Effects of the IMF direction on ion escape mechanism under a weak intrinsic magnetic field condition at Mars

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It is considered that Mars had kept the warm and wet climate before ˜4 billion years. However, atmosphere and water are lost by certain processes, resulting in that present Mars only leave thin atmosphere. One candidate of the escape mechanism is the ion outflow from the upper atmosphere associated with the magnetic field. It is expected that ancient Mars had a global intrinsic magnetic field because there exists the crustal magnetic field in present Mars, and thus investing the effect of intrinsic magnetic field on the ion escape leads to understanding the climate change of Mars from past through present.

The planetary intrinsic magnetic field is significantly important in considering the atmospheric escape from planets. The strength of intrinsic field particularly affects the interaction between the solar wind and terrestrial-type planets (e.g., Seki et al., 2001), and it would change the escape mechanism. The direction of interplanetary magnetic field (IMF) significantly changes the magnetospheric configuration, influencing the atmospheric escape rate and mechanism. Sakai et al. (2018) investigated the effect of a weak intrinsic magnetic field at the Martian equatorial surface on the escape mechanism. It was shown that the existence of the weak field results in an enhancement of the ion escape rate. A parker-spiral IMF was however used in order to obtain the escape rate in this earlier study. This study investigates effects of the IMF direction on the ion escape, when Mars has a weak intrinsic magnetic field. Three IMF conditions, namely, the northward, southward, and Parker-spiral IMFs under present solar wind conditions are compared based on multispecies magnetohydrodynamics simulations. In the northward IMF case, molecular ions escape from the high-latitude lobe-reconnection region, where ionospheric ions transported upward along the open field lines. Oxygen ions originated either in ionosphere or oxygen corona escape from a broader ring-shaped region in the magnetotail. In the southward IMF case, escape flux of heavy ions increases significantly and have two peaks around the equatorial tail flanks in dawn and dusk. The draped IMF can penetrate into the subsolar ionosphere by erosion and the IMF is mass-loaded as it is transported through the dayside ionosphere. The mass-loaded draped IMF is carried to the tail, contributing to the ion escape. The escape channels in the northward and southward IMF cases are quite different from in the Parker-spiral IMF case. The escape rate is higher in the southward IMF than in the northward IMF case. In the northward IMF case, a weak intrinsic dipole forms the magnetosphere configuration similar to Earth, quenching the escape rate, while the southward IMF causes the erosion in the subsolar region, promoting the ion escape from upper atmosphere.

References:
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