Study of ion acceleration in Ganymede's polar magnetosphere based on Galileo spacecraft observations

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Ganymede is one of the Jovian moons and is known as the only satellite that has an intrinsic magnetic field [Gurnett et al., 1996]. Ganymede is located in the Jovian magnetosphere and is immersed in the magnetospheric plasma corotating with Jupiter's rotation [e.g. Kivelson et al., 1998]. Since the spatial scale of Ganymede's magnetosphere is comparable to the Larmor radius of magnetospheric ions, the characteristic plasma environment is formed around Ganymede through the interaction between Ganymede's magnetosphere and Jovian magnetospheric plasma. Although previous studies discussed the morphology of Ganymede's magnetosphere and its plasma environment, most of the details are still unknown and understanding of the interaction is necessary to reveal processes occurring in Ganymede's magnetosphere.

In the present study, we discuss the plasma environment observed in Ganymede's polar region by the Galileo spacecraft. First, we identify the Upper-Hybrid Resonance (UHR) frequency observed by the Plasma Wave Subsystem (PWS). We then determine the electron density at the point of observation by estimating the electron plasma frequency from both the identified UHR frequency and the electron cyclotron frequency derived from the magnetometer observation results. We analyze four Ganymede encounters including those on orbits G01 and G02 which have been analyzed in the previous study [Gurnett et al., 1996]. Based on the results of the analysis, we obtain the distribution of the plasma density in the altitude range from 264 km to 5,262 km and find that the number density decreases rapidly with increase distance from Ganymede. At an altitude of 264 km corresponding to the closest approach during G02 encounter, the density reaches approximately 200 cm^{-3}, and the density in the region away from Ganymede converges to the plasma density of the Jovian magnetosphere. In order to study the physical process governing the plasma density profile, we examine an ion outflow from Ganymede's polar region. Since the most dominant ion species in Ganymede's magnetosphere has been considered to be O^+ [Vasyliunas and Eviatar, 2000], we assume that the obtained plasma density distribution reflects that of the O^+ density in Ganymede's magnetosphere. Based on the obtained distribution, we find that the density distribution can be expressed by $r^{-5.98}$, where r is the distance from Ganymede. Assuming that the flux is conserved along the trajectory of outflowing ions, we estimate that the ions are accelerated to between 3 and 7 times the assumed initial velocity. We propose that the acceleration process of outflowing ions is controlled by the convection electric field in Ganymede's polar magnetosphere applied through the interaction between Jovian magnetospheric plasma and Ganymede's magnetosphere. In order to evaluate the proposed acceleration mechanism, we carry out a test particle simulation of oxygen ions outflowing from Ganymede's polar region and quantitatively discuss both the trajectory and variation of kinetic energy of oxygen ions in Ganymede's polar magnetosphere.