Channels for ion escape at Mars and their effectiveness

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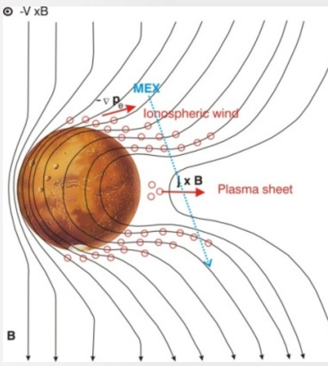
Main channels for solar wind induced escape :

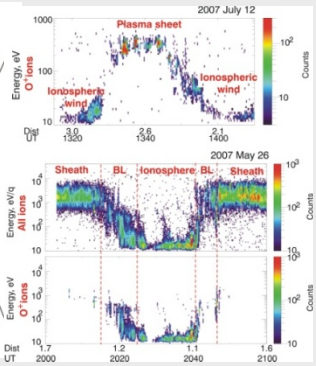
- Plasma sheet
- Boundary layer (mantle)
- Ionospheric ("polar") wind
- Escape through mini-cusps and auroral flux tubes (due to crustal magnetic fields)
- Scavenging (global and local)

How planetary ions are accelerated and escape?

$$E = -\frac{1}{c} V_i \times B + \frac{j \times B}{nec} - \frac{\nabla P_e}{ne}$$

VxB term dominates in the BL, Hall term is the mostimportant in PS. Electron pressure gradient is responsible for ionospheric wind





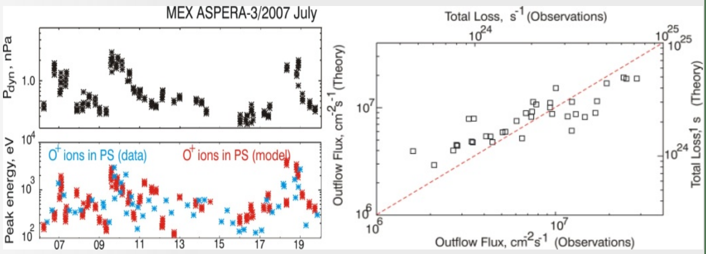
Examples of ion measurements in polar wind, plasma sheet and boundary layer

Variations of ion energy and escape fluxes with solar wind variations

Momentum flux carried by SW is transferred to the magnetic barrier on the dayside. Then the magnetic tensions of the draped and temporary captured magnetic field lines expel plasma into the tail

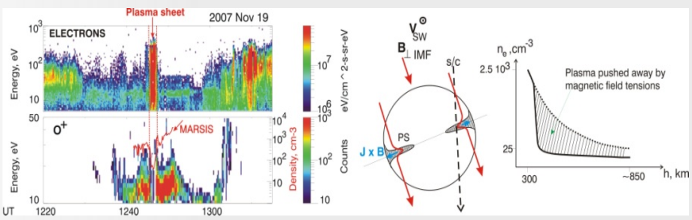
$$E_{O+} \approx k\rho_{sw}V_{sw}^{2}/2(1+2r) \text{ and } f_M = f_{sw}\frac{n_{O^+}}{n_{sw}}\left(\frac{k}{16(1+2r)}\right)^{1/2}$$

where $r = n_{O_2^+}/n_{O^+}$ K is efficiency of momentum transfer



Comparison of measured and model values of oxygen ion energies and escape fluxes

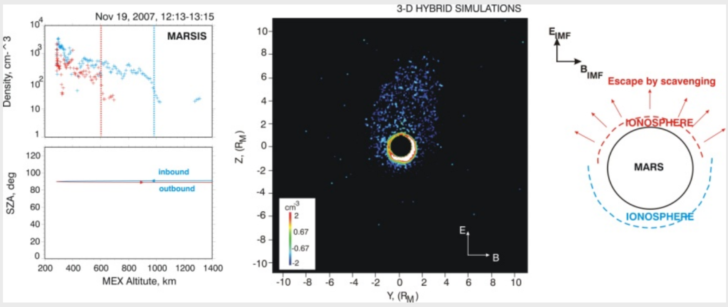
Magnetic field tensions produce two erosion channels in the upper ionosphere



Ion injection into tail via PS is one of the most important channels for escape $L \sim 1 \div 2\times 10^{24}\ s^{-1}$

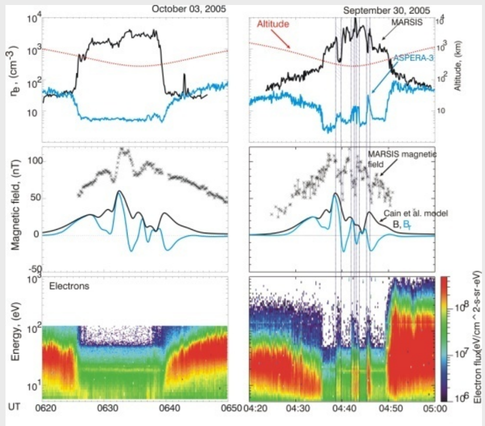
(Dubinin et al., JGR, 2008)

Asymmetrical scavenging due to v x B field



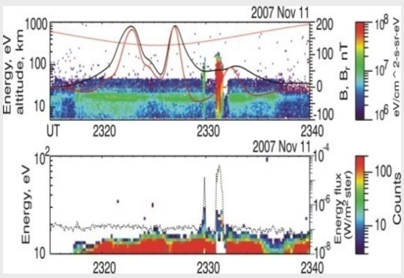
$$L = n\cdot V\cdot S \approx 300\ cm^{-3} \times (5\div 20)\ km/s \times \frac{\pi}{2}(1000^2 - 600^2)\ km^2 \approx (1.5\div 6)\times 10^{24} s^{-1}$$

Escape through mini-cusps



Two subsequent orbits over the same regions with strong crustal magnetic field. Intrusion of SW and ionospheric erosion is probably controlled by the IMF – direction.

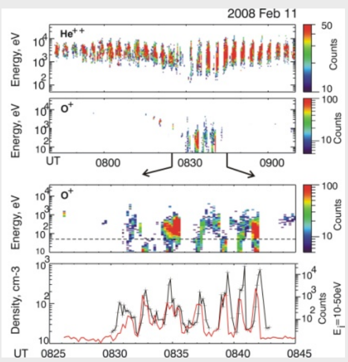
Escape through auroral flux tubes



Long-lived (at least, during almost two weeks) and active aurora-type magnetic flux tubes with width of 20-150 km are observed . Energy carried by precipitating electrons is sufficient for strong heating and acceleration of O^+ ions in the ionospheric O^+ layer (300-500 km).

Atmospheric loss driven in a single auroral flux tube is about $5x10^{22}$ s-1 (Dubinin et.al. , GRL, 2009a).

Ionospheric storms and erosion during impact of Corotating Interaction Regions



During impact of a dense and high pressure solar wind (CIR) on Mars the magnetic barrier ceases to be an effective shield and large blobs of solar wind penetrate into the ionosphere and sweep out a dense planetary plasma. Upper ionosphere becomes very fragmented . The scavenging effect enhances significantly (~$2x10^{25}s^{-1}$) the losses of volatiles from Mars

(Dubinin et al., GRL, 2009b)