【Grant-in-Aid for Specially Promoted Research】

Science and Engineering

Title of Project : X-ray Imaging of the Earth's Magnetosphere : Revealing Global Behavior of the Magnetosphere

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【Purpose and Background of the Research】

The purpose of this research is to realize the visualization of the Earth's magnetosphere by X-rays and to reveal dynamical couplings between solar wind and Earth's magnetosphere.

Most knowledge about the nature of the solar-magnetosphere interaction has been revealed through a number of in-situ observations by isolated spacecrafts. These in-situ observations do not provide the global view to investigate overall interaction mechanisms but statistical pictures such as bow shock, magnetopause, and cusp. Therefore, global variations of the magnetosphere have not been understood yet.

In recent years, soft X-ray emission associated with the magnetosphere has been discovered. The emission originates from a charge exchange (CX) reaction between solar wind ions and geocorona (neutral gas of the exosphere). Using the Japanese "Suzaku" satellite launched in 2005, we have studied the CX emission and have proposed the idea to realize the global imaging of the dayside magnetosphere with the CX emission. This idea, however, has not been demonstrated by the conventional X-ray astronomy satellites, because most targets of these satellites are distant celestial bodies and they operate narrow-field observation from low altitude. Therefore, we develop a new satellite GEO-X to realize the global imaging of the magnetosphere by X-ray observations.

【Research Methods】

In this research, we develop the satellite, launch it using piggyback launch opportunity and obtain scientific results. To realize the GEO-X mission, we need a microsatellite having a large Δv capability to increase the apogee altitude to 40-60 R_E (Earth radius). Thus, we will combine a CubeSat (~20 kg) with a hybrid kick motor (~30 kg) composed of liquid N_2O (oxidizer) and polyethylene (fuel).

To meet the science goals of GEO-X, a soft X-ray imager (0.3-2 keV) with a wide FOV (>5x5 deg ~ 5x5 R_E at 60 R_E) and a moderate spatial resolution (<10 arcmin ~ 0.2 R_E) is necessary. A large grasp, a multiple of the effective area and FOV, comparable to that of Suzaku, is needed to achieve a high signal to noise ratio within a short cadence. We thus develop a new payload that consists of an ultra light-weight micromachined (MEMS) X-ray telescope which is invented and being developed by ourselves. Flat sidewalls with silicon wafers are used for X-ray mirrors. We adopt a new CMOS detector with a fast frame rate, and combine it with an optical blocking filter, which allows us to reduce optical photon noise from the dayside of the Earth. Figure 1 shows the concept of the satellite and a simulated X-ray intensity map of the magnetosphere.

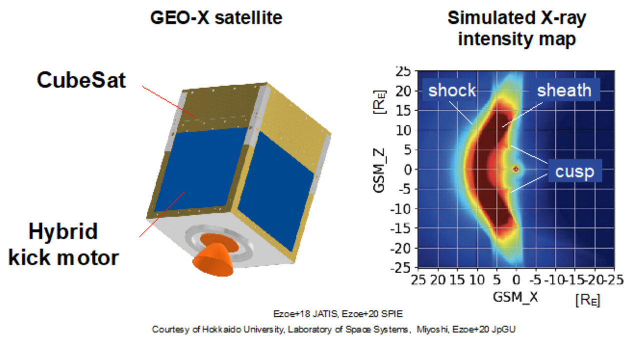

Figure 1 GEO-X satellite and simulated X-ray intensity map of the magnetosphere.

【Expected Research Achievements and Scientific Significance】

The global imaging of the Earth's magnetosphere will greatly advance our understanding of the magnetosphere, which will contribute not only magnetospheric physics but also space weather and astrophysics, especially exoplanet science. The X-ray payload can be used in other exploration missions (Mars, Jupiter, etc), which must foster the new academic field of "X-ray solar system astronomy".

From the engineering point of view, the microsatellite with the high-thrust propulsion system is a breakthrough technology which will greatly improve access to deep space missions, opening up a new world of solar system exploration by micro satellites.

【Publications Relevant to the Project】

- Y. Ezoe et al.,"Ultralightweight x-ray telescope missions: ORBIS and GEO-X", J. Astronomical Telescopes, Instruments and Systems 4, 046001 (2018).
- D. Sibeck, Y. Ezoe, et al., "Imaging Plasma Density Structures in the Soft X-Rays Generated by Solar Wind Charge Exchange with Neutrals", Space Science Review, 214, 79 (2018).

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