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Heavy ion enhancement in the vicinity of the Martian ionosphere during CIR passage: Mars Express ASPERA-3 Observations

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Because Mars doesn't possess a global intrinsic magnetic field, the solar wind can directly interact with the Martian ionosphere. Outflows of planetary ions of the Martian upper atmosphere by the solar wind induced process are thus considered important to understand the evolution of the Martian atmosphere. On the basis of plasma observations by the Phobos-2 and recently by the Mars Express (MEX) missions, outflows of planetary ions from Martian upper atmosphere have been reported. Those studies suggested that the estimated total escape fluxes from the Martian upper atmosphere are quite different between the solar minimum and maximum conditions. In addition, the detailed escape processes and their response to solar wind conditions are far from understood.
In this study, we investigated a response of planetary heavy ion escape from Mars with a focus on a characteristic heavy ion signature observed in the vicinity of Martian ionosphere during passages of CIR (Corotating Interaction Region) structures in the solar wind. CIRs are formed at the interface of slow- and high-speed solar wind streams. We analyzed data recorded by the Ion Mass Analyzer (IMA), which is a part of the ASPERA-3 (Analyzer of Space Plasma and Energetic Atoms) instrument onboard MEX, from September to November 2007. In this period, the solar activity was quite low, and the CIR structures often passed through Mars. The IMA instrument can observe ions from 10 [eV] to 30 [keV] with ability of mass discrimination between the solar wind light ions (mainly protons and alpha particles) and the planetary heavy ions (e.g. O+, O2+, CO2+).
First, we compared the solar wind velocity at Mars derived from three different methods: A shifted Maxwellian fitting of MEX ASPERA-3 IMA data, the time shift of ACE satellite data to Martian orbit, and a combination of MHD simulations and Interplanetary Scintillation (IPS) observations. Using the derived solar wind velocity at the Martian orbit, we identified four events of the coincidence between heavy ion flux enhancement and CIR arrival. The velocity distribution functions show that the high energy component (> 100 [eV]) has downward velocity to Mars, and the low energy component (< 100 [eV]) is traveling upward from Mars. A possible scenario to explain the enhancement might be the increase of the sputtering process. Due to the compressed interplanetary magnetic field structure embedded in the CIR, the gyro radii of picked up planetary heavy ions born around the dayside region become smaller to be comparable to Martian radius. Such picked up ions then have more chance to precipitate to the Martian atmosphere. The precipitated heavy ions sputter the planetary atmosphere such as oxygen at the Martian upper atmosphere. As a result, the low energy ions were enhanced during the passage of the CIR structures.

Keywords: Mars