Study of the contribution of electric field to the acceleration of cometary ions around comet 67P/Churyumov-Gerasimenko

*Kazuki Yamagishi[1], Yuto Katoh[1], Tomoki Kimura[1], Atsushi Kumamoto[1]

1. Department of Geophysics, Graduate School of Science, Tohoku University

Comet is a small celestial object whose size is a few to tens of kilometers, consists mainly of water. Some water molecules sublimated from the cometary surface are ionized by the electron impact ionization and by the photoionization, and spread into space. Understanding the physics related to the motion of cometary ions serves important clues in discussion of the temporal/spatial scale of the molecular supply process from the celestial body to space, the transportation process of materials from the comet to other objects, and the atmospheric outflow process in small bodies.

Rosetta is a spacecraft launched by European Space Agency in 2004 and performed in situ observation around comet 67/P Churyumov-Gerasimenko during 2 years, from August 2014 to September 2016. Previous studies of observation results of Rosetta showed that cometary ions are accelerated radially from the comet nucleus (Behar et al., 2018). The motion of cometary ions has been studied under the influence of the electric field, which is the ambipolar electric field, the motional electric field, and the Hall electric field. Behar et al. (2018) suggested that the ambipolar electric field formed by the pressure gradient of electrons contributes to the acceleration of cometary ions around the comet. Although the diffusion and acceleration due to the electric field around the comet are important in understanding the motion of cometary ions, a quantitative evaluation has not been performed. In the present study, we quantitatively evaluate the contribution of the electric field to the acceleration of cometary ions in order to understand the acceleration process of cometary ions observed by Rosetta. We evaluate the acceleration process of cometary ions under the assumed electric field and compare the simulation results with the observation result of Rosetta.

First, we estimate the distribution of the electric field in the region within 1000 km from the comet nucleus. As a first step, we only consider the ambipolar electric field due to the spatial gradient of the pressure distribution of electrons around the comet nucleus, following the discussion of previous studies. We calculate the pressure distribution of electrons from the release rate of comet gas and the ionization rate, which are determined based on observation results, and assume that the electron temperature is 5eV. Next, we perform a test particle analysis to calculate the time evolution of the speed of an H_2O^+ cometary ion under the assumed electric field. We find that the cometary ion with the initial speed of 0.7 km/s is accelerated to 22.6 km/s at the distance of 1000 km from the nucleus. On the other hand, based on Rosetta's observation results, H_2O^+ ions are accelerated to 40 to 80 km/s in the region from 600 to 1000 km from the comet nucleus. We suggest that the acceleration by the ambipolar electric field alone is insufficient to explain the observation results. In this study, we also consider the motional electric field and discuss the contribution of the electric field to the acceleration of ions around the comet.

Keywords: comet, electric field, ion acceleration, interaction of solar wind with small objects