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Plasma parameters at Europa's orbit estimated from the Hisaki observation

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Europa (9.4 R_J from Jupiter) has a tenuous molecular oxygen atmosphere, produced by magnetospheric plasma sputtering on its surface. To improve our understanding of the production and loss of the atmosphere, the density and temperature of the magnetospheric plasma around the satellite must be known. However, plasma observations at Europa's orbit are still limited.

In this study, we used JAXA's Hisaki data observed in May 2015 to estimate the plasma parameters at Europa's orbit.

An ultraviolet spectrograph (EXCEED) aboard Hisaki measured the sulfur and oxygen ion emission lines in the extreme ultraviolet (EUV) wavelength range (55-145 nm). The Jovian magnetosphere is filled with plasmas originating from satellite Io (5.9 R_J). The torus emission intensity peaks around Io's orbit and decays with increasing radial distance from the planet. At Europa's orbit, the brightness was so weak that contaminations from the terrestrial radiation belt and foreground emissions (geocorona) were carefully removed, and the spectrograph data were integrated for one week (over 1,080 min).

The emission intensity is a product of the ion density and natural transition probability along the line of sight. The torus ions are excited by electron impact, so that the ion density of a certain energy level depends on the density and temperature of the electrons. We used the CHIANTI atomic database to find the best-fit plasma parameters of the observed spectrum by minimizing the chi-square, a method known as plasma diagnosis.

The sulfur and oxygen ion emission lines were identified at Europa's orbit. Their brightness was 1.5 Rayleigh at 68.0 nm and 0.3 Rayleigh at 76.5 nm, which were approximately 2 to 6 % of those at Io's orbit. The signal-to-noise ratio (S/N) >2 was satisfied for the S^+, S^{2+}, and S^{3+} emission lines in 65-80 nm, O^+ and O^{2+} line at 83.4 nm, and S^{3+} lines at 106-108 nm. In the wavelength range longer than Ly-α (121.6 nm), S/N decreased because the intensity of the torus emission was comparable to that of the scattered geocoronal emission. The emission lines with S/N <2, including sulfur ion emission lines longer than 121.6 nm were excluded from plasma diagnosis.

We assumed that the plasma in the torus (S^+, S^{2+}, S^{3+}, O^+, O^{2+}, H^+, and e^-) was quasi-charge-neutral and O^{2+}/ O^+ was fixed at 0.1. The temperature of hot electrons was fixed to 300 eV. From plasma diagnosis, we found that the density of electron was 310 $\pm$ 200 cm^{-3}, the temperature of core electron was 4.6 $\pm$ 3.7 eV, and the fraction of hot electrons was 25 $\pm$ 27 % at Europa's orbit. The electron density in our result was larger than that in Galileo's PLS data, 63-190 cm^{-3}, while the core electron temperature in our result was cooler than that in Bagenal et al. (2015), 10-30 eV.

In plasma diagnosis, the emission lines of both short and long wavelengths are necessary to separate the density and temperature of the cold electrons, and the fraction of hot electrons. However, using only the emission lines in the short wavelength range ($<$121.6 nm), it is difficult to separate the density and temperature of cold electrons because the response of the volume emissivity in the shorter wavelength lines to these two parameters is similar. The hot fraction can be evaluated with only the emission lines shorter than 121.6 nm, but the longer emission lines are required for better accuracy. To resolve this, we plan to extend the integration time to more than 10,000 min to improve the S/N of the torus emission lines at longer wavelengths.