A Future Formation Flight Mission of Compact Satellites and Mission-Oriented Developments of Plasma/Neutral Particle Analyzers for Elucidating Space-Terrestrial Coupling Mechanisms

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In 21st century, we led the Reimei mission realizing the fine-scale auroral emission and particle observations by the high-time/spatial resolutions and also initiated the ERG mission based on the trinity research system consisting of in-situ observation using spacecraft, ground-based network observation, and data analysis/modeling approach. The main scientific targets of these missions are the space plasma dynamics occurring universally in the regional and energy couplings in the terrestrial ionosphere and magnetosphere. Through these space exploration missions, we have actually noticed and been proposing the importance of coherent cooperation in the different methodologies (in-situ/ground-based observations, data analyses, modeling/simulation) as well as the significance of appropriate international collaborations, especially in the instrumental developments. It should also be noted that some novel ideas and the cutting-edge technologies matching them have been stimulating new exploration missions. For example, the high-resolving simultaneous measurements of auroral emissions and particles were carried out in the Reimei mission by using both our original auroral camera and plasma instrument. Recently, we are also developing so-called software-type wave-particle interaction analyzer (S-WPIA) in ERG in order to elucidate the energy transport between the plasma waves and particles in the collisionless plasma regime. These research experiences and expertise in our community are now leading new research activities to propose a new exploration mission using polar formation-flight configuration of compact satellites for the space-terrestrial coupling mechanisms. In this future mission, we will directly investigate the interactions and couplings in the plasma and neutral particles and the electromagnetic fields and waves in addition to the plasma wave-particle interaction analyses for the ionospheric transverse ion acceleration (TIA) and the simultaneous auroral emission-particle observations for the magnetosphere-ionosphere coupling processes like Alfvenic electron acceleration and their related auroras, and the field-aligned current distribution and variation. In this presentation, We introduce the formation-flight exploration mission using compact satellites and also discuss the instrumental development plans for their realization.

Keywords: space plasma, atmospheric neutral particle, space electromagnetic fields and wave, integrated observation, compact satellite, formation flight

Digital Data Processing Module in the Low Frequency Analyzer System (LFAS) for the SS520-3 Rocket Experiment

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We introduce a digital data processing module for low frequency analyzer system (LFAS) on the “SS-520-3” rocket. The main objective of the SS520-3 rocket experiment is to identify ion acceleration and heating mechanism in the polar cusp region. The LFAS is equipped with two type of receivers; EFD (electric field) and WFC (waveform capture). The EFD measures electric wave field in the frequency range from DC to 400 Hz and the data will be sent by analogue telemetry, while WFC covers electric field measurements in the VLF range below 10 kHz and generate digital data which consist of one channel of spectrum and two channels of waveform. In order to achieve real-time data processing of the WFC receiver on the rocket, we plan to develop digital data processing modules on FPGA. The digital modules consist of three FFT modules with cascaded decimation filters for spectrum analyzers and a lossy data compression module for waveform data for the purpose of data reduction. We have already developed a general-purpose FPGA board for evaluation of various kinds of signal processing [1]. We can integrate our own signal processing module on it without any complicated wiring work for the peripheral circuits and evaluate the performance of our proposed module. In the presentation, we report the current design of these data processing modules.
[1] Y. Kasahara, H. Matsui, and Y. Goto, Abstract of JPGU Meeting 2015, PCG31-19.

Keywords: Plasma Wave Receiver, SS520-3 rocket, Digital signal processing

Development of short-range LIDAR for future Mars landing mission

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The thermal structure of the atmosphere is controled by the distribution of small particles (aerosol particles).
They absorb and scatter a part of the solar radiation and the thermal emission from the surface. The spatial and size distribution of small particles is therefore a key to understand the thermal structure of the atmosphere.
This is also the case for Mars. The red planet is known as having a dusty atmosphere whoes thermal structure drastically changes depending on the distribution of the dust grains. The total amount of the dust grains in martian atmosphere is to be decided by the balance between the supply of dust grains from the surface and the sink of dust grains onto the surface. But the mechanism of the dust supply is unclear yet. Although dust-devils are proposed to be the most plausible mechanism to make the dust grains detached from the surface, the efficiency of the dust detachment is still hard to estimate. This is because the efficiency depends on many factors, such as the shape of a dust grain, the humidity, the electrostatic state of the dust grain and the surface, the size distribution function of dust grains on the surface, and so on.
To unveil the distribution and the motion of dust grains in a dust devil, we are developping a LIDAR. This LIDAR observes the dust grains on the line of sight in the range of around 100m with the spacial and temporal resolution less than 1m and 1s, respectively. The verification test of the LIDAR is conducted at the large wind tunnel at Meteorological Research Institute, Japan Meteorological Agency.

Keywords: LIDAR, dust, dust devil

Development of an ultraviolet spectrometer for the Mars/Phobos exploration

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The UltraViolet Spectrometer (UVS) is a strong tool for observing the Martian atmosphere and the surface of its moon, Phobos. For example, UVS can observe the absorption of the ozone (~250 nm) in the Martian atmosphere. Ozone is a key species for understanding the stability and evolution of the Martian atmosphere. UVS can also observe the surface albedo of Phobos at the wavelength of 220 nm interpreted of polycyclic aromatic hydrocarbon (PAH) origin. The presence or absence of PAH is important to understand the origin and evolution of Phobos. In this presentation, we will show the optical design of UVS and the methods of measurements of the global distribution of total ozone on Mars and the surface composition of Phobos.

Keywords: Mars, Phobos, Deimos, Ultraviolet, Spectroscopy

SS520-3 Sounding Rocket Experiment Targeting the Ion Outflow over Dayside Cusp

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The SS520-3 sounding rocket is currently planned to be launched from Ny-Ålesund, Svalbard in Spitsbergen in December 2017. The objectives of this sounding rocket is to understand the particle acceleration processes that cause the ion outflow by making in-situ observation of the wave-particle interaction over the dayside cusp region. The wave-particle interaction is going to be resolved by WPIA (Wave Particle Interaction Analyzer) that is newly developed for satellite missions. Since these wave-particle interactions are predicted to be effective above ~800km altitude, a two-stage sounding rocket SS520 whose apex can be higher than 800km is necessary. The rocket range where SS520 can be launched over dayside cusp is only SvalRak at Ny-Ålesund in Svalbard. This sounding rocket experiment is a part of the comprehensive observation campaign including ground based radar (EISCAT Svalbard Radar) and optical observations. Following 10 science instruments are planning to be on board the SS520-3 sounding rocket. 1) Digital FluxGate magnetometer (DFG) 2) Coupled Dark State Magnetometer (CDSM) 3) Low Frequency Analyzer System (LFAS) 4) Thermal ion Spectrum Analyzer (TSA) 5) Low Energy Particle experiment (LEP) 6) Ion Mass Spectrometer (IMS) 7) Fast Langmuir Probe (FLP) 8) Needle Langmuir Probe (NLP) 9) Plasma and Wave Monitor (PWM) and 10) Sun Aspect Sensor (SAS). Part of the data simultaneously obtained by LFAS, TSA and IMS are stored in a memory on the sounding rocket with high data rate and the downloaded data are analyzed on the ground, which functions as WPIA. Two of the 10 science payloads CDSM and NLP are going to be provided by Austria and Norway, respectively.

Keywords: Sounding Rocket, Ion Outflow, Cusp

Development of a light-weight X-ray imager for future explorer missions

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We would like to introduce a ultra light-weight X-ray optics and present recent results on X-ray performance test with these optics.
X-ray observatories are essential for X-ray astrophysics. Hence, revolution of observation technologies could lead to new discoveries. Detection of X-rays from the solar system objects including planets (Venus, Earth, Mars, Jupiter, Saturn), satellites (Moon, Galilean satellites), comets, and heliosphere is one of the discovery by recent X-ray observatories, i.g., Chandra, XMM-Newton and Suzaku. Representative mechanisms of their X-ray emission could be divided into three categories. First one is an elastic and a fluorescent scattering of solar X-rays by neutrals in the planetary atmosphere. Second one is a charge exchange with neutrals in the tenuous planetary exosphere and the cometary gas. Last one is collisions of energetic electrons in the planetary aurora with atmospheric neutrals producing bremsstrahlung emission and emission lines. Since these mechanisms are closely related to surrounding environments of the objects, we can obtain detailed information on planets such as density and spatial distribution of not-well known planetary tenuous atmosphere and magnetosphere. Overall pictures of them can be taken with remote sensing X-ray observatories. On the other hand, snapshots are obtained by the in-situ explorer missions. They are complementary to the in-situ explorer missions.
A key technique for the X-ray explorer or small satellite missions is a reduction in weight of optics. Conventional X-ray optics have a trend that optics with better angular resolution have larger ratio of the weight to effective area. Therefore, it is difficult to utilize them for the X-ray planetary missions which has a severe weight limit. Micro pore optics are being developed based on a concept of a miniature optics. To compensate decrease of reflection area, amount of mirrors are needed to increase. We have developed a novel type of micro pore optics with MEMS (MicroElectroMechanical System) technologies (Ezoe et al. 2006, 2010). We call them MEMS X-ray optics.
An instrument composing of the MEMS X-ray optics and a radio-hard semiconductor pixel detector is being developed. It aims at the first in-situ measurement of X-ray emission related to planetary atmosphere and magnetosphere. For example, JUXTA (Jupiter X-ray Telescope Array) is intended to observe Jovian X-rays (Ezoe et al., 2013). It covers 0.3-2 keV with the energy resolution of <100 eV at 0.6 keV. The major advantage of JUXTA compared to the Earth-orbiting X-ray observatories is proximity. Hence, if JUXTA has the effective area of 3 cm^2 at 0.6 keV and the angular resolution of 5 arcmin and orbits in ~30 Jovian radii at periapsis, these numbers scaled to the Earth orbit observation of Jupiter are 24 m^2 and 1 arcsec, respectively.
We fabricated the MEMS X-ray optics for JUXTA. The MEMS X-ray optics are made of 4-inch silicon wafer with 300 um thickness. A lot of micro-pores are formed in the thin silicon wafer by photolithography and deep reactive ion etching (DRIE). A typical pore width is 20 um and the sidewall of these pores play a role as X-ray reflective surfaces. After DRIE, sidewalls of the pore structures are smoothed by annealing in order to reflect X-rays with a micro roughness of less ~1 nm rms. Finally, the wafer is plastically deformed to a spherical shape. We constructed an approximately Wolter type-I telescope stacked two bending 4-inch optics with different curvature radii, and confirmed a clear X-ray focus for the first time (Ogawa et al., submitted in MST). We

also confirmed a need of improvement for a surface roughness and a vertical profile of sidewalls within pores.

Keywords: X-ray, light-weight optics

Development of a Thermal and Supra-thermal ion Analyzer for an experiment of Sounding Rocket

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In the terrestrial magnetosphere, plasma particles with a wide energy range from < 1eV to MeV exist simultaneously. These particles are generated and/or transported via interactions with plasma waves. For example, in-situ particle observations have revealed that the inner magnetosphere contains significant fraction of low-energy plasma particles originated from the ionosphere. Their typical energy is a few tens of eV in contrast to much lower energies in the ionosphere. However, acceleration and transport processes of these particles are still unknown. This is mainly due to lack of observations of thermal and supra-thermal ions. In general, a measurement of plasma particles with energies less than a few tens of eV is easily affected by spacecraft potential. One of the solutions to suppress this effect is to mount the instrument on top of an extendable boom. The effects of the spacecraft potential are suppressed by controlling the chassis potential of the instrument.
We are developing a thermal and supra-thermal ion mass spectrometer which is light enough to be mountable on top of the boom. This instrument consists of a top-hat type electrostatic energy analyzer and a time-of-flight type mass analyzer. In the current design, diameter of the instrument is less than 10 cm. We will show the instrument design and its development status.

Keywords: Thermal and Supra-thermal ion, Ion analyzer, Sounding rocket

Plasma package for constellation of micro-satellite

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Multipoint observation of space plasma is essential to distinguish spatial and temporal variations and to increase the spatial coverage. However, making satellite needs too much cost and human power so that it has not been realistic to distribute tens of the plasma sensors at different points. Such situation is drastically and rapidly changing due to the appearance of micro or nano satellites with a weight less than 100 kg, which cost only 1/100 or even 1/1000 of conventional large satellite. Adding to Surrey Satellite Technology Ltd., a venture company of Surrey University in UK and one of the pioneers of microsatellite, not a few institutes, universities, space agencies and private companies started entering the international race of micro-satellite development. It is not unrealistic that 100s-1000 of satellites are launched every year in a several years from now. One of the fascinating ideas to realize super multipoint measurement for space weather monitoring might be installing a standardized scientific plasma sensor package at every micro-satellite to be launched in the world as a part of the BUS instruments. Here we would like to discuss how to promote and distribute this idea internationally.

Keywords: micro-satellite, nano-satellite, constellation, plasma instrument

The development of the one chip new spectrum plasma wave receiver

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The plasma wave receiver is essential instruments for plasma observation. However, the size of the receiver is the important problem, especially for small satellites. We have been attempting the miniaturization of the plasma wave receiver by designing the analog ASIC (Application Specific Integrated Circuit). In this presentation, we introduce the new spectrum receiver which is one kind of plasma wave receivers. Conventional spectrum receivers are categorized into three types: sweep frequency analyzer (SFA), multi channel analyzer (MCA), and fast Fourier transform (FFT) based receiver. The SFA and the MCA have the problem that its time resolution and frequency resolution are incompatible. Although the FFT based receiver can overcome this problem, it has a disadvantage that the receiver amplifies signals with a wide frequency band. To resolve above problems, we propose the new spectrum receiver.

The new spectrum receiver is composed of analog circuits and digital signal processor (DSP). Input signals are band limited and amplified by the analog circuits, and the band-limited signals are analog to digital converted and applied FFT by DSP. The receiver gets whole spectrum by repeating this process in three bands: from 10 Hz to 1 kHz, from 1kHz to 10 kHz, and from 10 kHz to 100 kHz. This method enables to realize the spectrum receiver which has high time and frequency resolution, and this method can avoid wide frequency band amplifying.

We succeeded in developing the analog circuits for the new spectrum receiver and the prototype model of the receiver. The analog circuits are realized in ASIC, and all components of the receiver except for analog to digital converter (ADC) and DSP is included in a 5 mm x 5 mm chip. The prototype model is composed of the ASIC, an ADC board, and a PC. The ADC is controlled by the program running on the PC, and converted data are applied FFT in the same program. The time resolution of the receiver is 0.4 second, and frequency resolution for frequencies from 10 Hz to 1 kHz, from 1 kHz to 10 kHz, and from 10 kHz to 100 kHz are 3.2 Hz, 32 Hz, and 320 Hz respectively. In this presentation, we introduce the design of the new spectrum receiver in detail, and we also introduce the measurement result of the receiver.

Keywords: Plasma wave, ASIC

The Miniaturization of Particle Detection Circuits Composing the Direct Observation System for Wave-Particle Interactions

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"Wave-Particle Interaction Analyzer (WPIA)'' is proposed for a direct and quantitative analysis of wave-particle interactions. We aim to integrate the WPIA on one-chip by using the ASIC (Application Specific Integrated Circuits). In order to realize the one-chip WPIA, small-size particle detection circuits are required which continuously output a detection signal derived from each plasma particle.
The operation of the particle detection circuit consists of two stages. Since the plasma particle cannot be detected directly, the pre-stage converts and amplifies electric charge detected by a sensor to voltage first, enabling the post-stage to detect the voltage signal. The input waveform to the pre-stage circuit appears as a current pulse with its pulse width of a few tens of nano-seconds. In order to keep an enough response to the short time pulse in converting the electric charge to the voltage, we chose a current conveyor and a latch comparator for the pre-stage and post-stage circuits, respectively. First, we designed a current conveyor. The response of the current conveyor depends on mutual conductance (g_m) of MOSFETs and the output impedance (Z_{out}). With a large value of g_m and Z_{out}, we designed a high response current conveyor circuit. Simulation results show that when the amplitude of the input current pulse was 103 uA, the output was raised from -12.7 mV to 316 mV at about 1.8 ns and converged at about 16.2 ns. The operational performance of the current conveyor circuit was also verified by the measurement and simulation results. Next, we designed a latch comparator. Adjusting the current and the aspect ratio of MOSFETs on the latch circuit, we designed a high response latch comparator with the delay time of less than 2 ns. The measurement results, however, showed the delay time of about 200 ns, due to the time constant increased by parasitic capacitance at the output port, which was improved by decreasing Z_{out} in simulation.
In this presentation, we introduce the design and evaluation of the small particle detection circuit on a chip and propose a direct observation system for wave-particle interactions including the designed particle detection circuits.

Keywords: Wave-Particle Interaction, Wave-Particle Interaction Analyzer(WPIA), Particle Detection, Application Specific Integrated Circuits(ASIC)

Development of wideband impedance probe system for observation of the ionosphric ion composition

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The performance of new wideband impedance probe system for observation of the ionospheric ion composition have been evaluated in the plasma chamber. Measurement system of Number density of Electron with Impedance probe (NEI) were developed by Oya [1966], and successfully utilized for numerous sounding rockets and spacecrafts such as Denpa, Taiyo, Jikiken, Hinotori, Ohzora, and Akebono [e.g. Wakabayashi et al., 2013]. NEI measures the equivalent capacitance of the probe immersed in the magnetized plasma. By applying RF signal to the probe, we can identify the minimum of equivalent capacitance due to upper hybrid resonance (UHR). The frequency of RF signal is swept from 100 kHz to 25 MHz, in order to cover the UHR frequency range in the Earth’s ionosphere. We can obtain accurate electron number density from the measured UHR frequency.
The effective capacitance of the probe in the magnetized plasma shows minimum not only at UHR frequency but also at another resonance frequency: Lower hybrid resonance (LHR). If we can measure LHR frequency with UHR frequency and electron cyclotron frequency, we can derive effective mass of ionospheric plasma and determine the ionospheric ion compositions. Because LHR frequency is about several kHz in the ionosphere, we have to extend the lower limit frequency of the current impedance probe system to 100 Hz.
Through the plasma chamber experiment in 2014 with bread-board model (BBM) of the new impedance probe system, we confirmed that it could measure (1) UHR in high frequency range as well as the current NEI could, and (2) equivalent capacitance profile from 100 Hz to 100 kHz, which indicates sheath capacitance of 120 pF and sheath resistance of 30 kohm. But it could not detect LHR as predicted due to high electron collision frequency in the chamber using backscatter-type plasma source. We are planning to perform another chamber test in 2015. In this test, we used large UV light source with propylene gas (C_3H_6) as plasma source in expectation of reduction of the electron collision frequency. However, although we found slight decrease of effective capacitance around 2 kHz, we could not confirm clear LHR depending on changes of background plasma density. The constant sheath resistance in low frequency range shows the existence of large sheath current due to potential difference between the probe and background plasma. Therefore, we are planning another chamber experiment in which we perform DC-potential control of the probe.

Keywords: Impedance probe, Lower hybrid resonance (LHR), Ionosphric ion composition

The UV photon detector on board spacecraft with high-efficiency and stability

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The remote observation with ultraviolet (30-330nm) lights is essential for planetary science because there are many effective lines emitted from the ion and atoms which compose the planetary magnetosphere or atmosphere (exosphere too). The straightest way to improve the quality of the data is to increase the efficiency of the instrument. In this presentation, we will show the way to improve the detection efficiency of the photon detector. Furthermore, the way to keep the efficiency during the ground operation (before the launch) is also shown from the experimental aspect.

Keywords: ultraviolet, spacecraft, efficiency

On relatively shifted centers of the analyzer electrodes of MIA onboard Mercury Magnetospheric Orbiter

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MIA (Mercury Ion Analyzer) on board MMO employs a top-hat electrostatic analyzer, which measures three dimensional velocity distribution of solar wind and magnetospheric ions around Mercury. The analyzer uses axisymmetric toroidal electrodes and is designed to have no dependence in its characteristics on azimuthal direction of incident ions. However, our ground calibration experiments have revealed that it has a slight dependence. We have tried to explain the dependence by means of model calculations. We assumes that all parts of electrode are manufactured precisely but their centers are not exactly coincident through assembling process. Our result of model calculations suggests that relative shift of 0.1 to 0.2 mm may be included and can be responsible for the azimuthal characteristics of the analyzer.

Keywords: MMO, MIA

A basic study of search coil with a built-in ASIC preamplifier

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Multipoint plasma wave observations by miniaturized scientific satellites in the magnetosphere are important to understand the magnetospheric dynamics. Physical limitations (mass, volume, and power) of scientific instruments become more severe in miniaturized satellites. We have been developing compact plasma wave instruments to reduce the system resources by using application specific integrated circuit (ASIC) technology. Search coil magnetometers based on Faraday’s law are commonly used for AC magnetic field observations of plasma waves. A typical search coil sensor consists of a single set of solenoidal coil and magnetic core. The sensor is placed at a tip of a mast away from a satellite body to prevent the noise generated from the body. The sensor is connected to a preamplifier installed in the satellite body with a long cable, then the electrical characteristics are degraded due to the effect of long cable’s capacitance component. In this study, we propose a new search coil with a built-in an ASIC preamplifier to improve the electrical characteristics. We have especially studied the following items. The first is the effect of effective permeability of the magnetic core. There is no space for putting the ASIC preamplifier in a traditional rod core. To make a space for putting the ASIC preamplifier in the sensor, the core is divided into a couple of thinner rod cores. To evaluate the effect of effective permeability for the divided the cores, we performed the electromagnetic field simulations. The simulation and measurement results show that the effective permeability of the divided cores are larger than that for the previous rod core. Next, the second item is the effect of the radiation environment. It is necessary to consider the effects of radiation, because the ASIC preamplifier is directly exposed in space environment. Degradation of electrical performance and latch-up of the ASIC preamplifier will be caused by the strong radiation as in the radiation belts. The radiation simulation result shows that a Copper plate (thickness : 5 mm) representing a dense coil winding acts as a radiation shield for alpha ray (60 MeV/(mg/cm2) or less) and gamma ray (0.05 MeV/(mg/cm2) or less). Thus, it is possible to shield the ASIC preamplifier in the coil from the radiation. The third item is the crosstalk problem. The AC magnetic field vectors are measured by using 3-axis search coil. The magnetic field is distorted by the 3-axis magnetic core. As a result, the crosstalk problem will be expected to occur. An optimal placement of the 3-axis magnetic core is evaluated by using the electromagnetic simulation. The simulation results show that the crosstalk becomes −40 dB or less (vector angle measurement error less than 1 degree) when the intervals between each core are less than 35 mm.
In this presentation, we will present the analysis results for a proposed search coil with a built-in ASIC preamplifier in detail.

Keywords: ASIC preamplifier, Plasma wave observations, Search coil

The result of ground calibration for ERG/MGF sensor

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Variations and disturbances of the magnetic field may accelerate plasma in the inner magnetosphere. To achieve scientific goal of revealing mechanism of plasma acceleration for the ERG satellite, high accuracy of magnetic field observations is required.

The sensor of the three-axis magnetic field experiment (MGF), which will be onboard the ERG satellite, have displacements on orthogonal axes and offset due to an attachment error and so on. Moreover, the sensitivity and offset of the fluxgate sensor, which will be exposed to space in an environment of violent temperature change, have temperature dependence. In order to acquire data in a high accuracy, the sensitivity, alignment, offset, and their temperature dependence need to be obtained from the ground examination before the satellite launches.

We have examined the sensitivity, alignment, offset, and their temperature dependence of ERG/MGF sensor by ground examination. We will show the result in this presentation.

A study of cruising-phase sciences using Solar Power Sail

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The Solar Power Sail is a Japanese candidate deep-space probe that will be powered by hybrid propulsion of solar photon acceleration and ion engines. The main scientific objectives are studies of Trojan asteroids in the Jovian L4 or L5 regions. The long distance and period from the launch to the swing-by at Jupiter will give us a good opportunity to explore the solar system between the Earth and the Jupiter, and to execute long-period, long-baseline observation for astronomy. We define the cruising-phase sciences of the Solar Power Sail as the scientific theme that will be explored or observed from the launch to the swing-by at Jupiter. In this paper, we report candidate instruments, as well as individual and integrated sciences of the cruising-phase sciences. Candidate instruments are as follows.

The Exo-zodiacal Infrared Telescope (EXZIT) is a visible-light and infrared (tentatively 0.4 to 10 micro-meters) offset Gregorian telescope with a 10cm-diameter aperture. The all-aluminum telescope and the Linear Variable Filter (LVF) are based on the Cosmic Infrared Background Experiment (CIBER)-2. EXZIT will observe the zodiacal light from the launch to the main asteroid belt, and then search for the first stars until it approaches to Jupiter.

Arrayed Large-area Dust Detectors in Interplanetary space (ALADDIN) 2 detects interplanetary dust using the Polyvinylidene Fluoride (PVDF) dust sensors installed on the membrane. It is an improved model of ALADDIN that was installed on IKAROS and observed interplanetary dust between the Earth and Venus. ALADDIN2 will detect interplanetary dust between the Earth and Jupiter and compare the distribution with the results of EXZIT. It will observe the dust around the Trojan asteroids after it approaches to the Trojan.

The Magnetometer (MAG) is an improved fluxgate magnetometer model of the Magnetic Field Experiment (MGF) on the Exploration of Energization and Radiation in Geospace (ERG) that will be injected into the orbit on the Earth. Two or four devices will be installed in the tip of the framework of the membrane to provide the resolution on the electron scale for interplanetary plasma turbulence. MAG will measure the interplanetary plasma in the cruising-phase, and it will measure the magnetic fields around the Trojan asteroids after it approaches to the Trojan.

The Gamma-ray Burst Polarimeter (GAP) 2 is an improved model of GAP on IKAROS. GAP2 will monitor gamma-ray burst phenomena to clarify the particle acceleration mechanism and gravitational waves. It will also search for exploding early stars in the early universe, which complements to the infrared first-star search by EXZIT.

Keywords: Solar Power Sail, zodiacal light, dust, plasma, gamma-ray burst

Study on prior information suitable for wave distribution function method

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The plasma waves propagating in the Earth's magnetosphere are influenced by plasmas on the propagation path in the generation and propagation process. In order to deeply understand the space plasma environment, in situ plasma wave observations by scientific satellites are indispensable. Spectral matrices which consist of cross spectra of electromagnetic field components are generally used for polarization analysis and direction finding of plasma waves.
On the plasma wave experiment (PWE) aboard the ERG mission, power spectra and spectral matrices of VLF waves are generated onboard and transmitted continuously to the Earth. These data are used in order to decide downlink timings of the high-resolution waveform data which are transmitted intermittently.
Conventional methods of direction-finding of VLF waves using a spectral matrix are classified as follows. One is based on the plane-wave approximation such as Means method, and the other is the wave distribution function (WDF) method which regards observed signals as random waves. The WDF method estimates direction of arrival for multiple waves included in observed signals, and the number of the model parameters is generally more than the number of the input data components. We therefore cannot determine the solution uniquely, and we need some prior information (model) in order to obtain the unique solution. Until now, the many models have been proposed. However, the estimated images are sensitive to the models, and we must evaluate the validity of the solutions by confirming the results of all the models. There are two problems that the validity of the WDF method cannot insure and its confirmation process is difficult for the users of the WDF method.
In the present study, we proposed a new WDF method without arbitrary assumption. This method is based on the boundedness of the solution set which is derived from the properties of the spectral matrices and the wave distribution function. Since the new method assumes an uniform distribution on the solution set and calculates statistic such as average and confidential intervals as estimated results, it doesn't need any models in order to obtain an unique solution. We also consider an evaluation method of the validity of models using some model selection references.

Keywords: Waves in plasma, Ill-posed Problem, Wave distribution function method, Model selection

Development of ultraslim magnetometers to discover the mechanism of the solar wind heating

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It has been thought that the solar wind is cooled down along radial directions of the Heliosphere, however, Richardson and Paulerena [1995] showed by the Voyager 2 that the observed temperatures ($T=\sim T_0 \cdot R^{-1/2}$)of the solar wind are higher than those of the adiabatic model ($T=T0 \cdot R^{-4/3}$). This suggests an acceleration process of the solar wind particles, although, its mechanism has not been understood. One of the possible acceleration mechanisms is the dissipation of plasma turbulences in the solar wind. The spectrum of the plasma turbulence in the solar wind have been investigated at the interplanetary space by the Helios 1 [Roberts+1987] and the Ulysses [Goldstein+1995], and at the near-Earth orbit by Cluster [Sahraoui+2007;2010]. In their observations the kinks at the wavenumber k corresponding to the inertia lengths of ion and electron were found in the relation between thepower of turbulences E and the wavenumber k ($\log_{10}(E)\sim kA+E_0$). These kinks possibly indicate the energy transfer from the plasma turbulence to the particles by the wave-particle interactions, however, the mechanism (e.g., the wave mode) has not been understood yet.
Since the one spacecraft observation cannot distinguish between temporal and spatial variations, the wave vector has not been estimated in the interplanetary space. Then the dispersion relation could not be obtained to determine the wave mode. In order to find the wavenumber by deploying four magnetometers at edges of the large thin film solar cell (~50m each) of the Solar Sail (Trojan asteroid exploration mission), we are developing an ultra-slim and light magnetometer integrated with signal processing circuits of low power and noises. One of the problems for installing our magnetometers is that the signal process circuits are too large and heavy to deploying into the solar cell. Therefore we developed the 5mm-chip (ASIC; Application Specific Integrated Circuit) for the analog parts of our signal process circuits to achieve both weight saving and downsizing. In our presentation, we will show the simulation results and the performance evaluations of the developed circuits of ASIC.

Keywords: fluxgate magnetometer, plasma turbulence, solar wind, wavenumber analysis

Investigation and Development of Seismic Observation Package for Asteroid and Small Body Explorations

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Exploration of small bodies in the solar system provides us important constraints on formation and early evolution of the solar system. Japanese Hayabusa mission, who carried out a sample return from an asteroid, was one of the most successful Japanese planetary missions and it opened a new possibility of future Japanese missions to asteroids and small bodies. While returned sample provide a unique opportunity to investigate the origin and evolution of the planetary bodies, in-situ observation also provides some complementary information that can only be obtained on site. Inner structure of asteroids and small bodies is one of the key parameters that need to be constrained through in-situ observation and seismic observation will be an effective approach to reveal the geophysical feature on the interior.
Here we discuss our investigation on seismic observation on asteroids and small bodies, especially on Phobos, which is the target of Japanese Mars Moon Exploration Mission (MMX). We will mainly discuss two subjects; 1. Estimation of seismic signal on small bodies and 2. Possible configuration for seismic observation on small bodies.
In the first section, we evaluate seismic signals from meteorite impacts and possible artificial impact. We calculate synthetic seismograms through normal modes summation and compare seismic signals from various sources. We also investigate the difference in seismic signal that arise from different inner structure models. The small bodies are likely to be covered with regolith and mega-regolith as it was observed on the Moon. For relatively large bodies, it is possible that solid non-contaminated layer (or core) exists under the mega-regolith. Such information on deep interior will provide an important constraints on the origin of the small body. Seismic observation is an effective to probe such deep structure that is difficult to observe from orbital observations and it will be important to carry out quantitative evaluations to optimize our observations.
Secondly, we will present our proposal for seismic observation package on asteroids and small bodies. The discussion is based on our proposal submitted to MMX science instruments. The observation package consists of a 3 axes short period seismometers and an active seismic source. While natural events are important seismuic source to probe the deep structure, it is important that we constrain relatively shallow structure with known and controlled seismic source. We will discuss possible achievements we expect from possible seismic source that we are able to provide. We also present our preliminary estimates on observation plans and expected output from our present configuration of seismic package for MMX. We point out some improvements that we are currently investigating and introduce possibilities of future missions that we will be able to contribute to.

Keywords: Planetary Science, Asteroid, Seismology, Small bodies

Newly developed ultraviolet detector for future space missions

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The extreme ultraviolet (EUV) telescopes and spectrometers have been used as powerful tools in a variety of space applications, especially in planetary science. For example, an EUV telescope onboard Japan’s lunar orbiter KAGUYA first took a global meridian image of the Earth’s plasmasphere. In addition, the EUV spectrometer EXCEED (Extreme Ultraviolet Spectroscope for Exospheric Dynamics) onboard the Japan's small satellite Hisaki was launched in 2013 and it has observed tenuous gases and plasmas around the planets in the solar system (e.g., Mercury, Venus, Mars, Jupiter, and Saturn). These EUV instruments adopted microchannel plate (MCP) detection systems with resistive anode encoders (RAEs). An RAE is one of the position sensitive anodes suitable for space-based applications because of its low power, mass, and volume coupled with very high reliability. However, this detection system with RAE has limitations of resolution (up to 512 x 512 pixels) and incident count rate (up to ~10^4 count/sec). Concerning the future space and planetary missions, a new detector with different position sensitive system is required in order to a higher resolution and dynamic range of incident photons. One of the solutions of this issue is using a CMOS imaging sensor. The CMOS imaging sensor with high resolution and high radiation tolerance has been widely used. Here we developed a new CMOS-coupled MCP detector for future UV space and planetary missions. It consists of MCPs followed by a phosphor screen, fiber optic plate, and a windowless CMOS. We manufactured a test model of this detector and performed vibration, thermal, and performance tests. In this paper, we report the concept of this detector and initial results of our tests.

Keywords: Ultraviolet, Detector, Planetary exploration

Development of the electric field sensor for a sounding rocket

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Measurements of electric fields are one of key elements for the investigation of ionospheric plasma. The detection of electric field is useful to identify global plasma dynamics and energetic processes in magnetosphere and ionosphere. The concrete examples are as follows.
・ Electric field structure associated with the charged particle precipitation and the global motion of the ionosphere
・ The role of the electric field in the acceleration and heating mechanisms of ions
・ Propagation mechanism of the electric field in the auroral ionosphere to the low latitude ionosphere
・ Electric field structure in the equatorial ionosphere
Many electric field measurements have been carried out in Japan. And the electric field detector onboard sounding rockets have been successfully used in the D, E and F regions of the ionosphere. The double probe technique have been extensively used on sounding rockets in order to measure electric field in the ionosphere. And the passive double probe technique has been proven to be a reliable technique in the high electron density plasmas of the ionosphere. The technique has been extended to the lower density plasmas of the D region of the ionosphere. For electric field measurement, a wire antenna has been used as a sensitive sensor onboard Japanese sounding rocket. And this antenna will be used for several spacecraft in the future mission. However, its extension mechanism is complicated and it is difficult for the sounding rocket to extend a wire antenna in the ionosphere. Accordingly new type sensors are developed in order to measure the electric field by the sounding rocket. Their sensors fulfill the severe requirements to the sensor system, i.e., light mass, enough stiffness, compact storage, safe extension, and reasonable test efforts. Four sensors were newly developed for the electric field measurement. These sensors were loaded on four sounding rockets in Japan (S-310-37, S-520-23, S-520-26 and S-310-44). And these new style sensors deployed normally during the flight of a sounding rocket, and succeeded in the electric field observation in the ionosphere.
This paper describes about the basic measurement techniques of the electric field in the ionosphere. In particular it explains about four new type sensors in detail. Then we show the electric field data in the ionosphere measured by the new type sensor onboard the Japanese sounding rocket.

Keywords: electric field sensor, sounding rocket, ionosphere, electric field measurement

