# Statistical study of heavy ion outflows from Mars observed by MAVEN

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Geological studies have suggested that Mars had a warm climate and liquid water on surface about 4 billion years ago, while Mars has a cold surface temperature and little water on surface at present. Escape of greenhouse gases such as $CO_2$ to space is considered as the plausible reason to cause the drastic climate change. On one hand, mechanisms enabling the large amount of the $CO_2$ loss are far from understood. The planetary ion escape through interaction between the solar wind and the Martian upper atmosphere is one of the candidate mechanisms of the atmospheric escape. Mars does not have global intrinsic magnetic field, but it has local crustal magnetic fields. Effects of this crustal magnetic fields on the atmospheric escape is far from understood. To understand atmospheric escape from Mars, Mars Atmosphere and Volatile EvolutioN (MAVEN) has observed the ion escape from Mars as well as space environment around Mars since November 2014.
In this study, we report on a statistical study of heavy ion outflows from Mars to investigate the influences of the local crustal magnetic fields and the direction of solar wind electric field on the ion outflows based on the MAVEN observations. The Supra-Thermal And Thermal Ion Composition (STATIC) instrument, the Solar Wind Ion Analyzer (SWIA), and the Magnetometer (MAG) data from July 2015 to March 2017 were used for the statistical study. We focused on the heavy ion outflows in the wake region. A fitting method enables us to derive densities of $O^+$, $O_2^+$, and $CO_2^+$ ions separately. We estimated $CO_2^+$ number density by subtracting $O_2^+$ contamination. In order to eliminate the $O_2^+$ contamination in $CO_2^+$ mass range, we determined the response functions of the STATIC instrument to $O_2^+$ ions and calculated the $CO_2^+$ number densities from the data after the subtraction of $O_2^+$ distribution. Average density ratio of heavy ions in the magnetotail ion outflow is $O^+:O_2^+:CO_2^+ = 29:68:3$.
We divided observed data by the location of the strong local crustal magnetic field around east longitude of 180 degrees into 4 local time groups: noon, dawn, dusk, and night. We also divided the data by locations of the ion outflow detection: upward E and downward E hemispheres in the Mars-Solar-Electric field (MSE) coordinates and north and south hemispheres in the Mars-Solar-Orbital (MSO) coordinates. The results show that number densities of heavy ions observed in the downward E hemisphere in the MSE coordinates tend to be higher than those observed in the upward E hemisphere, while the trend of heavy ion velocity is opposite. The results also show that the number fluxes of escaping heavy ions are similar in the both hemispheres, and fluxes observed in the upward E hemisphere tend to be smaller than those observed in the downward E hemisphere when the strong crustal magnetic field are located on the noon side. We will also report on other detailed features such as the energy and altitude dependences.

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