Effects of the intrinsic magnetic field on the ion loss from Mars at 3.5 Ga and 4.5 Ga

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Although Mars possessed a thick atmosphere in the Noachian period, Mars had lost the most part of the atmosphere and only have a thin CO_2 atmosphere today. Ion loss to space is one of the important processes of atmospheric escape from ancient Mars because the strong solar X-ray and extreme ultraviolet (XUV) flux and the harsh solar wind in the ancient day promotes the ion loss from the planet. On the other hand, ancient Mars had a global intrinsic magnetic field like the Earth. The existence of the intrinsic magnetic field changes the electromagnetic environment around the planet and thus affects processes and rates of the ion loss. However, the detailed effects are still in debate.

Our previous study investigated the ion loss from Mars under the extreme solar conditions at 4.5 Ga and the existence of dipole field with different strength based on the global multi-species magnetohydrodynamic (MHD) simulations. The solar XUV flux was 100 times higher than the present flux and the solar wind density, velocity, and the interplanetary magnetic field (IMF) strength were 1000 cm^{-3}, 2000 km/s, and 60 nT, respectively. The study indicates that the effects of the intrinsic magnetic field on the ion loss depends on whether the ionosphere is in the overpressure state. In the overpressure cases, where the solar wind dynamic pressure exceeds the sum of the maximum plasma pressure and the local magnetic pressure due to the intrinsic field in the ionosphere, the existence of an intrinsic magnetic field enhances the cusp outflow and increases the loss rates of molecular ions such as $O_2{}^+$ and $CO_2{}^+$. In the non-overpressure cases, however, the loss rates of molecular ions are reduced by two orders of magnitude. The effects on the O^+ loss rate are less pronounced than on molecular ions. This is because the mass-loading process at the extended oxygen corona created by the strong solar EUV flux contributes to the total O^+ loss and weakens the effects of the intrinsic magnetic field. We here investigated the effects of the intrinsic magnetic field on the ion loss from Mars under the more moderate solar conditions at 3.5 Ga in order to reveal how the effects of the intrinsic magnetic field depend on the solar XUV and solar wind conditions. We assumed that the solar XUV flux was 10 times higher and the solar wind density, velocity and the IMF strength were 70 cm^{-3}, 700 km/s, and 6.58 nT, respectively. We conducted simulations with different dipole field strength to compare the results in the overpressure cases and the non-overpressure cases.