SOLAR-WIND INDUCED ATMOSPHERIC EROSION AT MARS: FIRST RESULTS FROM ASPERA-3 ON MARS-EXPRESS

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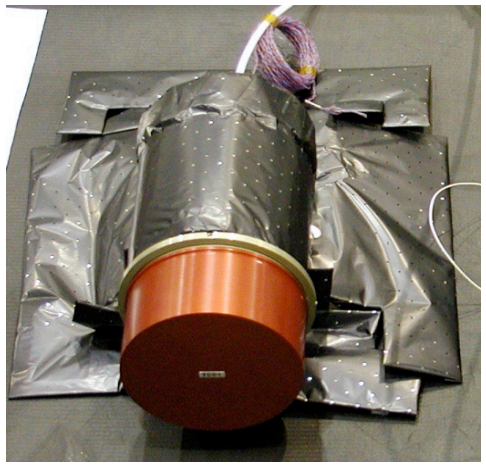
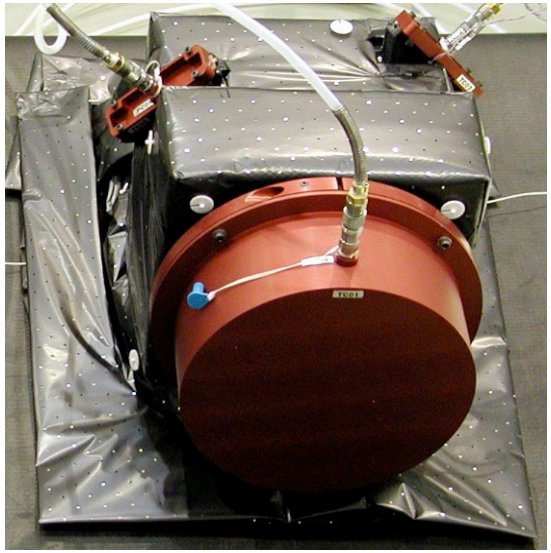
ASPERA-3

Objective: To measure solar wind scavenging : The slow “invisible” escape of volatiles (atmosphere, hydrosphere) from Mars.

Question: Is the solar wind erosion the prime reason for the present lack of water on Mars?



Ion mass analyzer



Main Unit:

- Data processing
- Neutral particle imagers (NPI, NPD)
- Electron spectrometer (ELS)
- Mechanical scanner

Solar wind atmospheric erosion at Mars

Planetary wind = Outflow of atmosphere and ionosphere

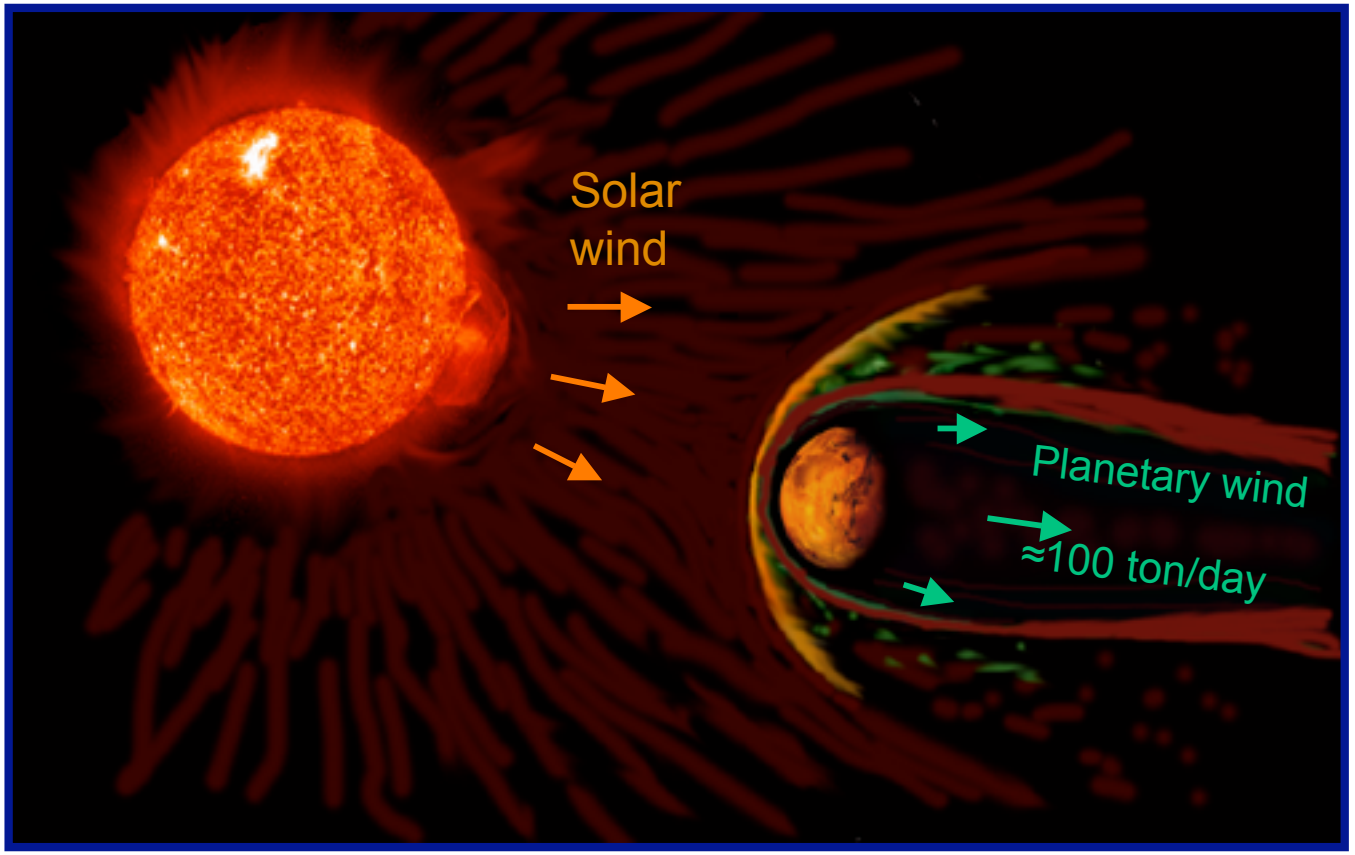
ASPERA is doing global imaging and *in-situ* measurements of:

Inflow - solar wind

Outflow - planetary wind

using:

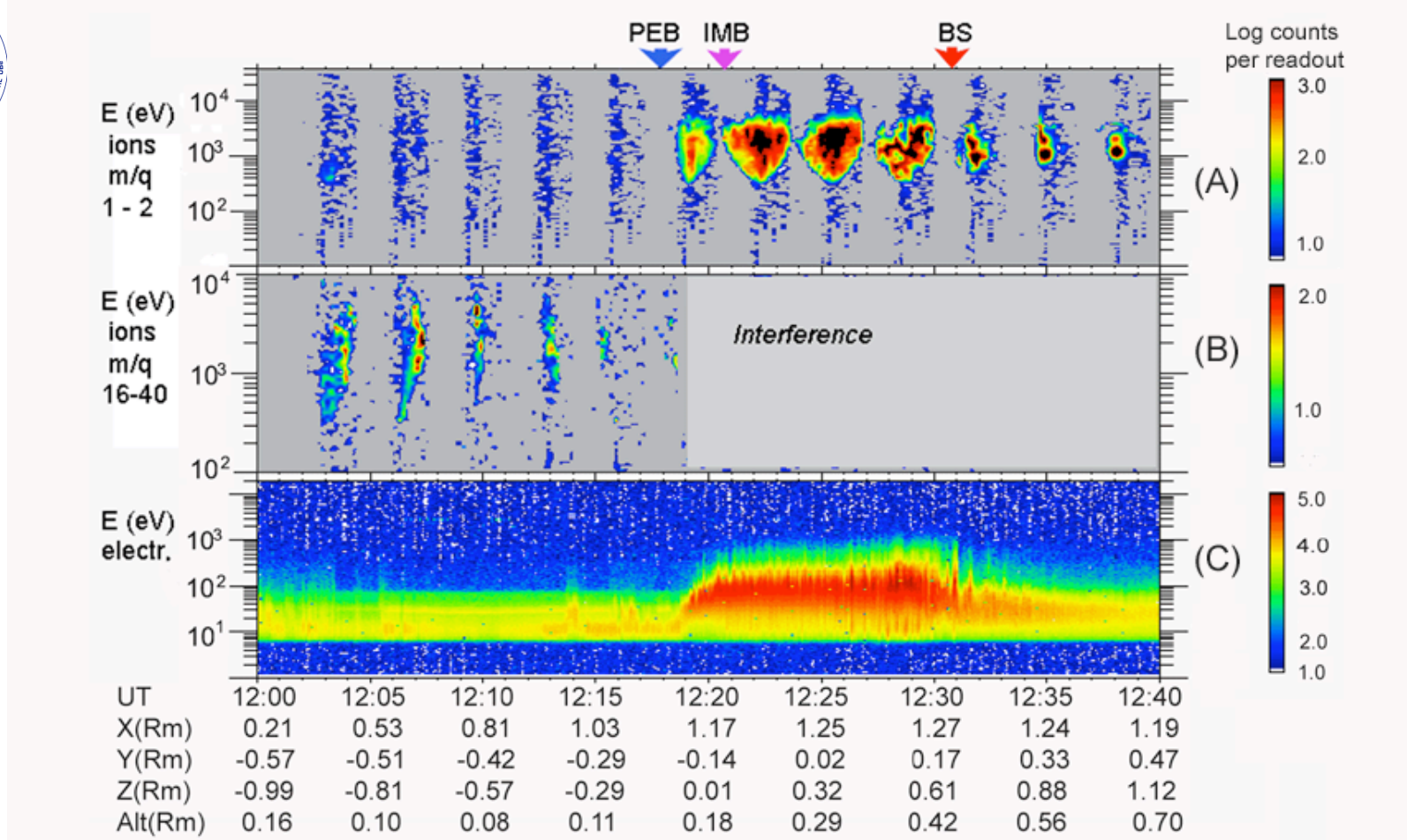
Energetic neutral atom cameras and plasma (ion+electron) spectrometers



Note: Mars (and Venus) are planets lacking a strong intrinsic magnetic field (umbrella) => dehydration.

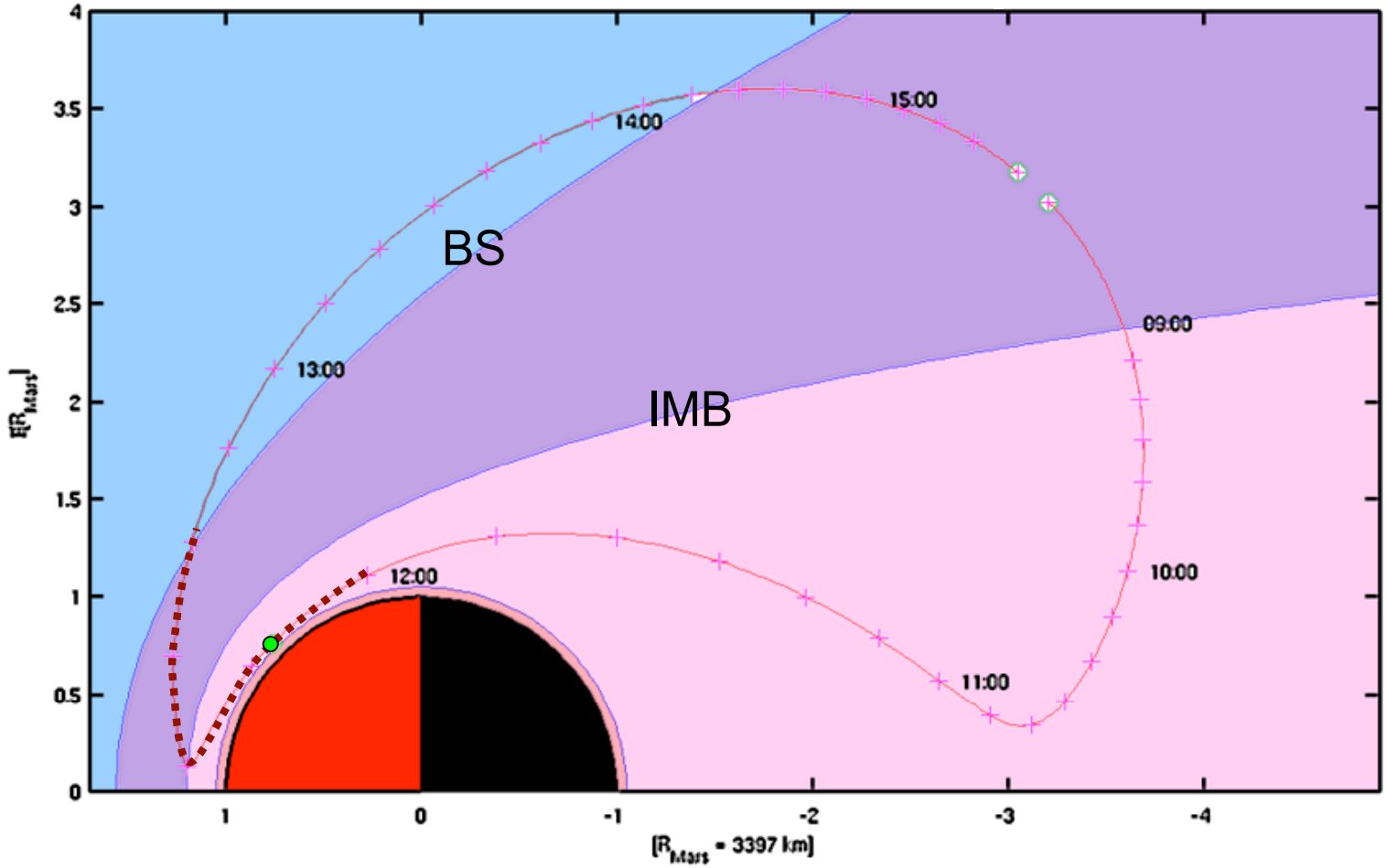
ASPERA-3 New Findings

1. **The Solar wind** may protrude very deep into the dayside atmosphere - down to pericenter altitudes ≈270 km
2. Acceleration processes responsible for the erosion of atmosphere - **the planetary wind** - start as low as ≈270 km above the surface of Mars.
3. Accelerated/outflowing O^+ may reach **several keV at 300 km** altitude!
4. The planetary wind comprise also **molecular species** (e.g. O_2^+), consistent with acceleration processes reaching low altitudes

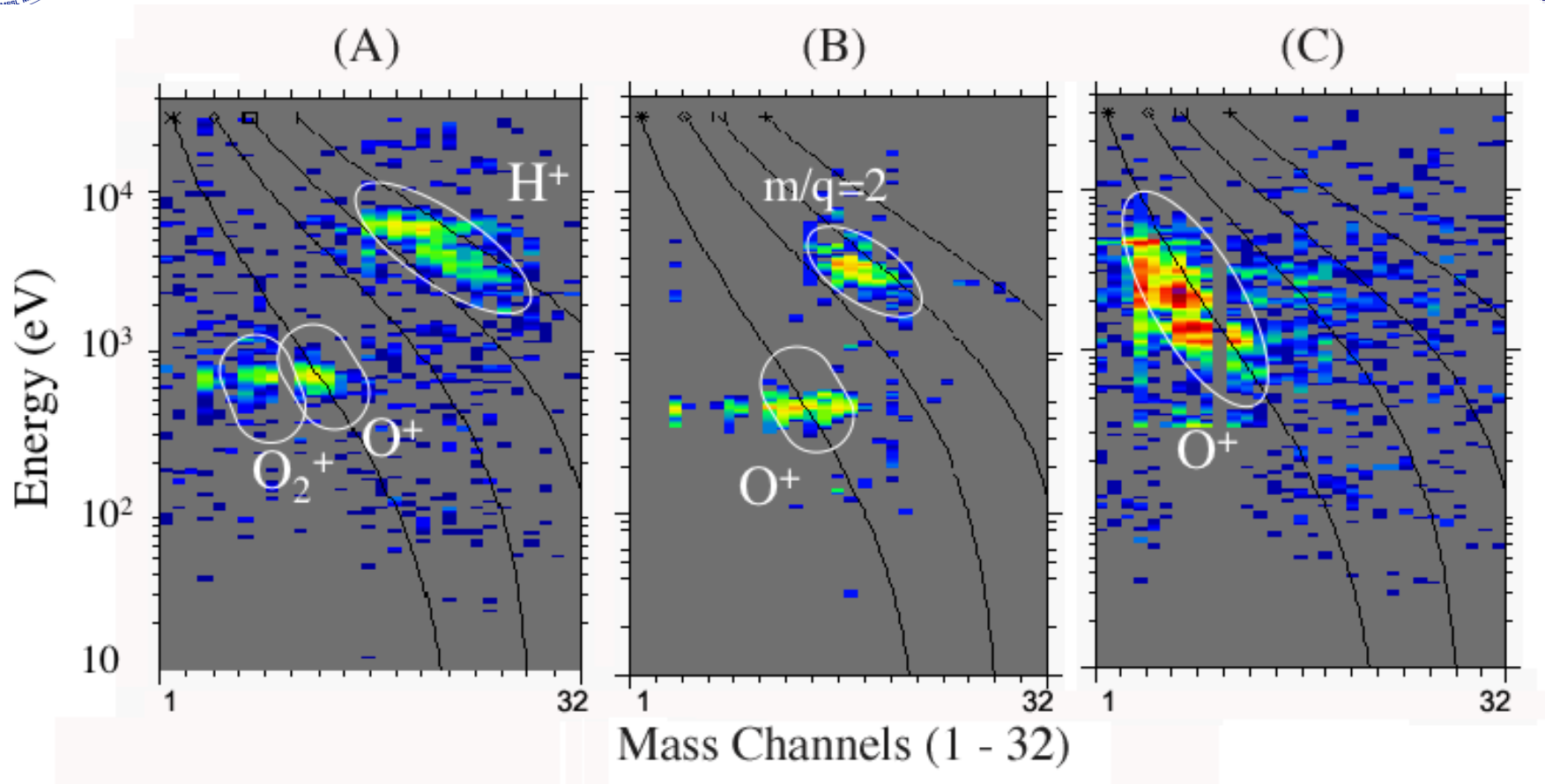


MEX pericenter pass on March 22, 2004 (≈12.08 UT) traversing the ionosphere photoelectron boundary (PEB), the induced magnetosphere boundary (IMB) and the bow shock (BS). The three panels depict H^+ (A), heavy ion, e.g. O^+ (B) and electron (C) energy-time spectra from the IMA and ELS spectrometers of ASPERA-3. "Interference" in the middle panel indicates contamination in the heavy ion mass channels by intense fluxes of H^+. X, Y, and Z give the spacecraft coordinates in Mars Solar Ecliptic coordinates (Rm=Mars radii) .

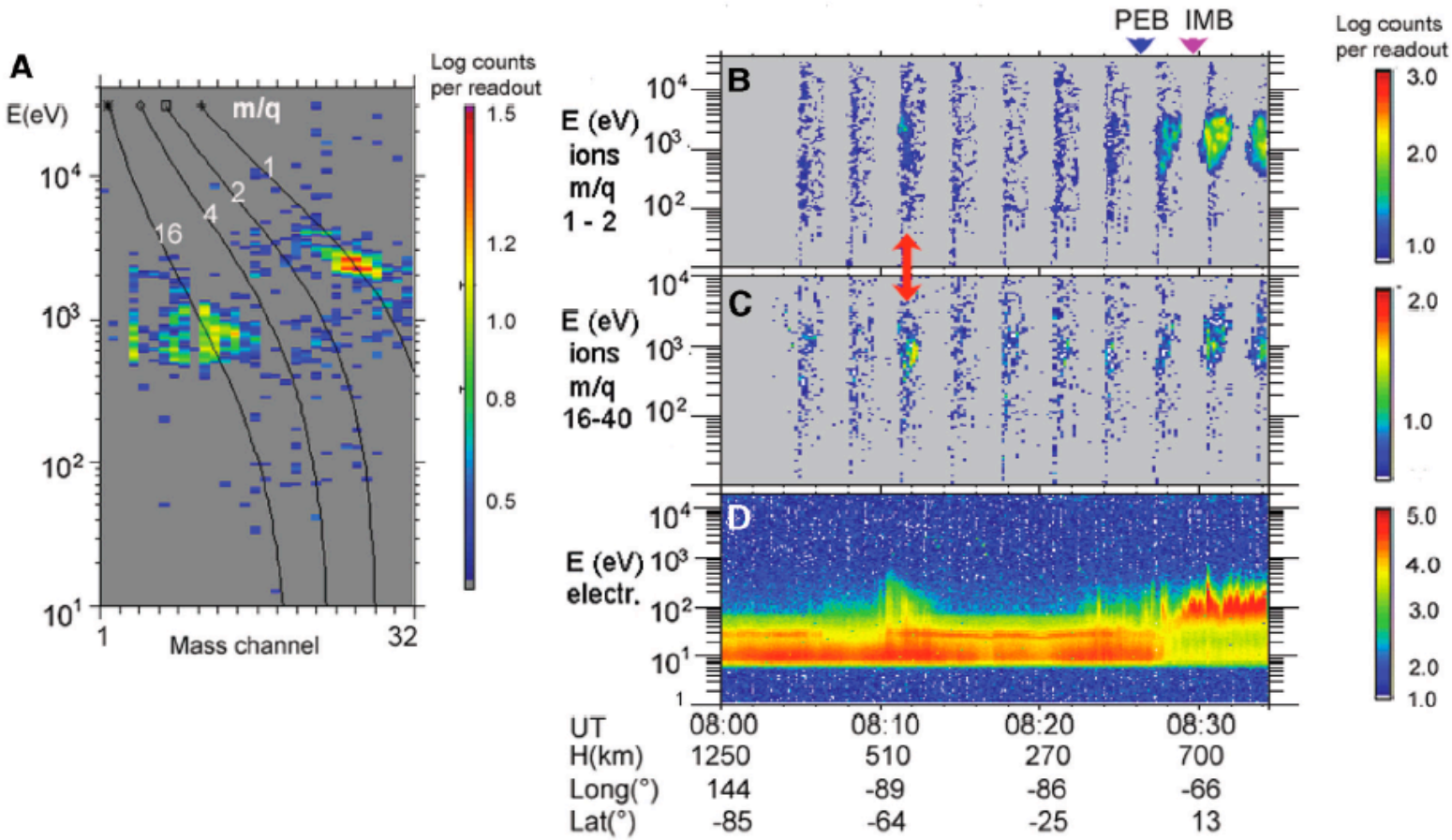
Mars Express Orbit, March 22, 2004



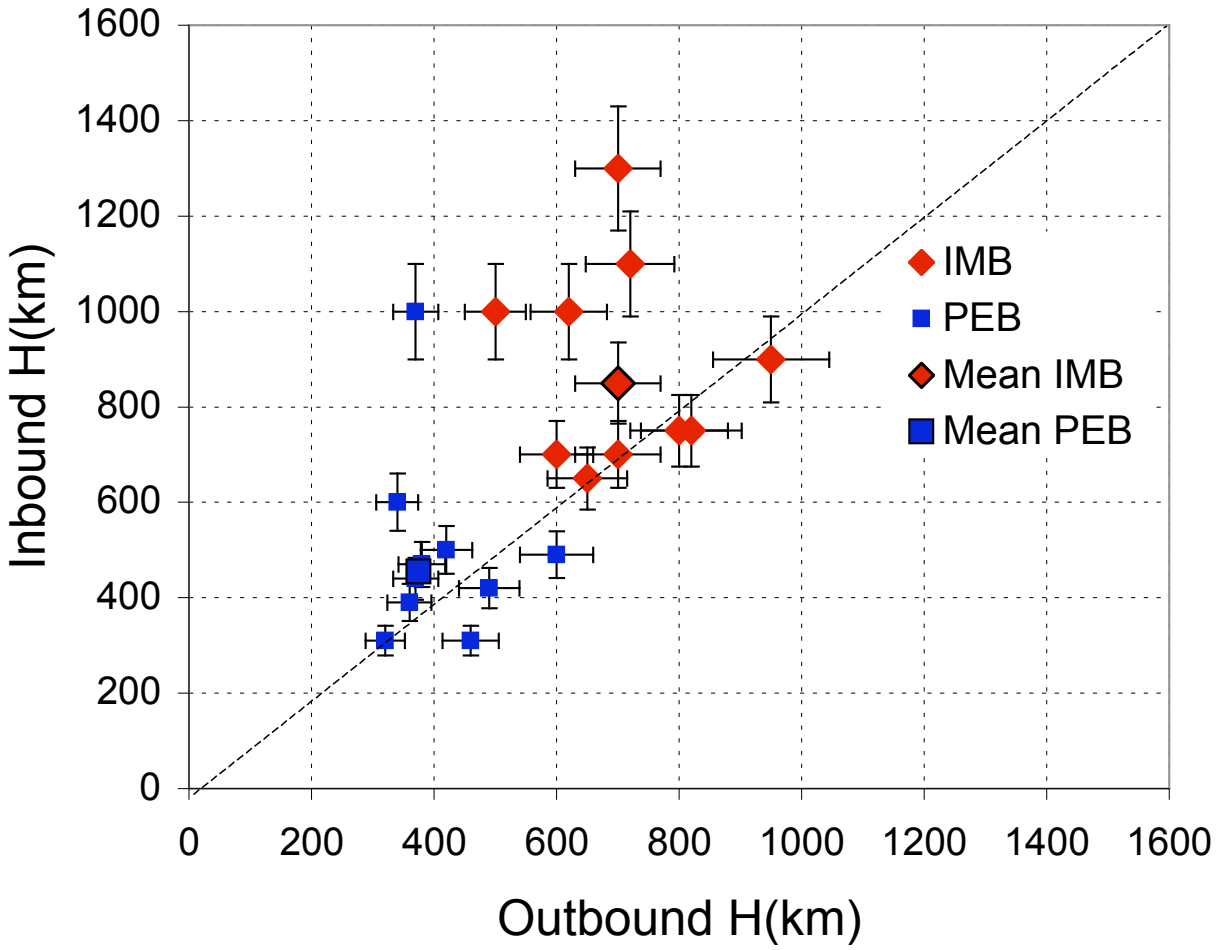
MEX orbit in cylindrical coordinate system. Pericenter at ≈12.08 UT is marked by green dot. Dasched line indicates data shown in previous data viewgraph. Colored areas indicates **solar wind** (blue), **magnetosheath** (magenta) and **inner magnetosphere** (light red). BS marks the bow shock and IMB marks the induced magnetosphere boundary.



Three examples of energy-m/q spectra for energized ions. Black lines indicate nominal mass-identification of m/q=1, 2, 4 and 16 ions respectively.
(A) 27 Feb, 2004, 2-7 keV H^+ and ≈700 eV heavy ions (O^+, O_2^+) at an altitude of ≈290 km.
(B) 25 Jan, 2004, ≈500 eV heavy ions and keV m/q=2 ions (He^{++}, H_2^+ , D^+ ?) at 900 km altitude
(C) 22 March 2004, strong energization of heavy ions at an altitude of ≈330 km.

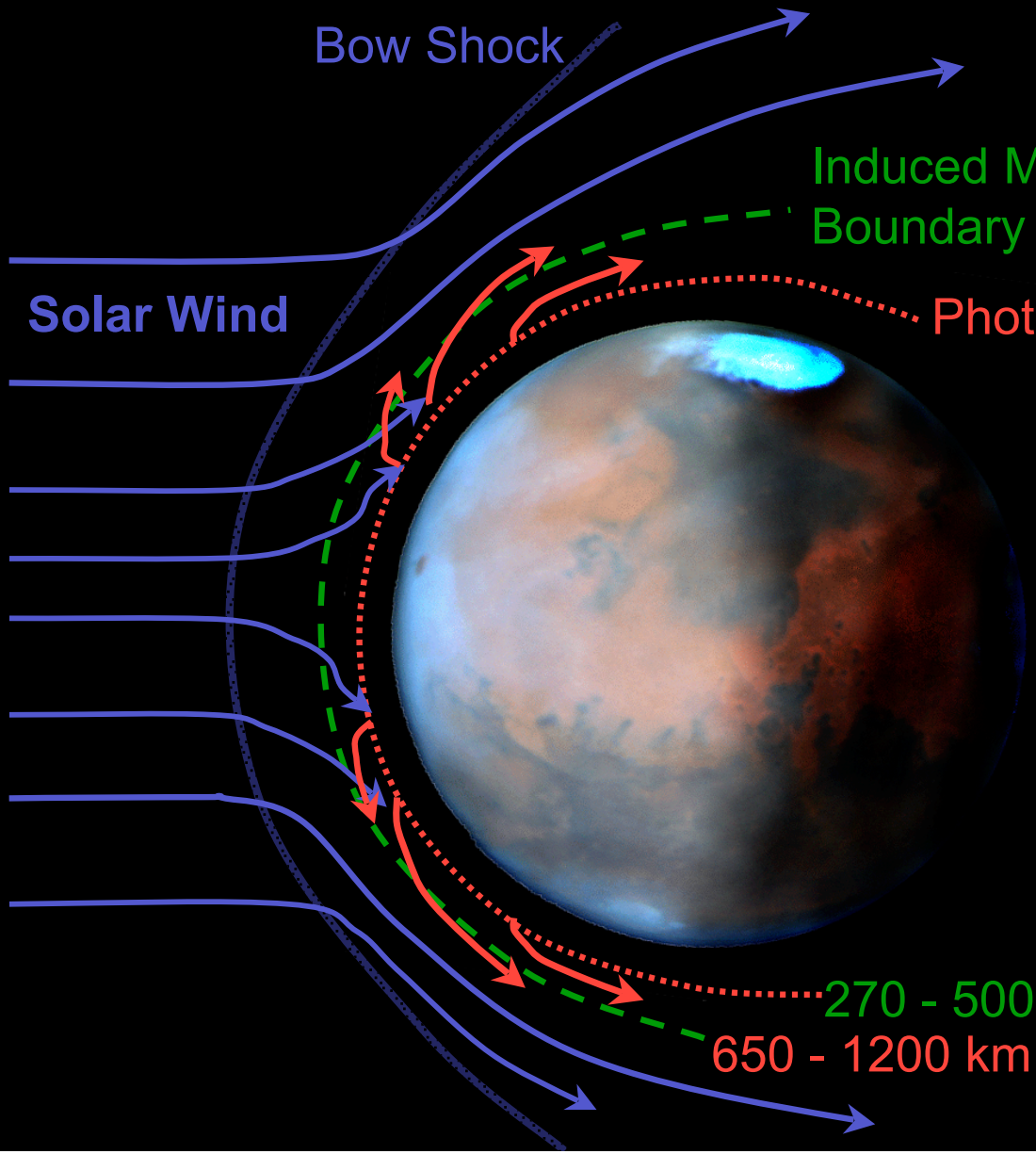


1 March, 2004, observations of energized heavy ions (≈0.8-1 keV) and electrons at an altitude of ≈460 km, at the same time observing H^+ (≈2 keV) of solar wind origin. Panel A show an energy-mass spectrum of the event marked out by the double arrow in the right panel (08:10 - 08:13 UT). Panel B, C and D show energy-time spectra for H^+ and He^{++} , heavy ions with m/q>16, and electrons respectively.



Altitude statistics of the dayside Martian Photo-electron boundary (PEB) and Induced magnetosphere boundary (IMB). The variability (in space and time) of the boundaries is demonstrated by plotting the inbound boundary versus the outbound boundary.

Ionospheric Outflow from Mars



Energization and outflow from the dayside atmosphere/ionosphere start between the PEB and IMB

(≈270 - 600 km)

Conclusion

1. Solar wind plasma protrudes fairly deep into the Martian ionosphere and atmosphere - occasionally down to pericenter altitudes ≈270 km
2. Acceleration processes responsible for the erosion and loss of the Martian ionosphere may go deep down in the ionosphere - the planetary wind from the dayside region sweeping tailward at altitudes as low as ≈270 km above the surface of Mars.
3. Accelerated/outflowing heavy ions (e.g. O^+) with several keV in energy are found at 300 km altitude.
4. The planetary wind comprise also molecular species, mainly as heavy ion molecules (e.g. CO_2^+. and O_2^+). This is consistent with an ionospheric ion energization processes reaching low altitudes.