Effects of the IMF direction on atmospheric escape under a weak intrinsic magnetic field at Mars

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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. In contrast, Mars would have kept the warm and wet climate around 4 Ga. 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 investigating the effect of intrinsic magnetic field on the ion escape leads to understanding the climate change of Mars from past through present.

Sakai et al. (2018) investigated the effect of an intrinsic magnetic field of 100 nT 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 interplanetary magnetic field (IMF) was used in order to obtain the escape rate in this earlier study.

In this study, influences of the IMF direction on the ion escape mechanism under the intrinsic magnetic field of 100 nT at the equatorial surface are investigated based on global multispecies single-fluid magnetohydrodynamics simulations (Terada et al., 2009; Sakai et al., 2018). Ion escape processes from Mars under two IMF conditions, namely, a northward and southward cases, are compared to those of the parker-spiral case. For the parker-spiral case, heavy ions escape through the channel associated with the open field lines and another channel associated with a magnetic reconnection between the planetary and solar wind magnetic fields at the flank magnetopause (Sakai et al., 2018). For the north-IMF case, the heavy ions mainly escape through the open or draped field lines formed by double lobe reconnections. The escape rate of heavy ions is about one order of magnitude smaller than for the parker-spiral IMF case and it is even smaller than for the no-dipole case. On the other hand, the heavy ions escape by the mass loading of draped field lines in the ionosphere for the south-IMF case. The escape rate of heavy ions is about one order of magnitude greater than for the parker-spiral case. For the north-IMF case, the interaction of the weak intrinsic magnetic field and IMF forms the firm magnetosphere, resulting in suppressing the ion escape. In contrast, the erosion of IMF into the deep ionosphere yields the increment of the ion escape rate for the south-IMF case.

References:

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