Global structure and heavy ion distribution in Mercury's magnetosphere

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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, center of dipole field is shifted to northward about 485km, which is equivalent to 0.2 Mercury's radius. Kinetic effects of heavy ions will also be important in Mercury's magnetosphere, 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 from 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 it to the global simulation of Mercury’ s magnetosphere. In this study, first we performed several cases of MHD simulation to investigate the interaction between solar wind plasma and offset dipole of Mercury. Solar wind densities are given 35cm^{-3}, and velocity for 400km/s which is typical value in the Mercury's orbit. IMF conditions comes from Parker Spiral which has strong Bx and By component at the Mercury's orbit, and fluctuations are added in By and Bz components. In the results of MHD simulations, global configuration of magnetosphere shows strong north-south asymmetry due to dipole offset and IMF-Bx in addition to dawn-dusk asymmetry which comes from IMF-By. IMF Bx also affects to the intensity ratio of north and south cusp pressure, while IMF By component “twist” the cusp region to longitudinal direction. The identification of global structures especially the cusp region is important not only for the understanding of magnetospheric physics itself, but also making a proposal to the observational plan of spacecraft such as Bepi-Colombo. In the presentation, we will also discuss the heavy ion distribution and precipitation on Mercury obtained by trajectory tracings of test particles.

Keywords: Mercury's magnetosphere, MHD simulation

LWA1 Jupiter radio monitoring during the Hisaki observation campaign

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The Long Wavelength Array (LWA) is a low-frequency radio telescope designed to produce high-sensitivity, high-resolution spectra 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. The sensitivity of the LWA1, combined with the low radio frequency interference environment, allows us to observe the fine spectral structure of Jupiter's decametric modulation lanes.
During the Hisaki observation campaign from January 1 to 15 in 2014 we made a series of observations to monitor Jupiter's decametric radio emissions by using LWA1. During this period we used 91 hours of total machine time of LWA1. We selected the LWA1 spectrograph observing mode (time resolution: 40ms, frequency resolution: 20kHz). The total volume size of the collected data was about 117GB.
During this observing period 14 non-Io-related events of Jupiter radio emissions were observed: 7 for the non-Io-A source, 6 for non-Io-B, and 1 for non-Io-C. We developed a system of semi-automatic data analysis in the study of Jupiter's decametric modulation lanes. By using this system we analyzed the 14 non-Io-related Jupiter radio emissions.
By the modulation lane method [Imai et al., 1997, 2002, 2006], the source parameters of the non-Io-related sources were analyzed. The source L-shell parameter in the case of non-Io-related sources is not well known; therefore, we assumed the fixed L-shell value. One non-Io-A event shows the different cone half-angle parameters between two groups of arc structures on the dynamic spectrum. All other non-Io-A events show almost the same value of cone half-angles based on the fixed L-shell value. The results of all non-Io-related data analysis will be discussed.

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Keywords: Jupiter radio, decametric emissions, modulation lanes, radio source parameters

Juno observations of Jupiter’ s dawnside magnetopause boundary layer

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Using recent observations obtained by particles and fields instrumentation on the Juno spacecraft, we present the properties of Jupiter’ s dawnside magnetopause in unprecedented detail. Through magnetic reconnection and viscous mixing (e.g., the Kelvin-Helmholtz instability) processes, Jupiter’ s dawnside magnetopause provides a pathway for solar wind plasmas to enter the Jovian magnetosphere. On 14 July 2016, we identify an extended magnetopause boundary layer (MPBL) indicative of significant mass transport across the magnetopause. For this event, minimum variance analysis revealed an open magnetopause with a sunward-tilted boundary normal, indicative of significant magnetospheric compression. Furthermore, we identify ~2 h increases in the total magnetospheric pressure adjacent to two magnetopause crossings. These structures are of an order of magnitude longer duration than typical magnetospheric transits (e.g., plasmoids, reconnection fronts) and may provide evidence of focused energy transport into the magnetosphere via magnetohydrodynamic waves.

Keywords: juno, jupiter , magnetosphere

Synergetic mission of simultaneous observations toward bow-shaped structures induced by atmospheric gravity wave on Venus with ALMA and Venus Climate Orbiter "Akatsuki"

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For understanding of the origin of short-term changes of the CO mixing ratio in the Venusian middle atmosphere observed by our ground based millimeter wave band 10m Telescope, SPART, it is essential to study the link between the atmospheric chemistry and dynamics in Venus. In December 9, 2015, the longwave infrared (LIR; 10 μm) band camera on board Venus Climate Orbiter "Akatsuki", which traces the temperature of the cloud tops, discovered the mysterious steady bow-shaped structures induced by atmospheric gravity waves on Venus. It is expected that the observations of the distributions of atmospheric minor constituents driven by the gravity waves/bow-shaped structures provide us important information about the link.

In November 20 and December 1, 2016 we carried out the synergetic observations with Atacama Large Millimeter/submillimeter Array (ALMA) and Akatsuki toward the western highland of Aphrodite terra where the next events of large stationary atmospheric gravity waves would be expected. The LIR camera of Akatsuki succeeded to shoot the images continuously at the perihelion. ALMA executed the observations of CO and ^{13}CO at 200 GHz band (Band 6) and CO, ^{13}CO, HDO, SO, and SO_2 at 300 GHz band (Band 7). ALMA in Cycle 4 consists of fifty 12m antenna arrays and Atacama compact arrays (twelve 7m antenna arrays and four 12m single dish antennas) to obtain a good coverage of the uv plane. The spatial resolutions for the Band 7 and Band 6 under the C40-4 antenna configuration during the observing period are 0.43 and 0.63 arcsec, respectively.

The Voigt line shapes of the spectral lines obtained by ALMA give us the information about vertical distributions of the minor constituents in the middle atmosphere of Venus. The wind velocity at the lower thermosphere of Venus is also derived from the Doppler shift of the spectral lines. On the other hand, by using the infrared and ultra-violet band cameras of Akatsuki the information about the dynamics and chemistry in the cloud region and troposphere are obtained. The highly resolved time-dependent 3D data obtained simultaneously by ALMA and Akatsuki give us a unique opportunity to standardize and connect our understandings of atmospheric dynamics and chemical reaction networks in the middle and lower atmospheres via H_2SO_4-H_2O clouds. In this conference, we will present the current status of the synergetic mission with ALMA and Akatsuki.

Keywords: Atacama Large Millimeter/submillimeter Array (ALMA), Venus Climate Orbiter "AKATSUKI", Venus, Atmospheric Gravity Wave , SPART Telescope, Planetary Atmosphere

Search of CH4 on Mars by SOFIA/EXES

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Discovery of CH4 in the Martian atmosphere has led to much discussion since it could be a signature of biological/geological activities on Mars. However, the presence of CH4 and its temporal and spatial variations are still under discussion. We performed sensitive measurements of Martian CH4 by using the Echelon-Cross-Echelle Spectrograph (EXES) onboard the Stratospheric Observatory for Infrared Astronomy (SOFIA) on 16 March 2016, which corresponds to summer (Ls = 123.2°) in the northern hemisphere on Mars. The high altitude of SOFIA telescope (~13.7 km) enables us to significantly reduce the effects of terrestrial atmosphere, and the high spectral resolution of EXES (R~90,000) enables us to detect the intrinsically narrow lines of Martian CH4 at the 7.5 μm band. . Mars disk was spatially resolved into 3 x 3 areas, none of the observed region showed the unambiguous detections of CH4. The upper limits on the CH4 volume mixing ratio ranges from 1 to 6 ppb.

Keywords: Mars, Methane, SOFIA

Toward development of a radiative transfer model for a planetary atmosphere general circulation model

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A lot of exoplanets have been discovered since late 1990s. One of the interesting open questions on those exoplanets is its surface environment and circulation structure. Exoplanets would have a wide variety of surface environment and circulation, since discovered exoplanets have a variety of orbital parameters, and composition and mass of atmospheres which may be significantly different from those of planets in solar system.
In order to investigate surface environment and circulation structure on exoplanets, the most important and difficult point is calculation of radiative transfer in its atmospheres. One of the difficulties to calculate accurate radiation field is to perform integration over wavenumber accurately. In the Earth's climate studies, many radiation models use the correlated k-distribution method to decrease calculation cost. As for a study of exoplanetary climate, we have to implement the k-distribution method for a wide variety of atmospheric composition and mass.
In order to investigate diversity of surface environment and circulation structure of exoplanetary atmospheres, we are trying to develop a radiative transfer model which can be used in atmospheric circulation models for various planetary atmospheres. In this study, as a first step, we are developing a longwave radiative transfer model for the Earth's atmosphere.
In developing a radiation model for atmospheric circulation models, a line-by-line model is developed, first. Then, we develop a radiation model based on correlated k-distribution method. In developing the correlated k-distribution model, the line-by-line model is used as a reference. The line-by-line calculation is performed with Voigt line profile calculated with Humlicek (1982) method. Gas absorption line parameters are obtained from HITRAN2012 (Rothman et al., 2013). Continuum absorption is considered by the use of the MT_CKD model (Mlawer et al., 2012). The line-by-line model is validated based on ICRCCM longwave radiation model intercomparison of Ellingson et al. (1991). In developing our longwave correlated k-distribution model, we set number and wavenumber ranges of bands and number of bins as the same as those of RRTM (Mlawer et al., 2012), which is a well-developed Earth's atmosphere radiation model. The developed correlated k-distribution model is validated by comparing flux and heating rate with those by our line-by-line model. In the presentation, details of the developed line-by-line model and the correlated k-distribution model will be presented. We will show some calculated results for the Earth's atmosphere, too.

Keywords: Planetary atmosphere, Radiative transfer, Earth

Global distribution of gravity waves activity in Mars' lower thermosphere derived from MAVEN/IUVS stellar occultations and analyzed using two Martian General Circulation Models

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Small-scale gravity waves (GWs) are recognized as an important part of the terrestrial climate system. They affect the dynamics, composition, and thermal structure of the terrestrial middle atmosphere and thermosphere. On Mars, most of information about GWs at altitudes 0-40 km has been obtained with radio occultation techniques and temperature profiles by MCS/MRO, while GW activity in the upper atmosphere was quantified using aerobraking measurements. Since previous studies did not establish a correlation between the GW activity in the lower and upper atmosphere, questions about thermospheric sources of the perturbations still remain to be addressed. Since October 2014, comprehensive studies of the Martian atmosphere have been performed with NASA's Mars Atmosphere EvolutioN (MAVEN) mission. In-situ measurement of the upper atmosphere, down to 130 km, revealed substantial wave structures in ions and neutrals. Wave structures have also been detected by remote sensing with Imaging Ultraviolet Spectrograph (IUVS) at altitudes between 30 and 150 km. IUVS measurement provide opportunities for investigating possible links between GWs in the Martian troposphere and thermosphere.
In this paper, we use the IUVS stellar occultation measurements to characterize a global distribution of GW activity in the lower thermosphere. We focus on the data obtained between March 2015 and March 2016. Two comprehensive general circulation models (MGCMs), a GWs resolving MGCM and the Max Planck Institute MGCM incorporating a state-of-the-art GW parameterization have been used to interpret the observations. The main results of this study are as follows.
(1) The observed perturbations demonstrate GW signatures with vertical wavelengths of 10-20 km and amplitudes of up to 10 % of the mean temperature (~13 K) and 15-20 % of the mean density.
(2) The observed wave potential energy in the lower thermosphere has larger values at middle latitudes. This is contrary to the distribution of GW activity in the lower thermosphere, whose maximum is located in low latitudes, but is consistent with simulations using the two MGCMs.
(3) Our MGCM simulations demonstrate that the background winds play a major role in vertical propagation of GWs generated in the lower atmosphere, which can explain the latitudinal distribution of the GW activity. High-resolution as well as parameterization GW simulations demonstrate a consistent picture of GW-induced temperature perturbations.
(4) The observed perturbations in the lower thermosphere are most likely caused by GWs of tropospheric origin penetrated from below.
We must emphasize that the spatial coverage of the existing MAVEN/IUVS occultation data is still poor to unambiguously establish the global distribution of the GW activity in the lower thermosphere. This should be a subject of further observations. However, the presented data, at least, do not contradict the model

predictions pointing to the lower atmospheric origin of these waves.

Keywords: Mars, gravity wave, thermosphere, MAVEN

MAVEN/NGIMS observations and full-particle DSMC modeling of gravity waves in the Martian upper thermosphere

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Global distribution and parameter dependences of gravity wave activity in the Martian upper thermosphere have been analyzed using density profiles obtained by the Neutral Gas Ion Mass Spectrometer (NGIMS) onboard the MAVEN spacecraft. The average amplitude of gravity waves around the Martian exobase is ~10% on the dayside and ~20% on the nightside, which is about two and ten times larger than those on Venus and in the low latitude region of Earth, respectively. The amplitudes are inversely proportional to the background atmospheric temperature, suggesting saturation due to convective instability in the Martian upper thermosphere. After removing the dependence on the background temperature, dependences of the average amplitude on the geographic latitude and longitude and solar wind parameters are found to be not larger than a few percent. These results suggest that the amplitudes of gravity waves are mainly determined by convective breaking/saturation in the upper thermosphere on Mars, unlike those on Venus and Earth. We have also performed numerical simulations of propagation, saturation, and dissipation processes of gravity waves in the Martian upper thermosphere using a full-particle Direct Simulation Monte-Carlo (DSMC) model. The modeling results are compared to the NGIMS observations with a particular emphasis on the vertical profiles of the wave amplitudes and their day-night variations to constrain the vertical and horizontal wavelengths of the observed waves.

Keywords: Gravity waves, Upper thermosphere, Mars

Solar energetic electron penetration into the Martian upper atmosphere observed by MAVEN

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Discovery of diffuse aurora at Mars caused by the SEP (solar energetic particle) electrons [Schneider et al., Science, 2015] sheds a new light on the high-energy particle environment at Mars. Since Mars has no global intrinsic magnetic field, direct interaction between the solar wind and Martian upper atmosphere results in the draping of the interplanetary magnetic field (IMF) around Mars and forms the induced magnetosphere. The diffuse aurora observation in the northern hemisphere, where the crustal field is absent, indicates penetration of the high-energy electrons of ~100 keV down to the altitudes around 70 km most likely along the draped IMF around the planet. However, to what extent the draped magnetic field configuration around Mars controls the SEP electron penetration to the atmosphere is far from understood.
In this study, we investigated three SEP events observed by MAVEN from December 2014 to March 2015. The pitch angle (PA) distributions of the high-energy (30-210 keV) electrons observed in the Martian ionosphere are analyzed in details. In order to achieve a good coverage in the 2-D (PA-energy) phase space, data obtained during a SEP event is accumulated and binned. Using the elevation angle of the local magnetic field, we also sorted the data so as to investigate the SEP electron loss below the MAVEN periapsis (~150 km altitude). The obtained PA distributions in the ionosphere are compared with the distributions of the source electrons in the magnetosheath. The results show that the field-aligned component is pronounced for the penetrating electrons and it does not significantly depend on the initial PA distributions in the magnetosheath. The observation also indicates that the highest energy of the SEP electrons lost into the Martian atmosphere depends on the magnetic field configuration draped around the planet. During the aurora event reported by Schneider et al. [2015], electrons with energy less than ~130 keV were lost into the atmosphere. These SEP observations thus support the scenario that the solar energetic electrons penetrate into the ionosphere along the draped magnetic field and the altitude to which they can penetrate depends on the magnetic field configuration.

Keywords: SEP, aurora, Mars, CME, MAVEN

Planetary SpaceWeather Services for the Europlanet 2020 Research Infrastructure

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Under Horizon 2020, the Europlanet 2020 Research Infrastructure (EPN2020-RI, http://www.europlanet-2020-ri.eu) includes an entirely new Virtual Access Service, “Planetary Space Weather Services” (PSWS) that will extend the concepts of space weather and space situational awareness to other planets in our Solar System and in particular to spacecraft that voyage through it. PSWS will provide at the end of 2017 12 services distributed over 4 different service domains –1) Prediction, 2) Detection, 3) Modelling, 4) Alerts. These services include **1.1) A 1D MHD solar wind prediction tool**, **1.2) Extensions of a Propagation Tool**, **1.3) A meteor showers prediction tool**, 1.4) A cometary tail crossing prediction tool, 2.1) Detection of lunar impacts, **2.2) Detection of giant planet fireballs**, 2.3) Detection of cometary tail events, **3.1) A Transplanet model of magnetosphere-ionosphere coupling**, 3.2) A model of the Mars radiation environment, 3.3.) A model of giant planet magnetodisc, 3.4) A model of Jupiter’s thermosphere, 4) A VO-event based alert system. We will detail in the present paper some of these services with a particular emphasis on **those already operational** at the time of the presentation.
The proposed Planetary Space Weather Services will be accessible to the research community, amateur astronomers as well as to industrial partners planning for space missions dedicated in particular to the following key planetary environments: Mars, in support of ESA’s ExoMars missions; comets, building on the success of the ESA Rosetta mission; and outer planets, in preparation for the ESA JUpiter ICy moon Explorer (JUICE). These services will also be augmented by the future Solar Orbiter and BepiColombo observations. This new facility will not only have an impact on planetary space missions but will also allow the hardness of spacecraft and their components to be evaluated under variety of known conditions, particularly radiation conditions, extending their knownflight-worthiness for terrestrial applications.
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Keywords: Planets, Space Weather, Services