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

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Previous ground-based and probe observations of Io plasma torus (IPT) in various wavelengths have detected a periodic variation which is longer than the System III period (9.925 h). It has been called the System IV periodicity.

In previous studies, the time variations in the System III longitude at the peak of the longitudinal modulation of several ions compositions and also those in the amplitude of them were investigated with the data obtained by the Cassini spacecraft [Steffl et al., 2006]. They found the following three features of the longitudinal modulation of the IPT. (i) The peak longitude shifted with respect to the System III longitude at the rate of 12.5deg/day, which shows the appearance of the System IV periodicity. (ii) The amplitude varied with the beat between the System III and IV periods, which shows that the IPT has the two periodicities (System III and IV). (iii) The phase relation between the densities of S^+ and S^{3+} was 180degout of phase. They proposed the longitudinal 1-D physical chemistry model named as "Dual hot electron model (DHE model)" to reproduce the results obtained by the Cassini spacecraft. This model includes two longitudinal modulations of hot electron. While one rotates with the System III period, another one sub-corotates with the System IV period. The System III periodicity could be produced by the longitudinal inhomogeneity of the Jovian magnetic field [Hess et al., 2011]. However, the origin of the System IV periodicity has been unknown.

In this study, we analyzed time variations in intensities of EUV emissions from the IPT obtained by the HISAKI satellite to understand the mechanism responsible for the System IV periodicity. The data used in this study was obtained during "1st season" (19 Dec. 2013 –24 Apr. 2015), "2nd season" (27 Nov. 2014 –14 May 2015) and "3rd season" (21 Jan. –30 Aug. 2016). During the 2nd season, the Io's volcanic event from the middle of Jan. to Mar. 2015 was reported from the ground based observation of Iogenic sodium emission [Yoneda et al., 2015]. To find temporal variations in the System IV period, temporal variations in the System III longitude at the peak of EUV intensity were derived by the function fitting to the light curves of three ion species (S^+ at 76.5 nm, S^{2+} at 68.0 nm, and S^{3+} at 65.7 nm+140.5 nm). The System IV periods of S^+ before and after the Io's volcanic event were 10.0461±0.0097 h and 9.9891±0.0084 h, respectively. On the other hands, the System IV period of S^+ was 9.9370±0.014 h during the Io's volcanic event. This result is the first observation evidence which shows that the System IV period has shortened after the Io volcanic event with the data for the period including the whole series of the Io volcanic event.

The timing when the System IV period became short roughly corresponded to the timing when transient aurora activities enhanced. The phase of the longitudinal modulation of S^{3+} also abruptly changed in the order from the outer to the inner at that timing. These facts show the existence of the injection. We

examined the effect of the gradient B drift of the injected hot electron and the collision relaxation time scale of the injected hot electron with the thermal electron. As the result, we suggest that the short System IV period just after the injection was produced by the gradient B drift of the injected hot electron whose energy was a few keV –a few ten keV. However, the origin of the “normal” System IV period, that is the period before the Io volcanic event, is not still understood.
Moreover, we investigated the phase relation between the densities of S^+ and S^{3+} to examine the DHE model with the spectral diagnosis for the data obtained by the HISAKI satellite. As the result, we found that the phase relation between the densities of S^+ and S^{3+} was not always 180deg out of phase, which was not consistent with the DHE model. Thus, additional or new ideas would be needed to explain these complex longitudinal modulations.

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