Temperature variation of sulfur ions in the Io plasma torus associated with a volcanic event with the Hisaki/EXCEED and ground-based observations

Mika Shishido[1], *Takeshi Sakanoi[1], Masato Kagitani[1], Fuminori Tsuchiya[1], Ichiro Yoshikawa[2], Atsushi Yamazaki[3], Kazuo Yoshioka[4], Go Murakami[3], Tomoki Kimura[5]

1. Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University, 2. Graduate School of Frontier Sciences, The University of Tokyo, 3. Institute of Space and Astronautical Science, JAXA, 4. Graduate School of Science, The University of Tokyo, 5. Riken

We report the time and spatial variation of sulfur ion emission lines from the Io plasma torus to understand the dynamical process in the torus associated with Io's volcanic event during the period from December 2014 to March 2015, using the data obtained with Hisaki/EXCEED (Extreme Ultraviolet Spectroscope for Exospheric Dynamics).
A large quantity of gas is ejected from Io's volcanoes, principally oxygen and sulfur atoms and their compounds. Once they are ionized through electron impact or charge exchange, the ions are accelerated to the nearly corotational speed of the ambient plasma to form a torus of ions (the Io plasma torus, about 6 from the center of Jupiter) surrounding Jupiter. The fresh ions lose their pickup energy to the ambient electrons through Coulomb collisions. Ultimately, the torus electrons lose energy by transiting electron energy state of ions into higher states, leading to the prodigious extreme ultraviolet (EUV), ultraviolet, and visible emissions from the torus.
During the period from December 2014 to March 2015, Io's outburst was observed by EXCEED, and the increase in the pickup ions were anticipated along with the increase in the neutral gas. To investigate energy flow from ions to electrons during the Io's outburst period, we derived sulfur ion temperatures parallel to magnetic field lines from the brightness scale height of the ion along the field line. From the spectral images of sulfur ion emission at 76.5 nm (SII), 68.0 nm (SIII) and 65.7 nm (SIV) observed by EXCEED, we identified the time variation of sulfur ion temperature increasing associated with enhanced volcanic activities, and interpreted that this was due to increase in the fresh ions by ion-pickup process. We also carried out the measurement of SII 671.6 nm emission with a monochromatic imager on the T60 telescope at Haleakala, Hawaii, which has a high spatial resolution capability, and found similar variation in ion temperature. We also evaluated the spatial resolution of EXCEED by comparing the brightness scale heights which were derived from EXCEED and T60, and then corrected the value of broadened scale height by EXCEED.
Furthermore, in order to interpret how electrons and ions exchange their energy, we reproduced the observation result (i.e., time variations of sulfur ion temperature, hot electron fraction, core electron temperature, and ion composition in the torus) using the zero-dimensional time evolution model based on *Delamere and Bagenal* [2003]. From the model we found that increase of hot electron fraction causes increase of core electron temperature, and makes the subsequent increase of new ion pickup via electron impact due to the increase of core electron temperature. Concerning the difference in the magnitude relationship among the sulfur ion temperature of SII, SIII, and SIV obtained from observed data and modeled value, we reproduced the spatial distribution of the Io torus along the magnetic field and found that the brightness scale height of roughly decreases by 60 % under conditions of the temperature anisotropy (T_S+perp / T_S+para) of 5. Related to the decrease in the brightness scale height of SII, the magnitude relationship among three of ion species obtained with our model significantly approached to that in the observed EXCEED data.

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