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Ionospheric dynamics at Mars and Venus

M. Fränz (1), E. Dubinin (1), E. Nielsen (1), A. Angsmann (1), J. Woch (1), S. Barabash (2), R. Lundin (2) and A. Fedorov (3)
(1) MPI for Solar System Research, Katlenburg-Lindau, Germany (fraenz@mps.mpg.de / Fax: +49-5556-979-240),
(2) Institute for Space Physics, Kiruna, Sweden, (3) CESR, Toulouse, France (fraenz@mps.mpg.de)

Abstract

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 and Venus by the ASPERA-3 and -4 experiments on board Mars and Venus Express. For Mars 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. 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. For Venus there is no independent observation of the cold plasma density by Venus Express and we can infer properties of the plasma distribution only using stronger assumption than for Mars. But measurements of the chemical plasma composition at low energies can help to get consistent flow parameters. 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.

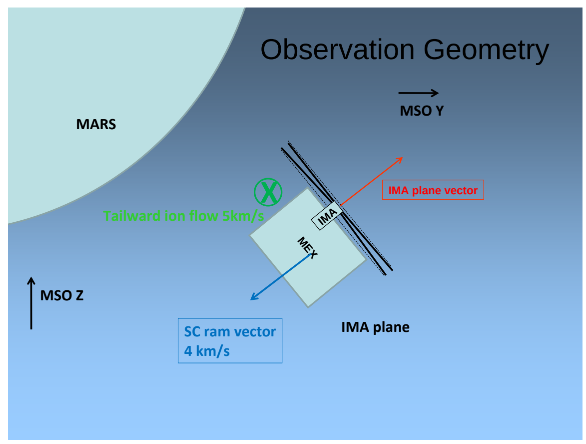

Figure 1: Sketch of the observation geometry when IMA plane vector is parallel to the spacecraft ram direction in the terminator plane. The Mars Solar Orbital (MSO) coordinate frame is defined by its X-axis pointing from the center of Mars to the Sun and its Y-axis against the direction of orbital motion of Mars, the Z-axis completes the right handed system. **Only in this configuration the trans-terminator flow can be observed by ASPERA-3.**

Orbit	Peric.Time Date 2007	Altitudes [km]	Flux [10^9/cm^{2}s]	Escape [$10^{25}/s$]	O^+/O_2^+
4985	11-19 12:53	290-450	0.8 ± 0.4	3.0 ± 1.0	0.4 ± 0.2
4988	11-20 09:04	290-400	0.9 ± 0.5	2.5 ± 0.5	0.5 ± 0.1
4989	11-20 15:47	290-500	0.8 ± 0.3	4.0 ± 0.5	1.2 ± 0.3
5009	11-26 06:23	290-460	0.9 ± 0.3	2.0 ± 1.0	2.0 ± 0.3
5010	11-26 13:08	290-450	1.0 ± 0.2	5.0 ± 0.5	0.9 ± 0.2
5013	11-27 09:25	290-380	0.5 ± 0.3	3.5 ± 1.5	1.3 ± 0.5
5035	12-03 07:22	290-360	0.5 ± 0.2	2.0 ± 1.0	0.8 ± 0.5
Mean		290-430	0.77 ± 0.2	3.1 ± 0.5	1.0 ± 0.2

Table 1: Cross-terminator ion flow data for 7 orbits between 2007-11-19 and 2007-12-03: Orbit number, Pericenter Time, Altitude range with flux $> 3 \cdot 10^8$/cm^{2}s, total escape, mean O^+/O_2^+ ratio.

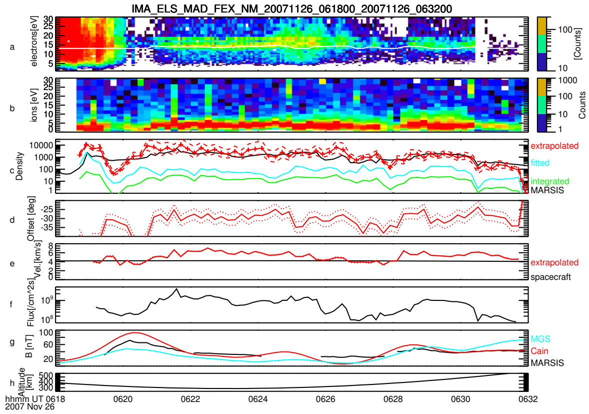

Figure 2: Observations by the ASPERA-3 and MARSIS experiments on Mars Express on 2007-11-26 06:18-06:32UT (orbit 5009) from top to bottom: a) electron spectrogram with photo electron energy (white) , b) ion spectrogram corrected by potential, c) Plasma density derived from: MARSIS frequency (black), IMA 2D integrated (green), IMA 2D fitted (cyan), IMA extrapolated to 3D (red), d) angle [deg] between: IMA plane and flow vector, e) spacecraft ram velocity (black) and IMA ion bulk velocity (red) [km/s], f) ion flux, g) magnetic field: observed by MARSIS (black), MGS crustal (cyan), Cain model (red), h) spacecraft altitude [km]. **We observe agreement between the plasma density extrapolated from the IMA 2D-observation and the total density observed by MARSIS.**

Acknowledgements

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References

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