Study of proton escape from Mars based on MAVEN observations

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Mars is considered to have had water on surface in ancient days, while there is no surface water at present. Escape of atmospheric gases to space is considered to play an important role in this climate change. Particularly, hydrogen loss is closely related to the water content on Mars. Its main mechanism is thought to be Jeans escape of hydrogen atoms, which are dissociated from hydrogen molecules, sourced from odd-hydrogen reactions with near-surface water vapor. Since the molecular hydrogen is long-lived, the seasonal variation of hydrogen escape is predicted to be typically less than a factor of two (Krasnopolsky, 2002). However, Halekas (2017) reported unexpectedly large (about one order of magnitude) seasonal variations in the hydrogen corona. The cause of the large seasonal variation is not understood. A candidate mechanism is rapid transport of water to upper atmosphere due to the Martian dust storms. The enhancement of the hydrogen corona will increase the proton escape originated from the neutral hydrogen. In order to assess the hypothesis, we investigated proton escape from Mars based on MAVEN (Mars Atmosphere and Volatile EvolutioN) observations from November 2014 to March 2019. We also investigated if the seasonal variation depends on size of the dust storms by comparing MY32, 33 and 34, since Martian global dust storm occurred only in MY34.
For this purpose, we implemented methods to separate planetary-origin protons from solar-origin protons, which utilize characteristics of phase space density (PSD) observed in the solar wind, magnetosheath, and magnetotail wake regions, by STATIC (Supra Thermal and Thermal Ion Composition) instrument. For identification of each region, we used data from MAG (magnetometer) and SWIA (Solar Wind Ion Analyzer) onboard MAVEN. STATIC can measure ion distribution functions with energy and mass discrimination. In the magnetotail wake region, we divided the energy range in three parts: less than 20eV, between 20eV and 100eV, and greater than 100eV. The ions in the lowest energy range were identified as planetary protons. The methods to separate planetary from solar wind protons in solar wind and magnetosheath regions need to be different from that in the wake region. We removed solar wind velocity distributions by fitting in the rest frame of the solar wind/magnetosheath bulk flow, and calculated partial moments of picked up protons originated from hydrogen corona. To calculate partial moments, we identified regions where picked up protons should distribute. The regions are different between solar wind and magnetosheath regions. The obtained variations of the planetary protons are compared by using the wavelet analysis. The result shows that planetary proton density in the wake region had a seasonal variability which was more than one order, while variations in MY32, 33 and 34 were similar. Therefore, it is thought that the size of dust storm does not affect proton escape through the magnetotail wake region. The result in the solar wind region has the same seasonal variation as the result in the wake region. However, the amplitude of the variation in the solar wind region is smaller than that in the wake region. The protons in the magnetosheath region shows variation in the shorter periods. The wave period is about 200 days. It is thought that this time variation depends on the solar zenith angle.

References:

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