Master thesis

Longitudinal variations of the sulfur ions in the Io plasma torus
observed by the HISAKI/EXCEED

（HISAKI/EXCEEDで観測されたイオプラズマトーラスにおける
硫黄イオンの経度方向変動）

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2017

Abstract

Previous ground-based and space probe observations of the Io plasma torus (IPT) in various wavelengths have detected a periodic variation which is a few % longer than the System III period (9.925 h). It has been called the System IV period. Although various ideas to explain the origin of the System IV period have been proposed, little progress has been made.

A previous study reported that the System IV period was 10.07 h during Cassini's Jupiter flyby in 2000 [Steffl et al., 2006]. This period was shorter than the System IV period of 10.21h obtained from the ground based observation [Brown 1995]. It is speculated that Io's volcanic event just before Cassini's flyby was related with the short System IV period [Steffl et al., 2006]. "The dual hot electron model" (here after the DHE model) was proposed to reproduce the longitudinal modulation of IPT during Cassini's flyby [Steffl et al., 2008]. This model includes two kinds of hot electrons with different longitudinal modulations. While one rotates with the System III period, another one sub-corotates with the 10.07 h period (System IV period). Since Cassini's observation was started one month after the Io volcanic event, the model has never been compared with the IPT observation during the volcanically quiet period. Moreover, it was not clear whether the Io volcanic event caused to change the System IV periodicity observed by Cassini.

In order to understand the mechanism responsible for the System IV period and the influence of Io's volcanic event on the periodicity in IPT, we analyzed time variations in intensities of EUV emissions from IPT obtained by the HISAKI satellite. The data used in this study were obtained for the "1st season" (19 December 2013 – 24 April 2014), "2nd season" (27 November 2014 – 14 May 2015) and "3rd season" (21 January – 30 August 2016). In the 2nd season, Io's volcanic event from the middle of January to March 2015 was reported from the observation of Iogenic sodium emission [Yoneda et al., 2015]. The HISAKI observation period completely included the Io volcanic event. To find temporal variations in the System IV period, the System III longitude at the peak of EUV intensity was derived by fitting the sinusoidal function to the light curves of three ion species (S II at 76.5 nm, S III at 68.0 nm, and S IV at 65.7 nm + 140.5 nm). The System IV periods of S II before and after the Io's volcanic event were 10.0461 ± 0.0097 h and 9.9891 ± 0.0014 h, respectively. On the other hands, the System IV period of S II was 9.9370 ± 0.003 h during the Io's volcanic event. This result is the first observation evidence which shows

that the System IV period has shortened during an Io volcanic event. This result is consistent with the implication from Cassini that the System IV period has shortened associated with the Io volcanic event. It is also found that the timing when the System IV period became short corresponded to the timing when the activity of Jupiter's UV transient aurora enhanced. The phase of the longitudinal modulation of S IV abruptly changed sequentially from the outer to the inner part of IPT. These facts suggest that the longitudinal modulation was related with the injection of hot electrons population into IPT.

To investigate the origin of the System IV periodicity, we examined the effect of the magnetic field gradient drift of the hot electron on the System IV period and estimated the energy of the hot electron from the drift period as well as the collision relaxation time scale of the hot electron with thermal electrons in IPT. Based on these considerations, we proposed that the short System IV period during the Io volcanic events was produced by the magnetic field gradient drift of the injected hot electrons whose energy was several keV – a few ten keV. On the other hand, further studies are required to understand origins of the System IV period during the volcanically quiet period.

Moreover, we investigated the phase relation between the densities of SII and SIV to assess the DHE model. The spectral diagnosis was used to derive the densities of SII and SIV from the data obtained by the HISAKI satellite. We found that the phase relation between the densities of SII and SIV was complex and not consistent with the prediction from the DHE model. Further investigation to resolve the complex longitudinal modulations observed by the HISAKI satellite is needed in future works.