Estimation of dawn-to-dusk electric field in the Jovian inner magnetosphere from emission asymmetry in the Io plasma torus

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Past ground-based and probe observations show existence of dawn dusk asymmetry (DDA) in brightness distribution of the Io plasma torus (IPT) and suggest that it is caused by the dawn-to-dusk electric field (DDEF) of about 4 mV/m. Recent observation of IPT with the HISAKI satellite reveals that the DDA of emission intensity shows temporal changes in response to solar wind dynamic pressure, indicating the solar wind influence on the Jovian inner magnetosphere. Purpose of this study is to derive DDEF quantitatively from DDA of emission intensity from HISAKI observations and find which processes cause to make DDA in the emission intensity.

Because DDEF causes to shift a drift orbit of plasma to dawnward, electron temperature becomes higher in the dusk side than the dawn side due to the conservation of first adiabatic invariant. As an efficiency of electron impact excitation of ion depends on electron temperature, the emission intensity in the dusk side becomes higher than that in the dawn side. To estimate DDEF from the brightness asymmetry quantitatively, we considered following procedures. (1)Orbit of plasma is calculated by solving an equation of motion with the Runge-Kutta method under corotational and dawn-to-dusk electric fields. Two temperature electron distributions, thermal(5eV) and hot(50eV) components are considered and the adiabatic heating and cooling of electron are calculated for each component. (2)Assuming a conservation of total amount of plasma in a unit flux tube electron density changes by magnetic field intensity changes are also calculated at both the dawn and dusk sides. (3)Applying typical values of thermal and hot electron density of 2000/cc and 20/cc, respectively, and changes in electron temperature and density evaluated in (1) and (2). The ion volume emissivity is calculated by using the atomic data base (CHIANTI) for ion species : S++(68nm). (4)The change in the plasma distribution due to DDEF also changes line-of-sight lengths of IPT between the dawn and dusk sides seen from the earth. This effect is also taken into account. We carried out the procedure from (1) to (4) in the range of DDEF intensity from 0 to 10mV/m and derived the relation between electric field and the DDA of emission intensity.

To investigate contributions of the five factors described above (thermal and hot electron temperatures, thermal and hot electron densities, and the line-of-sight length) on the asymmetry in the emission intensity, we evaluated dependence of the asymmetry on each factor, where other four factors were fixed. From the result, it was found that the thermal electron temperature change dominated the asymmetry of emission intensity while hot electron has very minor contribution to it. This is responsible for electron temperature dependence of ion volume emissivity. The ion volume emissivity has weak dependence on electron temperature above 20eV in the wave length range of EUV. By using the relation between DDEF and the asymmetry of emission intensity in the IPT derived in our study, we estimated DDEF intensity from HISAKI observations. The ratios of emission intensity at the dusk side to that at the dawn side on January 1 and 14, 2014 were 1.49 and 1.13, respectively. From these ratios we estimated DDEF intensity is 3.4mV/m and 1.0mV/m. To estimate DDEF intensity from HISAKI observations quantitatively, a more realistic model which includes radial plasma distribution in IPT and electron cooling effect due to radiation is needed.

Keywords: Io plasma torus, Dawn dusk electric field, Dawn dusk asymmetry