Contamination in electron observations from Cluster/RAPID/IES instrument in the Earth's radiation belts and ring current

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For over 16 years, the Cluster mission passes through Earth’ s radiation belts at least once every two days for several hours, measuring the energetic electron intensity at energies from 30 to 400 keV. This vast amount of data has previously been considered as rather useless due to contamination by penetrating energetic particles (protons at >100 keV and electrons at >400 keV). In this study, we assess the efficiency with which aluminium shielding of RAPID/IES detector filters out contaminating high-energy electrons and protons. We base our estimation on the analysis of experimental data and a radiation transport code (Geant4). In our simulations, we use the incident particle energy distribution of the AE9/AP9 radiation belt models. We identify the Roederer L-values and energy channels that should be used with caution and show examples of misinterpreting the data. Comparison of the data with electron and proton observations from RBSP/MagEis indicates that the subtraction from the IES electron data of proton intensities at energies ˜230–630 keV cleans well the data from the proton contamination. We show that the data from this detector measured in the radiation belts is still useful for many scientific applications. This is very valuable as it provides one of the longest available radiation belt data sets.

Keywords: particle detector, contamination, radiation belts

An Overview of the First Japanese Formation Flight Mission Using Compact Satellites for In-Situ Observations of the Space-Earth Coupling Mechanisms

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We summarize the recent progress and latest status of our formation flight mission for the integrated in-situ observations using compact satellites in a polar orbit at altitudes of about 300-4000 km, particularly on the technical investigations and the possibilities of substantial international collaborations. The most important science target in this mission is the demonstrative and quantitative investigation concerning the physical processes and mechanisms controlling the space-Earth connections. In the case of our planet, Earth, the magnetosphere-ionosphere-thermosphere couplings are the observational objectives on the basis of the direct and simultaneous measurements at multipoints using 2-4 compact or micro satellites designated for the advanced space explorations. We tentatively call this mission FF-MIT (Formation Flight exploration for Magnetosphere-Ionosphere-Thermosphere coupling mechanisms). The detailed mission targets and the state-of-the-art methodology will be given in this presentation. The key issues of this FF-MIT could be listed as follows: Transports and conversions of plasma and electromagnetic energies across the space-Earth boundaries, Planetary/space plasma accelerations and mass escape via the wave-particle interactions, Response of the neutral atmosphere to space plasma activities via the plasma-neutral interactions.
Because we have been carrying out the novel types of the observations with the previous polar orbiting satellite, Reimei, and several sounding rockets called SS-520, it is quite realistic and appropriate that we make a convincing and promising proposal for more advanced future mission. Our team also has the best experience and heritage in Japan of the space plasma measurements owing to our essential participations and contributions in previous and on-going missions, for instance, Geotail, Kaguya, BepiColombo-MMO, ERG(Arase), and MMS. In particular, the challenging technique for the wave-particle interaction analyses developed for the Arase satellite mission would be applied also in the FF-MIT mission for quantitative estimates of the energy transports in the transversal ion accelerations and Alfvenic electron accelerations parallel to the local magnetic field occuring in the polar ionosphere.
Since September of 2016, we have been addressing several technical and engineering subjects through the discussions and investigations with the engineering groups in JAXA and the design/fabrication teams in manufacturers. The satellite configuration/specification and the cluster launch capability with the Epsilon rocket of JAXA should be clarified and fixed before the working group establishment and the mission proposal submission. It is also plausible to consider some international collaborations regarding the satellite provision and the instrumental contributions in order to strengthen the scientific objectives and simply increase the possibily of simultaneous multi-point observations. From this viewpoint, we have already started the face-to-face discussions with some overseas research groups.
In addition to this FF-MIT space exploration using the formation flight technique, it is also essential to coordinate and perform simultaneous observations with progressing ground-based observational facilities/equipments like EISCAT_3D, high-speed optical imagers using EMCCD in order to obtain the physical parameters especially in the wider dimensions/areas of the upper atmosphere. The specialized science center would be required for effectively coodinating these integrated observations in space and on the ground and significantly organize and expand the data analyses/modeling/simulation activities,

which are very similar to the situation of the successfully on-going Arase project owing to our vast efforts. We are planning to propose the FF-MIT mission toward the realization of the fascinating demonstrative research based on this cutting-edge space exploration mission and the powerful ground-based sites in mid 2020s.

Keywords: Space Plasma, Neutral Atmosphere, Space Electromagnetic Fields and Wave, Integrated Observation, Formation Flight, Advanced Compact Satellite

Development of TOF-MS for planetary exploration

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In-situ material measurement in planetary exploration is important in understanding origin and evolution of the planets. For the purpose of performing in-situ elemental analysis, mass spectrometers are installed, for example, on NASA’s Curiosity rover and the ESA’s Rosetta spacecraft. However, researchers in Japan still do not have a mass spectrometer that is suitable for the future planetary exploration. Therefore, we have decided to develop a Time-Of-Flight Mass Spectrometer (TOF-MS) aiming at using for the future planetary exploration. Among different applications for our mass spectrometer is in-situ Potassium-Argon (K-Ar) isochron dating. In situ Potassium-Argon (K-Ar) isochron dating is the combination of a laser-induced breakdown spectroscopy (LIBS) for the K concentration measurement and a mass spectrometer for the Ar isotopic measurement. Considering that the instrument should be installed on a planetary lander, there exists limitation on the weight, size and power, it is necessary to design a small size mass spectrometer which has a mass resolution capable of the Ar isotopic measurements. In order to minimize the variation of the initial position and initial energy of the ionized ions for maximizing the mass resolution, we adopted a single-stage reflectron with two-stage acceleration part. We have analytically optimized the design parameters of the TOF-MS. By using SIMION field and charged particle trajectory simulation software we have confirmed that mass resolution of our TOF-MS is high enough for Ar isotopic measurements. We will report the current status of our TOF-MS development. In addition, we will report the status of the multi-reflector type TOF-MS which has the potential to increase mass resolution under the size constraint.

Keywords: TOF-MS, K-Ar dating, Planetary Exploration

One-chip plasma wave observation system

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Plasma waves are important observational targets for scientific missions investigating space plasma phenomena. Thus plasma wave receivers are commonly used in space explore scientific missions; however, a size of the receivers is the common issues. Since plasma wave receivers require high-performance analog circuit such as low-noise filter, high order filter, and high gain amplifier, the area of the analog part of the receiver tend to be large. In addition, recent plasma wave receivers perform various digital processing onboard, and it leads to an increase in size and power consumption.
We propose a one-chip plasma wave observation system. Plasma wave receiver is composed of three parts: analog part, analog to digital converter (ADC), and digital part. In the conventional receiver, analog part is realized by discrete electronic circuits, and digital part is realized by using FPGAs or CPUs. The one-chip plasma wave observation system aims to realize both analog and digital part in a chip as an analog-digital mixed Application Specific Integrated Circuits (ASIC). It allows miniaturizing plasma wave receiver extremely.
Figure 1 shows the block diagram of the one-chip plasma wave observation system. The system includes two types of plasma wave receivers: waveform and spectrum receivers. Since two types of plasma wave receivers have complementary characteristics, using both types of receivers is recommended for plasma observations. We plan that the system includes six channels of waveform receivers and two channels of spectrum receivers on a 10 mm x 10 mm chip. Two receivers require different analog and digital circuits. We succeeded in developing the analog circuit for waveform receiver, the analog circuit for spectrum receiver, and ADC, and the dimensions of each circuit were 2.9 mm x 0.7 mm, 4.2 mm x 1.2 mm, and 3.2 mm x 0.8 mm, respectively. Regarding digital circuits, waveform compression circuit for waveform receiver and fast Fourier transform circuit and the controller for spectrum receiver are required. We address to realize one-chip receiver by developing digital part as an ASIC and combine analog and digital part into one ASIC chip.
In the presentation, we will introduce the detailed design of the one-chip plasma wave observation system, especially the spectrum receiver that uses our new method that can overcome the disadvantage of conventional spectrum receiver.

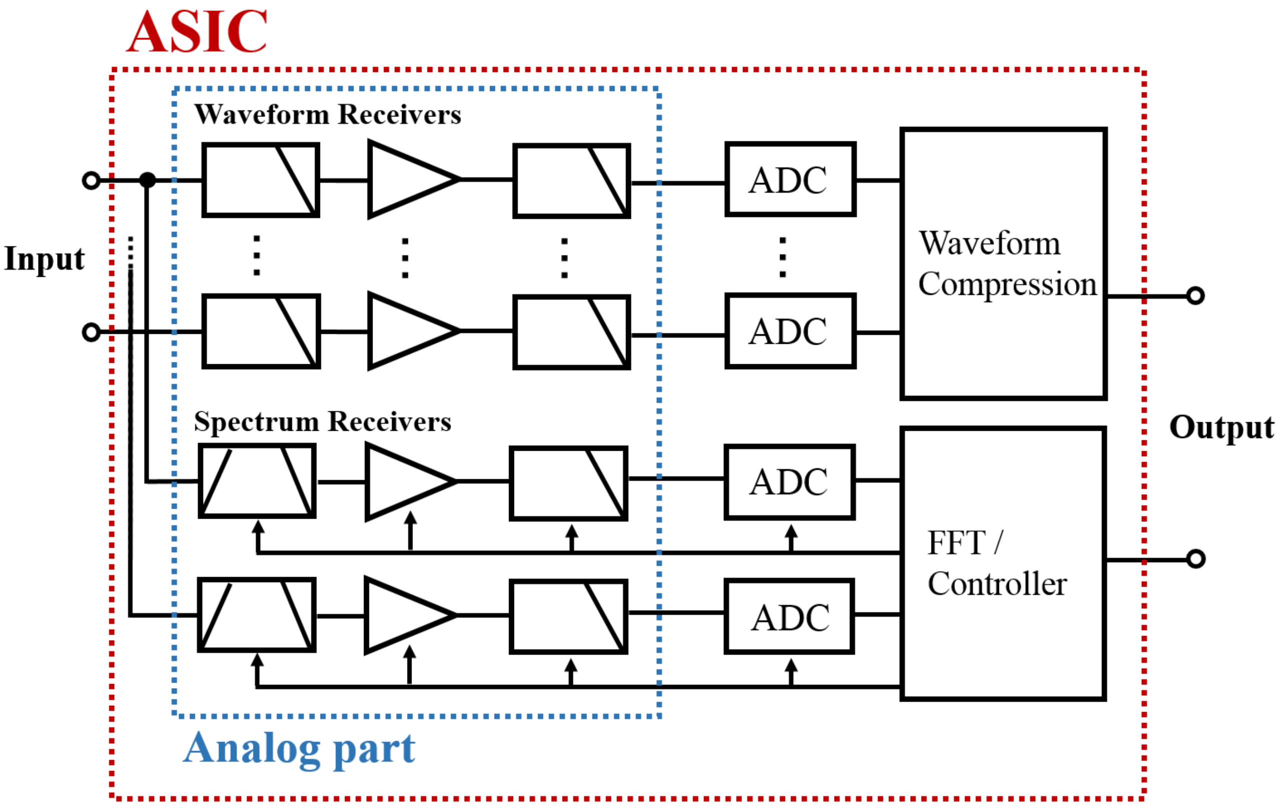

Figure 1. Block diagram of the one-chip plasma wave observation system.

Development of a miniaturized search coil magnetometer for cube-satellite experiments

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Since the size of a cube-satellite is very small (e.g, a 1U cube-satellite has a size of 10 cubic centimeters), it is required a miniaturization technique of scientific instruments for probing the plasma waves using cube satellites. We have developed a miniaturized search coil magnetometer for 1U cube-satellite experiments, by using Application Specific Integrated Circuit (ASIC) technology to drastically reduce the system resources (mass, volume and power).
A 6-cm search coil is developed to probe the plasma waves onboard a 1U cube-satellite. The magnetic sensitivity of the search coil depends on its sensor size. Since the effective permeability of a magnetic core decreases with the sensor seize, the magnetic sensitivity using a small sensor degrades. It is necessary to compensate for the low effective permeability by using a low noise preamplifier. We have developed a low noise ASIC preamplifier. The size of the ASIC preamplifier is 6.25 mm^2 and the power is 5.1 mW. The input equivalent noise is 10 nV/sqrt(Hz) at the frequency of 1 kHz. The ASIC preamplifier has a high tolerance against harsh space (radiation and temperature) environments. In the radiation tests, the ASIC preamplifier did not break down for high energy alpha ray incidence (220 MeV, over 5-hour exposure). The input equivalent noise of the ASIC preamplifier did not change before and after the gamma ray (3 Mrad) exposure. The operation temperature range of the ASIC preamplifier is minus 60 to plus 100 degrees Celsius. Additionally, we have developed an ASIC waveform receiver to miniaturize all of the wave measurement systems. The size of the ASIC waveform receiver including a 6th-order Chebyshev anti-aliasing low pass filter is 2.8 mm^2, the power is 26 mW, and the input equivalent noise is 660 nV/sqrt(Hz) at the frequency of 1 kHz. In the radiation test (alpha ray of 220 MeV), the input equivalent noise of the ASIC waveform receiver increased by up to 10 dB at the frequency of 100 Hz by the effect of the Total Ionizing Dose. However, the ASIC waveform receiver did not break down at the total dose of 400 krad. The operation temperature range of the ASIC waveform receiver is 0 to 60 degrees Celsius. We measured the magnetic sensitivity of a 6-cm search coil connected to the ASIC preamplifier and the ASIC wave form receiver. The magnetic sensitivity of the sensor is 0.2 pT/sqrt(Hz) at the frequency of 1 kHz, with which it is possible to probe the typical plasma waves such as chorus and hiss in the Earth’s magnetosphere.
In the presentation, we will present the miniaturized search coil magnetometer designed for 1U cube-satellite experiments in detail.

Keywords: Search coil, Cube satellite, ASIC

NANOSATS FOR A LOW FREQUENCY SPACE-BASED RADIO INTERFEROMETER

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During the last decades, space physics and radioastronomy have dramatically changed our knowledge of the Universe and his evolution. However our view is still incomplete at the lowest frequencies range (below 30 MHz), which remains the last unexplored spectral band. Below 30 MHz, ionospheric fluctuations strongly perturb ground based radioastronomy observations. They are impossible below 10 MHz due to the ionospheric cutoff. Furthermore, man made radio interferences make these observations even more difficult. Deploying a space borne radio observatory is the only way to open the last window on the Universe. This spectral window starts at a few kHz, which is the local solar wind radio cutoff frequency and ends between 10 and 30 MHz. The science objectives of this observatory are diverse and numerous: the dark ages of the Universe, the mapping of the Galaxy, pulsars and astrophysical transients, space weather, the atmosphere and magnetospheres of solar system planets and exoplanets.

NOIRE (Nanosats pour un Observatoire Interfromtrique Radio dans l’Espace; Nanosats for a space borne in- terferometric radio observatory) is an ongoing feasibility study with PASO (Plateau d’Architecture des Syst`emes Orbitaux; Space Systems Architecture Service) at CNES that assesses the feasibility of a low frequency space radio interferometer using nanosatellites.. It is conducted in collaboration with Dutch colleagues involved in several space borne low frequency radio interferometers projects (OLFAR, DEx, SURO, DSL...) Bentum et al. (2011). The goal spectral range of NOIRE is 0.1 to 100 MHz. The technologies and methods (particularly interferometric imaging) developed for LOFAR, NenuFAR or SKA are useful ingredients for such a project.

Keywords: Radioastronomy, Interferometry, Space Physics, Nanosatellites

JPL’ s Strategic Plan for Solar System Exploration

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As NASA’ s lead center for solar system exploration, JPL is responsible for the design, implementation, launch and operation of NASA’ s large strategic missions. JPL also competes for NASA medium-size New Frontiers and smaller-size Discovery, “cubesat” and “smallsat” missions. The Laboratory also contributes scientific instruments to US and international missions via the announcement of opportunity proposal process that is conducted by NASA. JPL also develops enabling technologies using funds provided by NASA, non-NASA US agencies, and JPL internal funds. The decisions that lead to the portfolio of missions, science instruments and technologies are based upon the most current decadal survey that is created every ten years by the US National Research Council (NRC) at the request of NASA. The refrain “we follow the decadal” is often heard at NASA, JPL and throughout the US solar system exploration community. In this talk, I will summarize the key elements of the current NRC decadal survey called “Visions and Voyages,” and show how the portfolio of JPL missions, instruments and technologies relate to the recommendations of “Vision and Voyages.”

Keywords: Solar System, Space missions, Space instruments

Concept Study of Coring Sampling System for Martian Moons Exploration Mission

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Japan Aerospace Exploration Agency (JAXA) /Institute of Space and Astronautical and Science (ISAS) is studying Martian Moons Exploration (MMX) Mission that is the first mission in the world to collect and return sample from Phobos or Deimos. MMX is planned to be launched in or after 2024.
We conducted a concept study of a specific sampling system that is one of the most important mission equipment of MMX for engineering mission objectives as well as science objectives. We studied a sophisticate sampling system applying coring technic and manipulation system to meet both science / engineering mission objectives and requirements. In this report, we will report a result of the concept study and outline of the sampling operation in MMX mission.

Keywords: Sampling System, Martinan Moons Exploration

An experimental study of permeable membrane for Ne isotope measurement aiming for future Mars mission.

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Present Mars has cold and dry climate with a very thin atmosphere. However, early Mars may have possessed warm and wet climate with a large amount of atmosphere. One possible cause for such drastic change in climate and atmospheric mass on Mars is escape of atmosphere to space, but actual process of such possible atmospheric loss has not been understood well yet. One of the reasons for this uncertainty comes from the lack of our knowledge on how much Martian atmosphere has been lost. Noble gases, which are chemically inactive, are important for estimating the degree of the atmospheric loss. The non-thermal escape, such as pick-up ion sputtering, induces isotopic fractionation because lighter isotopes are selectively lost, resulting isotopic compositions in the atmosphere to be heavier. Since light noble gases, such as Ne, are sensitive to such a mass fractionation process, its isotopic ratios are useful for constraining the degree of the atmospheric loss. Thus, isotopic ratios of Ne are important in understanding the evolution of Martian atmosphere.

However, the Ne isotopic composition of Martian atmosphere has not been measured directly either by Viking or Curiosity. A typical lightweight mass spectrometer with moderate mass resolution ($m/\Delta m$ ~ 100) , such as a quadrupole mass spectrometer (QMS), cannot distinguish $^{40}Ar^{++}$ from $^{20}Ne^{+}$ signal because the difference in their mass/charge ratios is very small ($m/\Delta m = 1777$). Thus, Ar needs to be removed from sample gas before mass spectrometric measurements.

In order to achieve direct measurements of the Ne isotopic ratio with a future Mars lander, we are developing a gas measurement system with a permeable membrane. In this study, we experimentally investigate the difference in permeability of Viton sheets between Ar and Ne. Our experimental results indicate that a Viton sheet with 1 mm in thickness can increase the abundance ratio of Ne to Ar from the atmospheric value of ~10^{-3} to ~1. We also measured the ratio of $^{40}Ar^{++}$ to $^{40}Ar^{+}$ using a QMS with a typical ionization voltage (70V). The results show that the amount of $^{40}Ar^{++}$ produced during the ionization process in the QMS is about 10% of that of $^{40}Ar^{+}$. Thus, gas sample permeated through the Viton sheet would have $^{40}Ar^{++}$ contribution about 10% of $^{20}Ne^{+}$ contribution. These results suggest that the Ne isotope measurements can be achieved with uncertainty better than 10% after correcting for the contribution of $^{40}Ar^{++}$. Since Martian atmospheric pressure is about two orders of magnitude lower and $^{20}Ne/^{40}Ar$ ratio is about one order of magnitude lower in Martian atmosphere, the separation efficiency could decrease compared to that at the terrestrial atmospheric condition. However, it has a room for significant improvement by optimization for various parameters, such as materials, thickness, and duration of permeation. These results suggest that measurements of Ne isotopic ratio in Martian atmosphere may be achieved with this approach after optimization.

Keywords: Martian atmosphere, Ne measurement, Mars mission, mass spectrometer, instrument development

Development of LDM (Life Detection Microscope) for the in situ imaging of living cells on surface of Mars

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Past trial of direct detection of life on Mars by 1970's Viking mission ended up with a negative conclusion [1]. Whereas, numbers of new finding provided by Mars exploration missions in the last decade indicate that there are good reasons to perform another life detection program. The sensitivity of the gas chromatograph mass spectrometer onboard the Viking mission was not very high, and was not able to detect the microbes 10**6 cells in 1 gram clay [2,3]. Here we propose Life Detection Microscope (LDM) that has much higher sensitivity than the instrument onboard Viking. LDM will achieve high sensitivity of microbial cells by observing sufficient volume of soil sample on Mars. It is also important to have the resolution 1 micrometer to detect microbial cells.

Resent observations on Mars have found the evidences of past water activities. MSL Curiosity has found the temporal increase of methane concentration in Martian atmosphere [4]. The presence of reduced sulfur compound such as pyrite in Martian soil was also detected by MSL [5]. Methane and reduced sulfur compound can be the energy source to support the growth of chemoautotrophic microbes [6]. Possible presence of liquid water at Recurring Slope Lineae has been supported by the detection of hydrated salts [7]. The presence of organic compounds of Martian origin has been reported [8]. These evidences tend to support the possible presence of living microbes near the surface of Mars.

Physical and chemical limits for terrestrial life have been major foci in astrobiology [9], and are summarized in ref. [6]. Combining the environmental factors, anywhere in the Martian environment where we can find the three components, water molecules, reducing compounds and oxidative compounds could be an environment where life can be sustained for long periods of time, if other factors such as temperature, pressure, UV and other radiations permit [6]. Among these factors, most of the factors including ionic radiation, can be endured by terrestrial extremophiles. Only UV can kill the most UV-resistant microbes within minutes. However, UV can be shielded by a-few-centimeter sail layer. These evaluation lead to the conclusion that the Martian soil under a few cm can be the place to support the growth of microbes, if the water activity is higher than 0.6.

We will report the current status of the development of the LDM. We propose to search for cells from a depth of about 5 - 10 cm below the surface, which is feasible with current technology. Microscopic observation has the potential to detect single cells. We have developed the solution and combination of fluorescence pigments to detect organic compounds, and to differentiate organic compounds surrounded by membrane. The subsequent analysis of amino acids, in the following mission, will provide the information needed to elucidate the origin of the cell.

LDM that we propose here could detect less than 10**4 cells in 1 gram clay [6]. Our life-detecting instrument has the sensitivity that is two orders of magnitude higher than the one onboard Viking. LDM is capable of identifying what we think to be the most fundamental features that a cell should possess to constitute life. Our Investigation Goals are the followings. 1) Identify cell-like structure in which organic compounds are enveloped by membrane, which may represent Martian life. 2) Search for any type of organic compounds in Mars surface samples. The compounds include cells, other biological materials, and abiotic polycyclic aromatic hydrocarbon (PAH). 3) High-resolution characterization of regolith and dust particles. The current status of development of LDM will be presented.

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Keywords: Mars, Life search, Fluorescence microscope, Microbe, Organic compounds

Ultraviolet Spectrograph for Exoplanet Transit Investigations (UVSETI) onboard World Space Observatory - Ultraviolet (WSO-UV)

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The Russian space telescope, World Space Observatory - Ultraviolet (WSO-UV), will be launched in 2021. WSO-UV has a primary mirror with 1.7 m diameter and several spectroscopic instruments. We are now proposing to install a spectrometer, Ultraviolet Spectrograph for Exoplanets Transit Investigation (UVSETI), to WSO-UV in a partnership with Space Research Institute of the Russian Academy of Sciences (IKI). The key science target of UVSETI is detecting biomarkers of exoplanets by transit observations of Earth-type exoplanets. If the Earth is located in a habitable zone of a M-dwarf star, we expect that optically thick oxygen exosphere is expanded up to 8 Earth-radii due to the short distance from the star and thus strong UV flux. In such case we can detect the oxygen atmosphere of an Earth-type exoplanet by UV transit observation. UVSETI consists of a input slit, a troidal grating (2400 lines/mm), and a microchannel plate (MCP) detector. The target spectral range is 120-135 nm including OI (130.5 nm) and H Ly-alpha (121.6 nm). As a baseline design, all components are qualified in several space missions (e.g., Hisaki/EXCEED, BepiColombo/PHEBUS, and CLASP). In parallel we have started new developments to increase the detection efficiency of the instrument. In this presentation we show the key sciences, the preliminary desin, and the feasibility of UVSETI.

Keywords: Exoplanet, Oxygen atmosphere, Transit

EUV imaging for Earth's plasmasphere from Earth-Moon L2 point by nano-spacecraft named EQUULEUS

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The nano-spacecraft mission named EQUULEUS is now under development. It will be launched in 2018 as one of the secondary payloads of SLS (Space Launch System) mission of NASA. EQUULEUS will fly to a libration orbit around the Earth-Moon L2 point and demonstrate trajectory control techniques within the Sun-Earth-Moon region (e.g. low-energy transfers using weak stability regions) for the first time by a nano-spacecraft. A small telescope in extreme ultraviolet named PHOENIX will be boarded on EQUULEUS. It consists of multilayer-coated entrance mirror (diameter of 6 cm) and photon counting device (microchannel plate and resistive anode), and electronics parts. The reflectance of mirror is optimized for the emission line of ionic helium (wavelength of 30.4 nm) which is the important component of the plasmasphere of the Earth. By flying far from the Earth, the entire image of plasmasphere can be obtained. Our observation will complement and enhance the geospace in-situ plasma measurements conducted by the ERG (JAXA) and Van Allen probe (NASA) missions. As a result, we can understand natures of geospace and radiation belt, which we have to understand to realize future manned space exploration. In this presentation, the mission concept and the design of the telescope will be shown. The status of the development will also be shown.

Keywords: nano-spacecraft, Plasmasphere, EUV imaging