論文内容の要旨

Meridional distribution of the Earth's plasmasphere derived from extreme ultraviolet images

（極端紫外光による撮像から明らかにする地球プラズマ圏の子午面分布）

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The plasmasphere plays a central role in many of the complex processes in Earth’s inner magnetosphere. Four decades of studies by a variety of in-situ techniques revealed the dynamical aspect of the plasmasphere changing depending on geomagnetic conditions. However, the in-situ measurements are local observations with which it is difficult to separate the temporal development and the spatial structure of the plasmasphere. Recent advances in satellite-based imaging techniques have overcome this difficulty and made it possible to routinely obtain full global images of the plasmasphere. The Extreme Ultraviolet Imager (EUV) on the IMAGE satellite produced consecutive images of the plasmasphere from the high-latitude view with a time resolution of 10 min and a spatial resolution of 0.1 Re.

The EUV images have revealed the details of a highly structured and dynamic entity of the plasmasphere, and demonstrated that the remote sensing with EUV techniques is a promising means to explore the plasmasphere. On the other hand, their remains some unsolved problems which are difficult to clarify by the imaging from a limited perspective, i.e. only from the high-latitude view. For example, a radial structure of enhanced brightness called a “finger” was found by the EUV instrument but the cause of this structure is still not understood. Furthermore, the gap between the results of the EUV measurements and the conventional theories for the plasmapause formation has been pointed out. In order to solve these problems, the imaging of the plasmasphere from a different perspective has been emphasized.

We have developed the Telescope of Extreme Ultraviolet (TEX) onboard the lunar orbiter KAGUYA launched in September 2007. Data available from the TEX instrument allow us for the first time to study the plasmasphere from a meridian perspective. The TEX instrument images the He^+ distribution in the plasmasphere by detecting the resonantly scattered solar 30.4-nm radiation and produces images encompassing the entire plasmasphere. The author has participated intensively in the laboratory and in-orbit calibrations and data evaluation for the onboard instrument.

The performance of the TEX instrument after launch was verified using the in-orbit data obtained from February 2008 to May 2009. The result of this in-orbit calibration is presented in Chapter 2. From March to June 2008, the TEX instrument had produced the first sequential images of the plasmasphere viewed from the meridian perspective. The analysis and evaluation of these first images are demonstrated in Chapter 3. The corotation and the erosion of the plasmasphere were identified in the sequential images during the geomagnetically quiet (Kp < 3) and disturbed period (Kp = 5), respectively. The angular rotation rate for the corotation and the inward velocity of the nightside plasmapause for the erosion are estimated by analyzing these images, and the results are consistent with those derived from IMAGE/EUV observations. This confirms that the TEX instrument successfully detected the spatial distribution and temporal development of the plasmasphere.

Furthermore, a new striking feature of enhanced brightness in the plasmasphere, called as a plasmaspheric “filament”, was found in the TEX image during a prolonged quiet period (Kp < 2). The shape of the filament was closely aligned to the dipole magnetic field line, and this suggests that the filaments are caused by isolated magnetic flux tubes filled with denser plasmas than their neighbors. The nature of the filament agrees with that of the finger structure observed by IMAGE/EUV. Consequently, thanks to the novel view of the TEX instrument from the meridian perspective, this study reveals that the finger structure seen in the EUV images are the equatorial projection of isolated flux tubes filled with denser plasmas than its neighbors.

The formation mechanism of the plasmapause was studied in Chapter 4. The sequential TEX images during the geomagnetic disturbance (Kp = 5) on 1-2 May 2008 were analyzed. The plasmapause positions at the post-midnight observed from the meridian perspective clearly agreed with those predicted by the dynamic simulations based on the interchange mechanism. Furthermore, after the convection enhancement, the He^+ column density in the nightside plasmasphere decreased by ~30% only at the low latitudes (< 20 deg). This suggests that the formation of the new plasmapause occurs first near the equatorial region during a geomagnetically disturbed period. These results agree with the formation mechanism of the plasmapause based on the quasi-interchange instability.

For the next plasmaspheric imaging from the International Space Station (ISS), new multilayer coatings having high reflectivity at 30.4 nm and low reflectivity at 58.4 nm were developed. Chapter 5 deals with this topic. For the He II imaging from ISS, the contamination from geocoronal He I (58.4 nm) emission should be eliminated more effectively than the TEX instrument because ISS orbits at a low altitude of ~350 km, inside the geocorona. The newly developed Y_2O_3/Al multilayer coating designed for normal incidence reflection had higher reflectivity (24.9%) at 30.4 nm and significantly lower reflectivity (1.3%) at 58.4 nm than the conventional coatings such as Mo/Si. The temporal stability of the Y_2O_3/Al multilayer coating was also evaluated and found to be highly stable under vacuum, dry N_2 purge, and normal atmosphere. Then, based on these results, the Y_2O_3/Al multilayer coating was selected to apply for the flight mirror of the Extreme Ultraviole Imager (EUVI) onboard ISS. The calibration of the flight mirror was performed, and it was confirmed that EUVI can produce the plasmaspheric images from ISS with a high SNR of 16.