太古の火星からのイオン散逸に対する弱い固有磁場の影響

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Effects of a weak planetary intrinsic magnetic field on the ion loss from ancient Mars

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Mars had a thick atmosphere and liquid water in ancient days but lost most of them. One of the candidate processes of the removal of the atmosphere is the ion loss. The ancient solar XUV (X-ray and extreme ultra-violet) irradiance was more intense and the ancient solar wind was faster and denser. Recent studies have pointed out that the ion loss rate at Mars increases several orders of magnitude under such severer solar conditions. On the other hand, the existence of the crustal magnetic field suggests that ancient Mars had an intrinsic magnetic field. The existence of an intrinsic magnetic field can affect the structure of the magnetosphere and thus the ion loss processes. To understand the atmospheric escape from ancient Mars, it is important to investigate how the intrinsic magnetic field influences the ion loss processes.

We studied the ion loss processes from early Mars under ancient solar conditions and the existence of weak intrinsic magnetic field with magnetohydrodynamic (MHD) simulations. We used 3D multi-species MHD model introduced by Terada et al. (2009a) and added the planetary intrinsic magnetic field. We assumed that the interplanetary magnetic field was a parker spiral and solar wind proton density, the solar wind velocity, and the solar XUV flux were 1000 /cm^3, 2000 km/s, and 100 times higher than the present-day XUV flux, respectively. These parameters are same as those used in Terada et al. (2009b), in which the neutral atmosphere profile of ancient Mars is adopted from the model introduced by Kulikov et al. (2007). We conducted three cases of simulations with different intrinsic magnetic field conditions, that is, dipole fields with the strength of 0 nT, 100 nT, and 1000 nT on the equatorial surface. It should be noted that the dynamic pressure of the solar wind in this study is equivalent to the magnetic pressure of field strength of 4100 nT.

The results of 1000 nT case show that the tailward flux structure and the plasma sheet in the tail region incline towards the dusk side in the northern hemisphere and towards the dawn side in the southern hemisphere. Also, the escape rates of heavier ions such as CO_2^+ and O_2^+ are several times higher than those with no (0 nT) intrinsic magnetic field. The escape channels of these ions correspond to the open magnetic field lines, that is, the field lines with one end connected to the planet and the other end connected to the interplanetary magnetic field. These phenomena are due to the magnetic reconnection between the intrinsic magnetic field and the interplanetary magnetic field. The increases in escape rates of heavy ions and the reconnections in the tail region also occur in 100 nT case. However, the inclination of the tailward-flux structure and the correspondence of the escape channels to the open field lines are less distinct. The structure of tailward flux is along to the plasma sheet with no (0 nT) intrinsic magnetic field.

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