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

