux ratio was more than 10 in southern summer but only 0.2-0.4 in northern summer. In this presentation, we will also show the correlation of these trends to the SKR rotational period, solar EUV activity, etc. (Cassini Solstice Mission will be finished in Sep.

2017.)

Keywords: Saturn, SKR(Saturn kilometric radiation), North-south activity ratio, seasonal variation, Cassini

[OI]630.0nm emission in the Enceladus torus obtained with Haleakala T60/Vispec

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The moon Enceladus, revolves round Saturn at 3.9 Saturn Radii(Rs), emits the plume mainly composed of water vapor from cracks in south polar region called “Tiger Stripe”. This plume cause the neutral particle rich inner magnetosphere and the neutral density is ten times greater than the plasma density. Though, its time variation and spatial distribution has been discussed by models and simulation studies, there are few studies based on observation data. We aim to understand the physical processes in the Saturn’s inner magnetosphere based on continuous observation of atomic oxygen [OI]630.0nm emission. The [OI]630.0nm emission are caused by resonance scattering with sunlight and by electron impact excitation.
In this study, we carried out the Enceladus torus observation with a 60-cm telescope(T60) at Haleakala observatory and a high-dispersion spectrograph (Vispec:Visible Imager and Spectrograph with Coronagrphy). During a period from 2015/7/13 through 2015/9/18. Vispec adopts 1024pix×1024pix cooled-CCD as a detector covering the wavelength of 629[nm]~632[nm] with a wavelength dispersion of 5.98×10^{-3}[nm/pix] with a 2x2 binning mode.
We used two kind of slits; one is 60[μm] width×10[mm] length, or 100[μm] width×10[mm] length, of which correspond to FOVs of 300”x2”,300”x3”, respectively. In the former slit case, the slit was centered at a distance of 3.9Rs from Saturn and aligned parallel to the east-west direction of Saturn’s equatorial plane (E-W slit), and in the latter slit case, the slit was aligned in north-south direction(N-S slit) centered the same point. Exposure time was 20[min] per 1 frame, and we totally obtained 74 frames (38 frames of E-W data, 36 frames of N-S data). Using the N-S silt data(22 frames, total exposure time is 7.3[hour]), we estimated the [OI]630.0[nm] at 3.9Rs in the east side of Saturn, and the result indicates that the emission intensity was below the detection limit of our observation system, which is less than 2.4[R] in 3-σ. But there is the possibility to improve this limit about three times better. Since the past study obtained in 2009 reported that the emission of [OI]630.0[nm] was 4.0±2.0[R]. We would be able to discuss the time variation of the [OI]630.0nm emission. One of the possible cause of variation is the difference of observation geometry. Saturn’s Ring-Opening Angle(ROA) observed from the earth vary every 15 years. Against ROA is 4.5[deg.](nearly horizontal) in 2009, ROA during our observation period is 22.4[deg.] So the number of atomic oxygen along the line of sight and the apparent spatial distribution of Enceladus torus were changed during the period. We also have to consider the variability of solar EUV flux, the activity of Enceladus plume and so on as the cause of this variation. In this presentation, I will discuss these causes by comparison with condition of past study.

Keywords: Saturn's inner magnetosphere, Enceladus, groundbased-observation

Test-particle simulation of elastic collisions between magnetospheric 500eV-50keV electrons and neutral H_2O molecules originated from Enceladus

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Water group neutrals (H_2O, OH, and O) in Saturn’s inner magnetosphere play the dominant role in loss of energetic electrons and ions because of abundance of the neutrals [e.g., *Paranicas et al.,* 2007; *Sittler et al.,* 2008]. The observations of injected plasmas in the inner magnetosphere suggest that these particles do not survive very long time due to the neutral cloud originated from Enceladus [e.g., Paranicas et al., 2007; 2008]. Thus, the previous studies suggested that the neutral cloud contributes to loss processes of plasma in the inner magnetosphere. However, little has been reported on a quantitative study of the electron loss process due to electron-neutral collisions.

In the present study, we examine the variation of energetic electron pitch angle distribution at the magnetic equator and loss rate of precipitated electrons into Saturn’s atmosphere through pitch angle scattering due to elastic collisions with neutral H_2O along Saturn’s dipole magnetic field line around Enceladus. We conduct one dimensional test-particle simulation for monoenergetic electrons along Saturn’s dipole magnetic field line around Enceladus when the co-rotating electron flux tube passes the dense H_2O region in the vicinity of Enceladus (~6.4 minutes). The initial electron pitch angle distribution is assumed to be isotropic.

Tadokoro et al., [2014] examined the variation of 1keV electron pitch angle distribution due to elastic collisions with the dense region of H_2O originated from Enceladus. The examination of elastic collisions with other electron energy is required to understand the electron loss process due to elastic collision. We show the loss rates through pitch angle scattering of electrons with 500 eV –50keV.

Keywords: Enceladus, Saturn, electron-neutral collision

