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Ion escape from the Martian Ionosphere

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The upper ionospheres of Mars and Venus are permeated by the magnetic fields induced by the solar wind. It is a long-standing question whether these fields can put the dense ionospheric plasma into motion. If so, the transterminator flow of the upper ionosphere could explain a significant part of the ion escape from the planets atmospheres. But it has been technically very challenging to measure the ion flow at energies below 20eV. The only such measurements have been made by the ORPA instrument of the Pioneer Venus Orbiter reporting speeds of 1-5km/s for O+ ions at Venus above 300km altitude at the terminator (Knudsen et al. 1982). At Venus the transterminator flow is sufficient to sustain a permanent nightside ionosphere, at Mars a nightside ionosphere is observed only sporadically. We here report on new measurements of the ionospheric ion flows at Mars by the ASPERA-3 experiment on board Mars Express. We use support from the MARSIS radar experiment for some orbits with fortunate observation geometry. Here we have observed a transterminator flow of O^+ and O_2^+ ions with a super-sonic velocity of around 5km/s and fluxes of $0.8 \cdot 10^9$/cm^{2}s. If we assume a symmetric flux around the terminator this corresponds to an ion flow of $3.1 \pm 0.5 \times 10^{25}/s$ half of which is expected to escape from Mars (Fraenz et al, 2010). This escape flux is significantly higher than previously observed on the tailside of Mars, we discuss possible reasons for the difference. Since 2008 the MARSIS radar does nightside local plasma density measurement which sometimes coincide with ASPERA-3 measurements. A first analysis of the combined nightside datasets confirms that at leat half of the transterminator ionospheric flow escapes from the planet. Possible mechanism to generate this flux can be the ionospheric pressure gradient between dayside and nightside or momentum transfer from the solar wind via the induced magnetic field since the flow velocity is in the Alfvénic regime.

We discuss the implication of these new observations for ion escape and possible extensions of the analysis to dayside observations which might allow us to infer the flow structure imposed by the induced magnetic field.