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

Shotaro Sakai[1]; Kanako Seki[1]; Naoki Terada[2]; Hiroyuki Shinagawa[3]; Ryoya Sakata[1]; Takashi Tanaka[4]; Yusuke Ebihara[5]
[1] Dept. Earth & Planetary Sci., Science, Univ. Tokyo; [2] Dept. Geophys., Grad. Sch. Sci., Tohoku Univ.; [3] NICT; [4] REPPU code Institute; [5] RISH, Kyoto Univ.

Understanding the atmospheric escape mechanism leads to reveal the Martian climate history. Present Mars has a thin atmosphere and little water on the surface, while ancient Mars could keep liquid water and a thick atmosphere. This suggests that Mars has experienced significant atmospheric loss from the past through the present. The atmosphere escapes as shapes of neutral gas or ions. Ion outflow is one of the important atmospheric loss mechanisms. In the present day, Mars does not have a global magnetic field such as that of Earth, and thus, ions escape by the direct interaction with the solar wind. In contrast, it is expected that ancient Mars had a global magnetic field. The global magnetic field forms the magnetosphere around the planet and change the ion escape mechanism. Sakai et al. (2018) showed that the existence of a weak dipole field results in an enhancement of the ion escape rate under a parker spiral type interplanetary magnetic field (IMF).

In this study, effects of the IMF direction on the ion escape processes 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 a parker-spiral cases, are compared. In the parker-spiral case, heavy ions escape through the two channels associated with the open field lines and other two channels associated with a magnetic reconnection between the planetary and solar wind magnetic fields at the flank magnetopause (Sakai et al., 2018). In contrast, the heavy ions mainly escape through the open field line related to the cusp in the northward case. The escape rate of heavy ions in the north-IMF case is about one order of magnitude smaller than in the parker-spiral IMF case and it is even smaller than in the no-dipole case. It suggests that the interaction of the weak intrinsic magnetic field and northward IMF forms the firm magnetosphere, resulting in suppressing the ion escape. The results also show that the IMF direction significantly affects the ion escape processes.

References:
Sakai, S., Seki, K., Terada, N., Shinagawa, H., Tanaka, T., & Ebihara, Y. (2018). Effects of a weak intrinsic magnetic field on atmospheric escape from Mars. Geophys. Res. Lett., submitted.
Terada, N., Kulikov, Y. N., Lammer, H., Lichtenegger, H. I. M., Tanaka, T., Shinagawa, H., & Zhang, T. (2009). Atmospheric and water loss from early Mars under extreme solar wind and extreme ultraviolet conditions. Astrobiology, 9, 55-70. https://doi.org/10.1089/ast.2008.0250