First results of the Analyzer of Space Plasma and Energetic Neutral Atoms (ASPERA-3) onboard Mars Express

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and

THE ASPERA-3 TEAM

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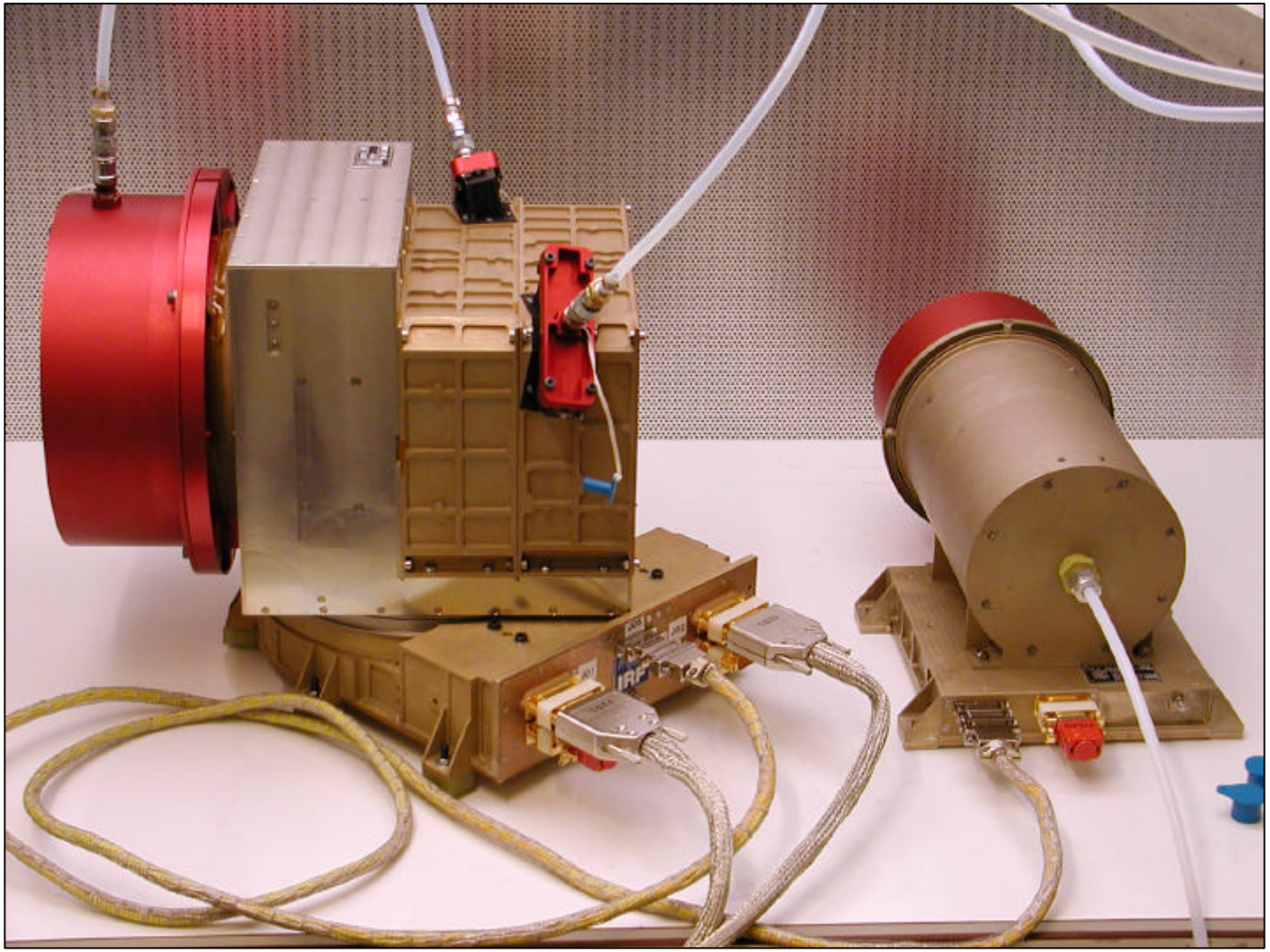
Outline

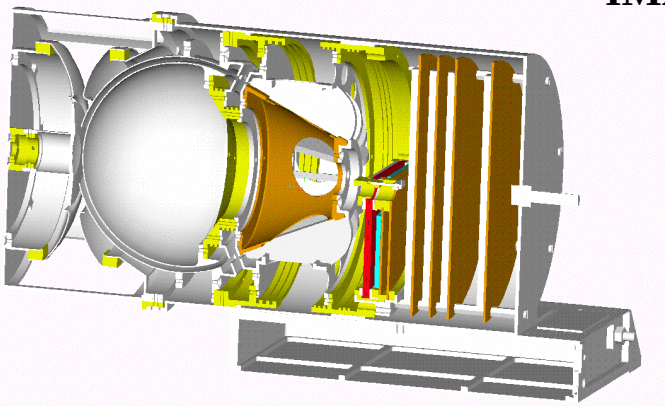
- ASPERA-3 instrument
- MEX orbit
- Experiment novelty
- First results (focus on ENA measurements)
  - Boundary crossings in electron and ion data
  - Electron measurements in the ionosphere (photoelectron peaks)
  - Ion composition measurements (following talks)
    - Overview of the ion measurements (Lundin et. al, next talk)
    - Plasma measurements over magnetic anomalies (Lundin et al.,)
    - Energy distribution of outflowing ions (Fedorov et. al., poster)
  - ENA occultation
  - Backscattering hydrogen
  - Unexplained neutral beams

ASPERA -3

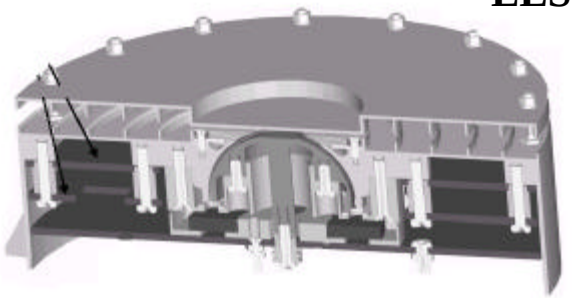


Ion and electron detectors

IMA



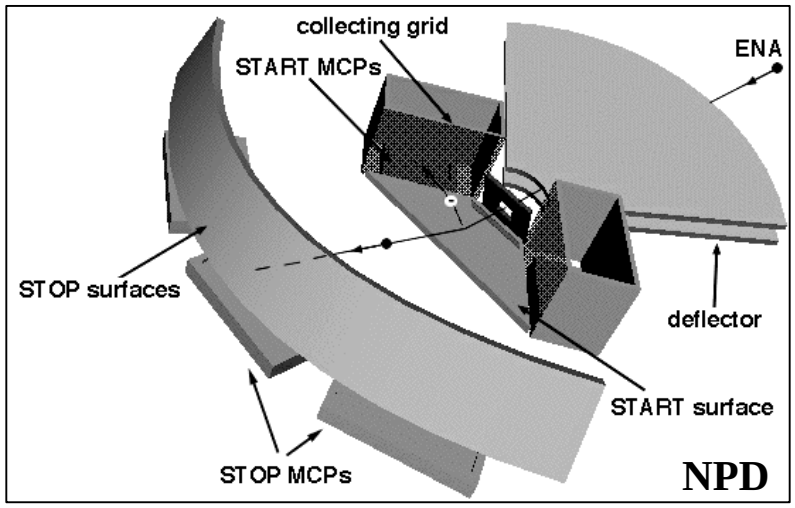
ELS

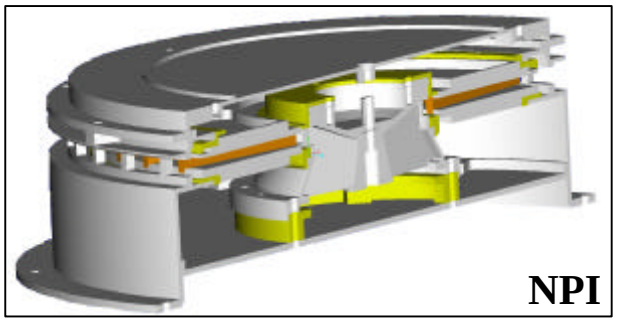


The instrument performance

	ELS	*IMA*
Particles	*Electrons*	*Ions*
Energy range, keV	*0.01 - 20*	*0.01 - 36*
Energy resolution, DE/E	*7%*	*7%*
Mass resolution, amu	*N/A*	*1, 2, 4, 8, 16, >20*
Intrinsic field of view	*10° ´360°*	*90° ´ 360°*
Angular resolution (FWHM)	*5° ´ 22.5°*	*5° ´ 22.5°*
G-factor/pixel, cm^2sr	*7 ´10^{-5}*	*3.5 ´10^{-4}*

ENA detectors

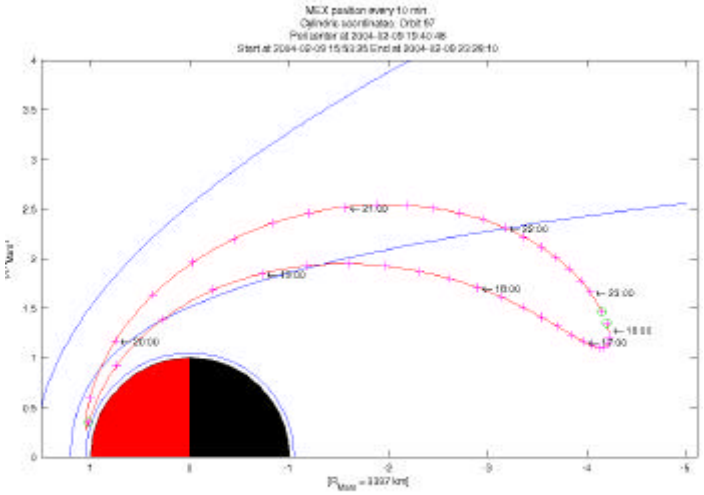


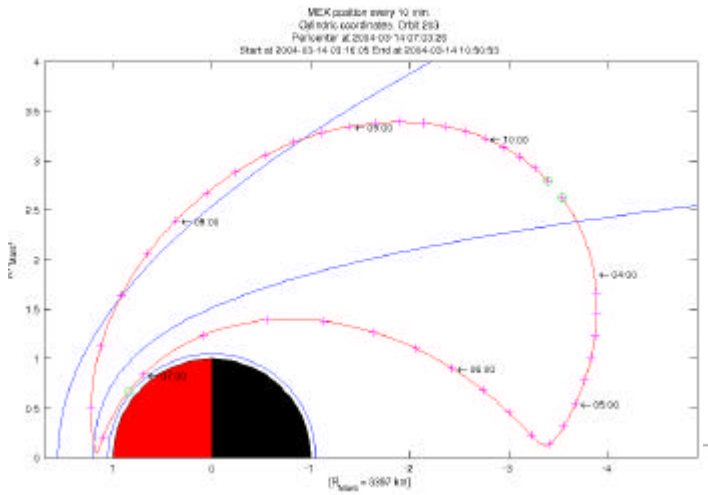


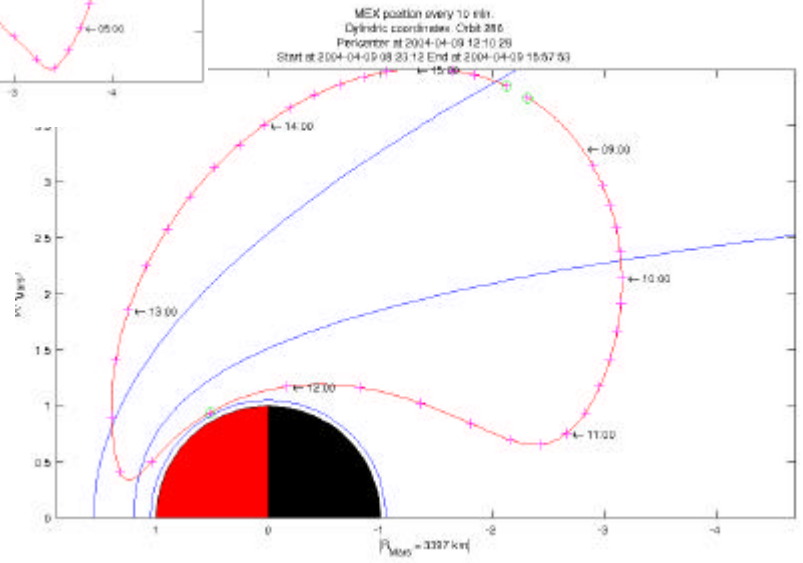
The instrument performance (NPI, NPD)

	NPI	*NPD*
Energy range, keV	*- 0.1 - 60*	*0.1 - 10*
Energy resolution, DE/E	*No*	*0.8*
Mass resolution,	*No*	*H, O*
Intrinsic field of view	*9° ´ 344°*	*9° ´ 180°*
Angular resolution	*4.6° ´ 11.5°*	*5° ´ 40°*
G-factor/pixel (e not included), cm^2sr	*2.5 ´ 10^{-3}*	*6.2 ´ 10^{-3}*
Efficiency	*0.1 - 1%*	*1 – 15%*

MEX orbit


MEX position every 10 min
Cylindric coordinates: Orbit 67
Pericenter at 2004-02-09 15:40:46
Start at 2004-02-09 15:53:35 End at 2004-02-09 22:26:10
21:00
22:00
19:00
18:00
23:00
20:00
17:00


MEX position every 10 min
Cylindric coordinates: Orbit 283
Pericenter at 2004-03-14 07:03:28
Start at 2004-03-14 03:16:05 End at 2004-03-14 10:50:53
09:00
10:00
08:00
04:00
05:00

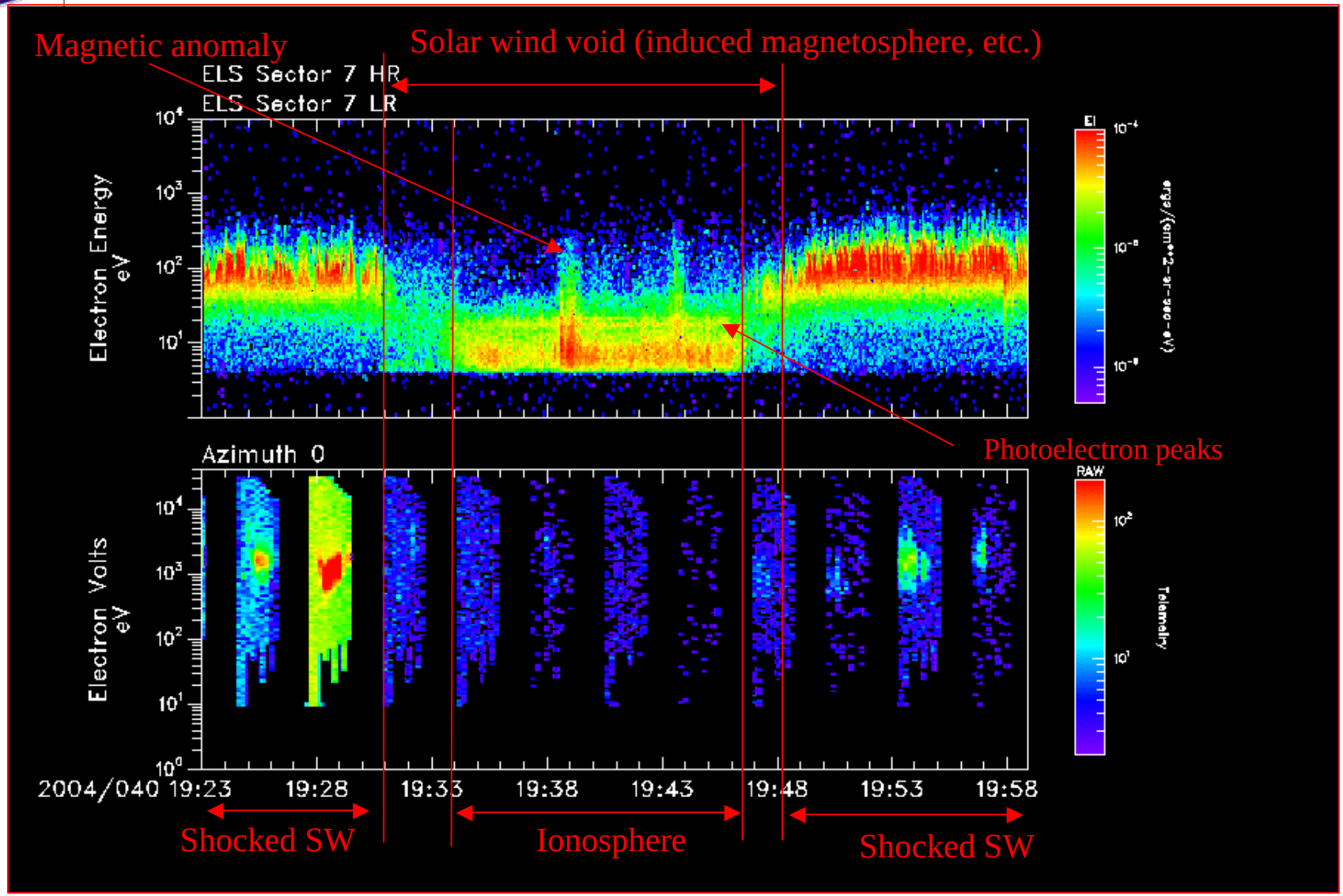

MEX position every 10 min
Cylindric coordinates: Orbit 386
Pericenter at 2004-04-09 12:10:28
Start at 2004-04-09 08:23:12 End at 2004-04-09 15:57:53
15:00
14:00
09:00
10:00
13:00
12:00
11:00

Specifics of the experiment

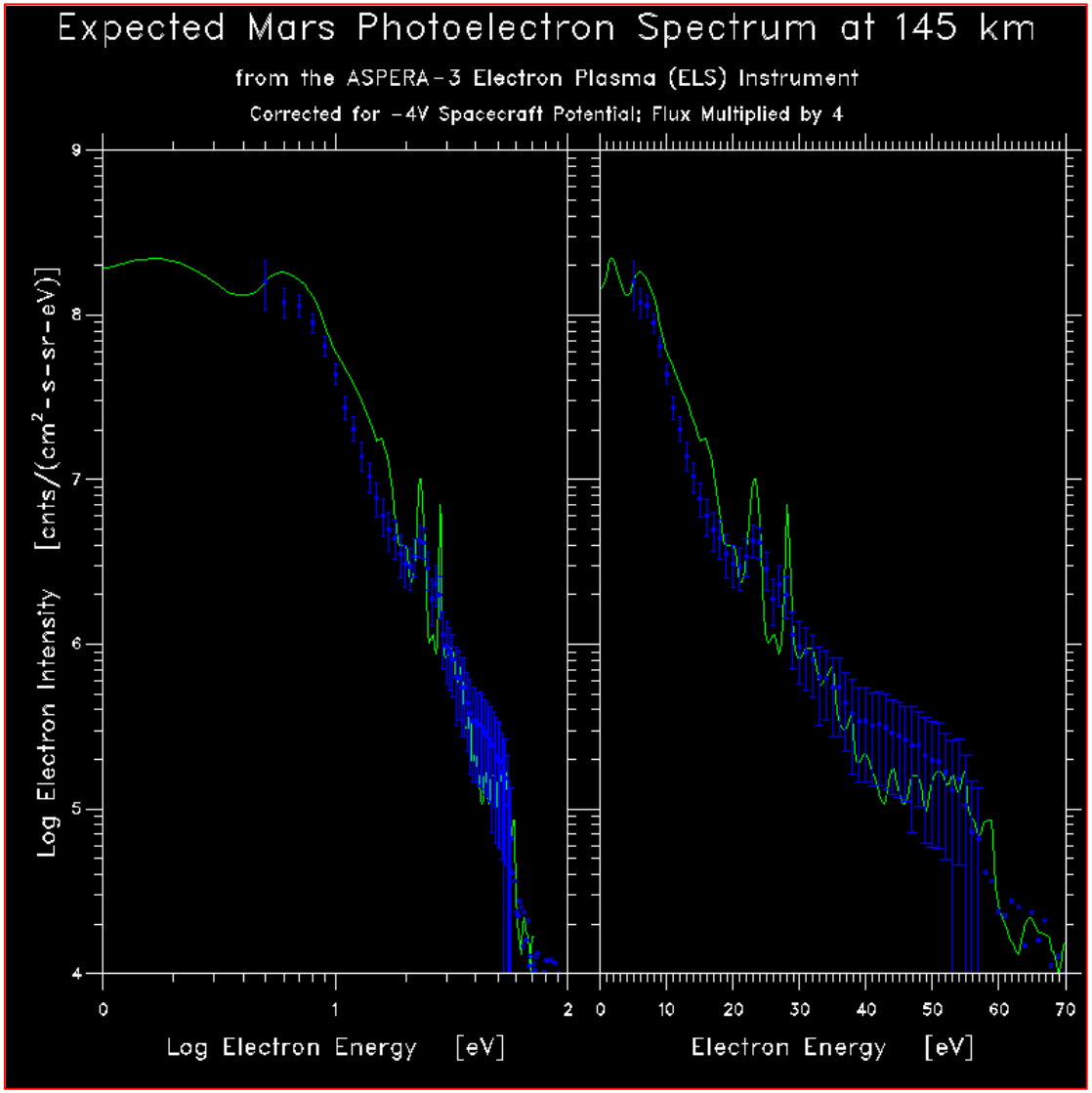
- First ever ENA imaging
- Optimal orbit for plasma measurements
- Highest energy resolution for electron measurements (7% vs. 25% MGS)
- Second mass analyzer at Mars (PHOBOS ASPERA - first)
- Unique conjunctions with MGS (Magnetometer / Electron spectrometer)

- No magnetic field measurements: focus on the atmosphere / ionosphere related studies
- 3 axis stabilized platform: scanner is still off due to spacecraft constraints
- Very limited operations because of satellite constraints
- But we are still commissioning the instrument.

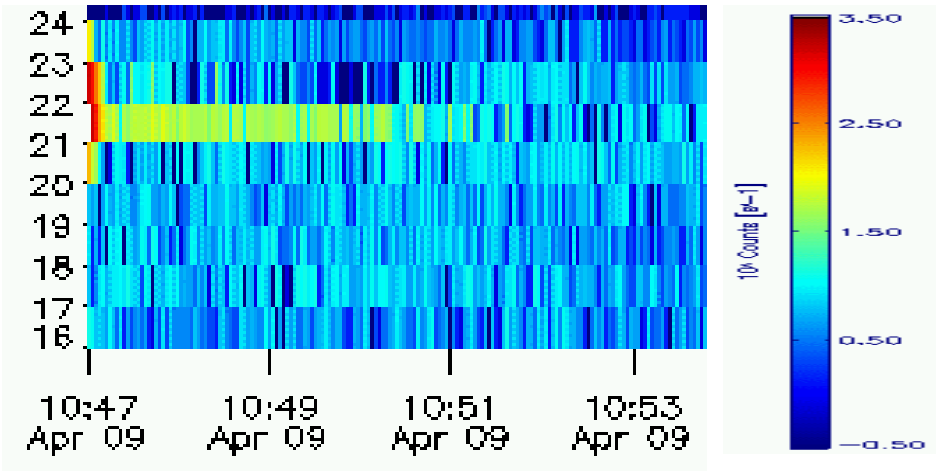
Boundary crossing

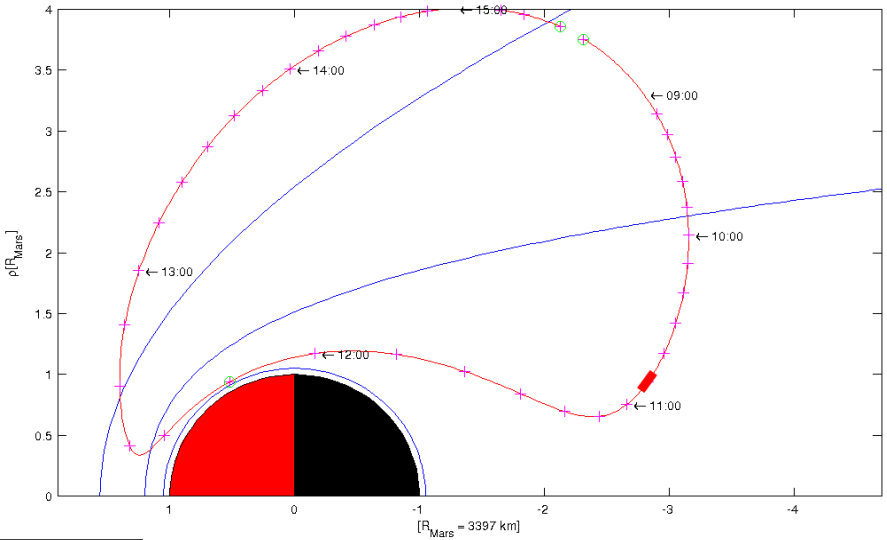


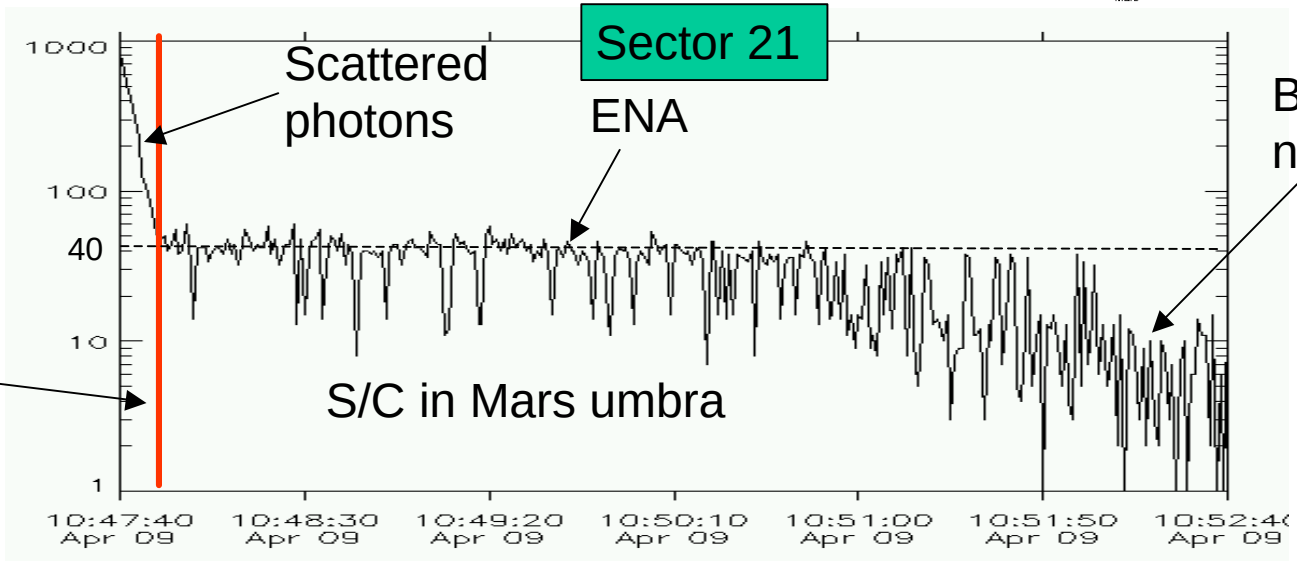
Photoelectron spectrum



ENA Occultation at Mars (1)







ENA Occultation at Mars (2)

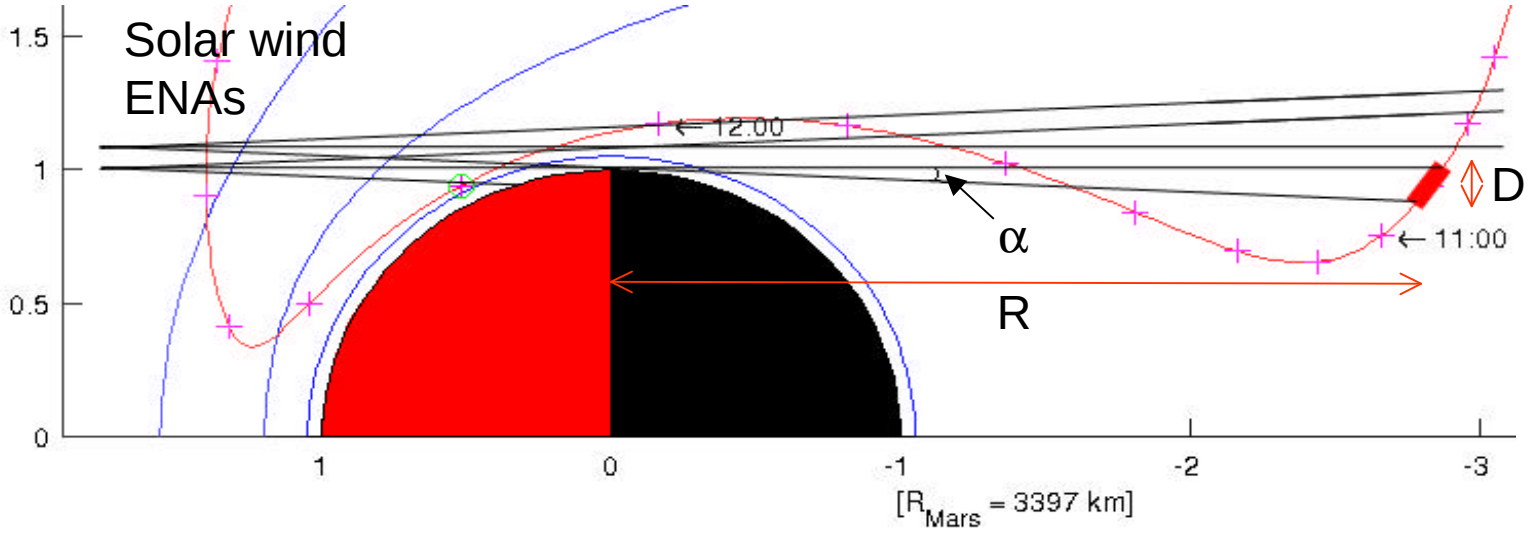
Spreading angle:

$$\alpha = \tan^{-1}\frac{D}{R} = \tan^{-1}\frac{0.25\ R_M}{2.84\ R_M} \sim 5°$$

Beam temperature estimation:

$$T_{sw} \sim E_{sw}\ \frac{D}{R} = 90\ \text{eV}$$

$$E_{sw} \sim 1\ \text{keV}$$

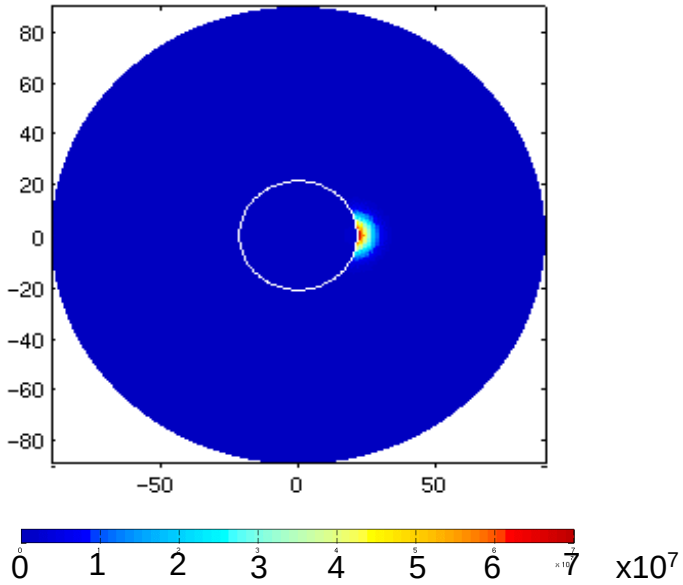


ENA Occultation at Mars (3)

Measured ENA flux:

$$f = \frac{N - N_n}{G_{NPI} \cdot \varepsilon_{NPI}} \sim \frac{40 - 4.2}{2.7 \cdot 10^{-3} \cdot 10^{-3}} = 2.7 \cdot 10^{7}\ cm^{-2} sr^{-1} s^{-1}$$

N = Count rate [s^{-1}]
N_n = Sensor dark count [s^{-1}]
G_{NPI} = Geometrical factor of NPI aperture [cm^2 sr]
ε_{NPI} = NPI efficiency

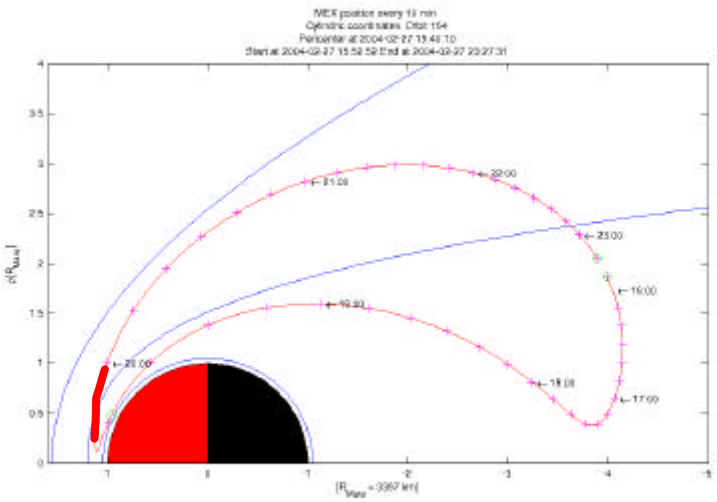


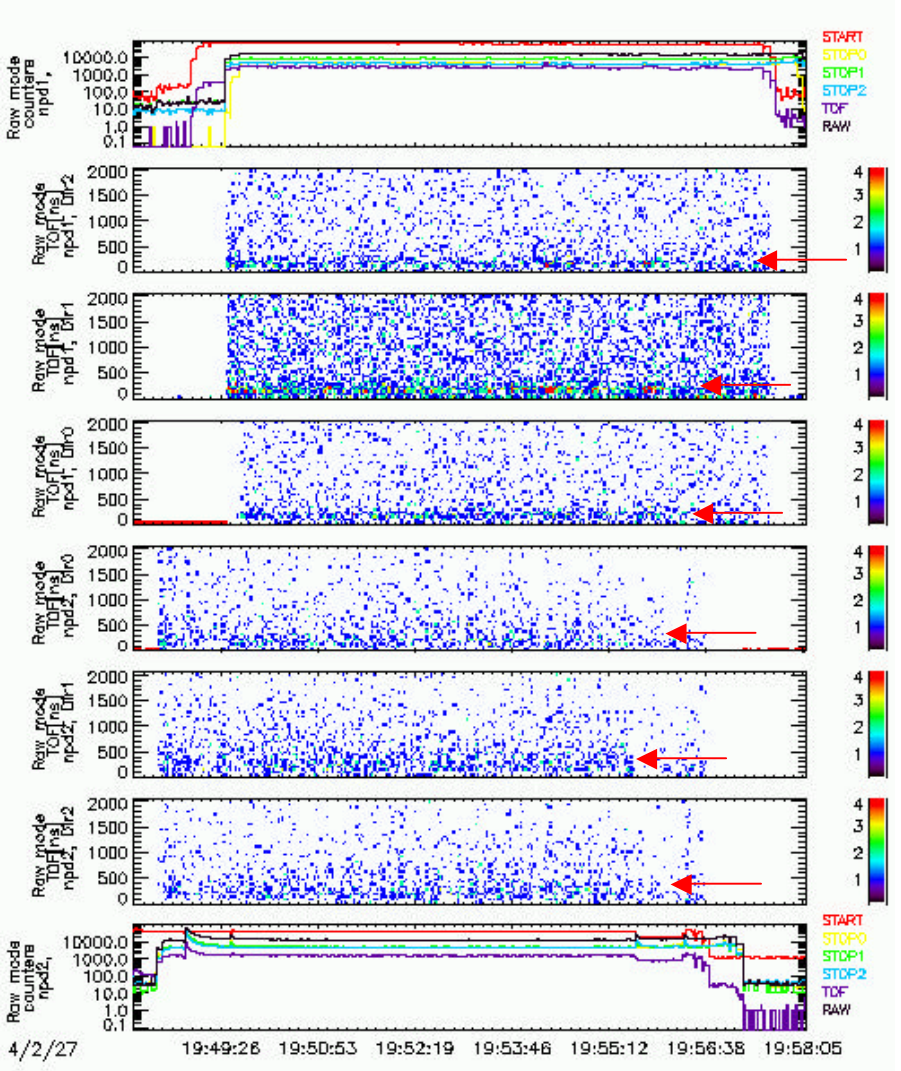
Simulated ENA flux at SZA=160°
Holmström et al [2001]

- **ENA flux profile is determined by (1) the exosphere profile (charge - exchange), (2) stripping and scattering at the exobase**
- **ENA occultation may be a new method to probe an atmosphere**
- **Can it be attempted on IMAGE / LENA using NSW?**

Backscattering H-ENAs (1)

- ***Kallio and Barabash* (2001) predicted backscattering H atoms caused by hydrogen ENA and solar wind proton precipitation**
- **E_{bs}/E_{nsw} ~ 0.6**
- **F_{bs}/F_{nsw} ~ 0.6**

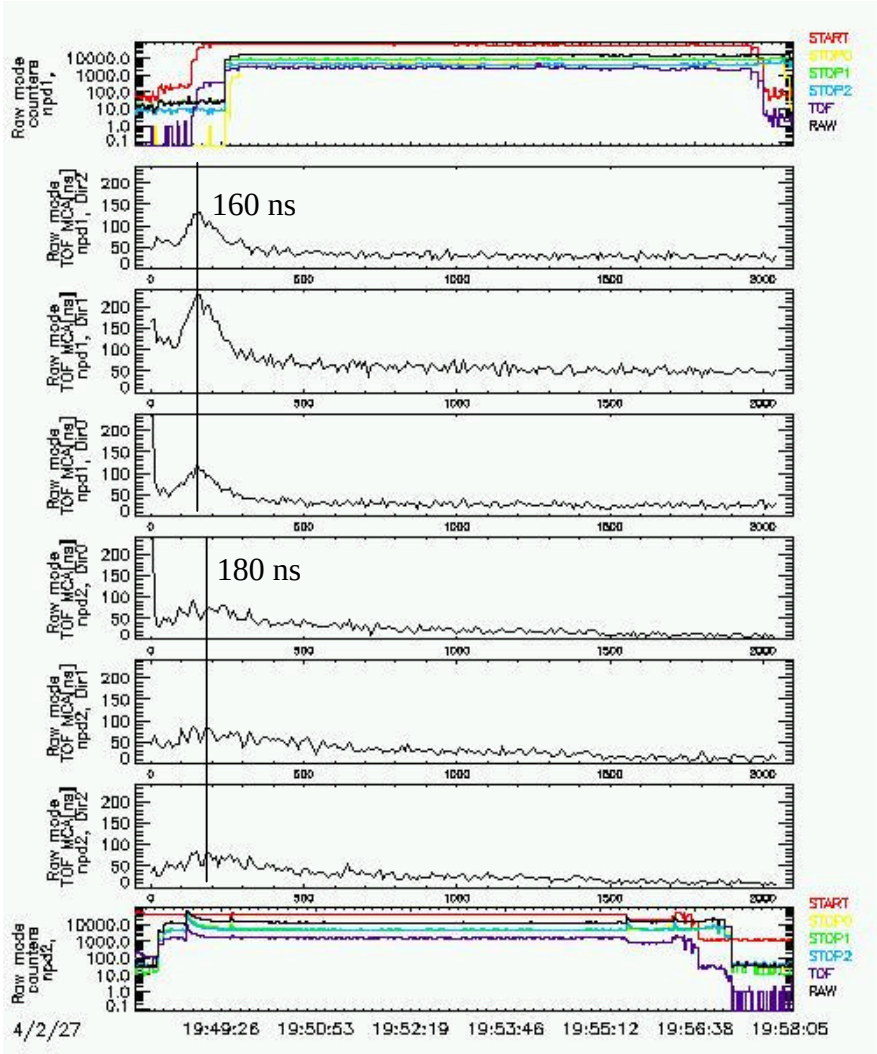




Backscattering H-ENAs (2)

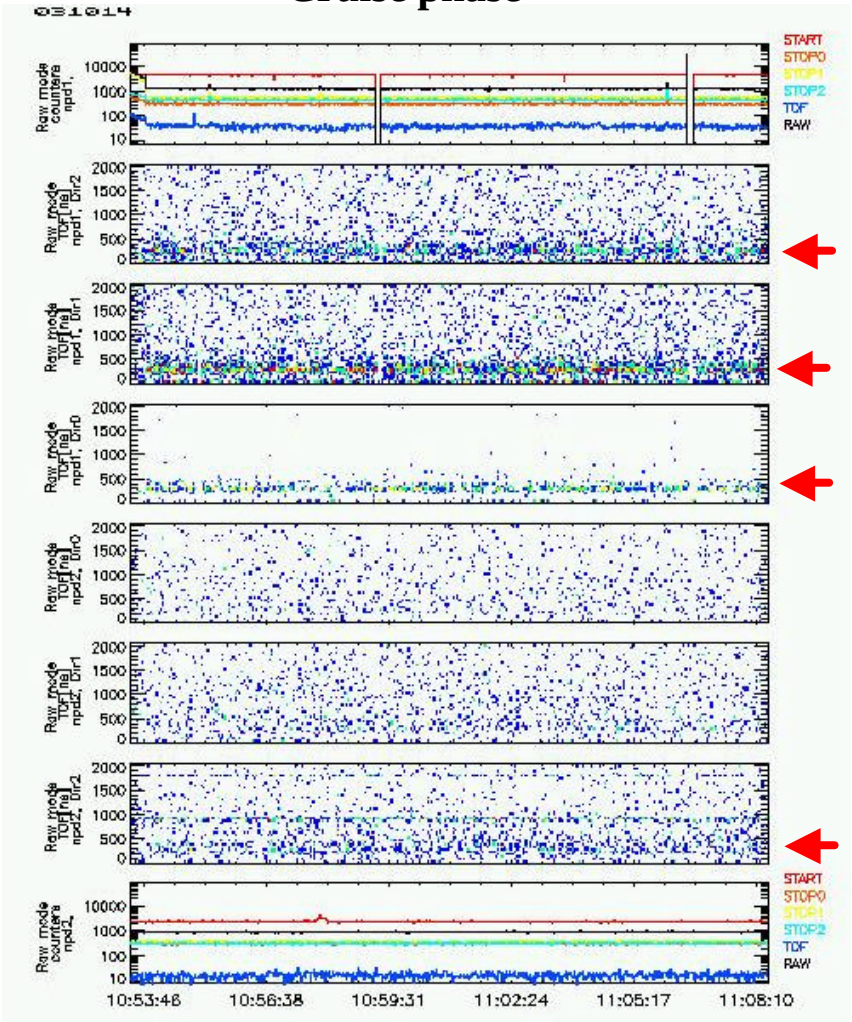
- H atom Energy: 1.69 - 2.14 keV (160 - 180 ns)
- Compare with ~2 keV shocked solar wind as measured by IMA in the magnetosheath
- Flux: (8 - 14)·10^6 cm^{-2} sr^{-1} s^{-1}

- **Only direct precipitation of the solar wind can be accounted for such high fluxes!**

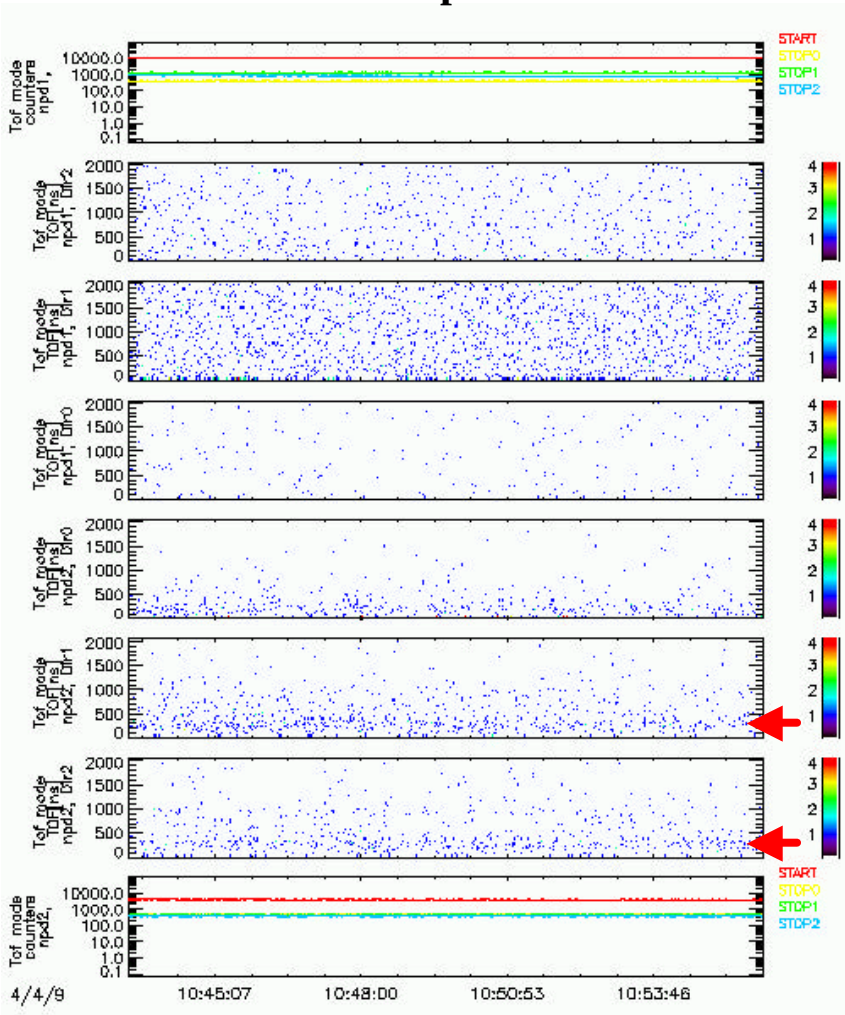


Unexplained neutral beams (1)

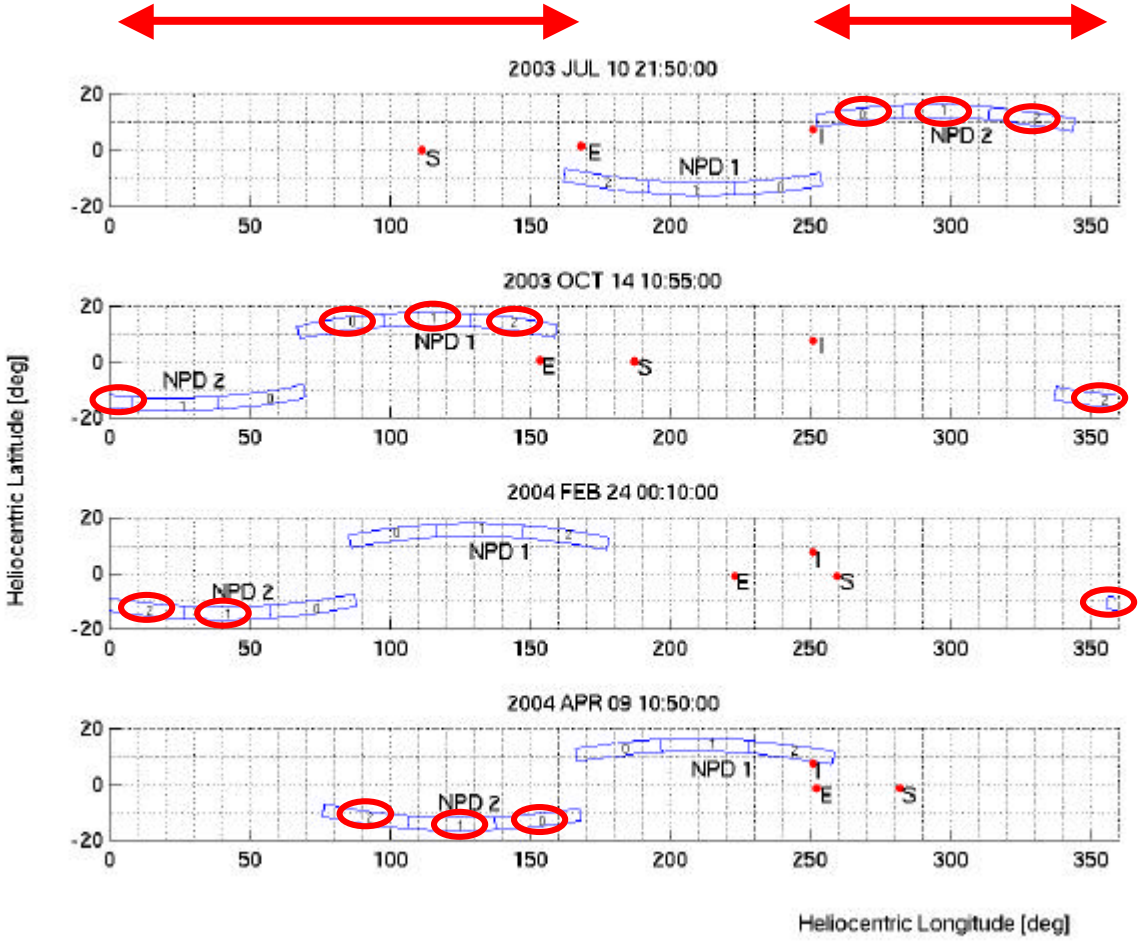
Cruise phase

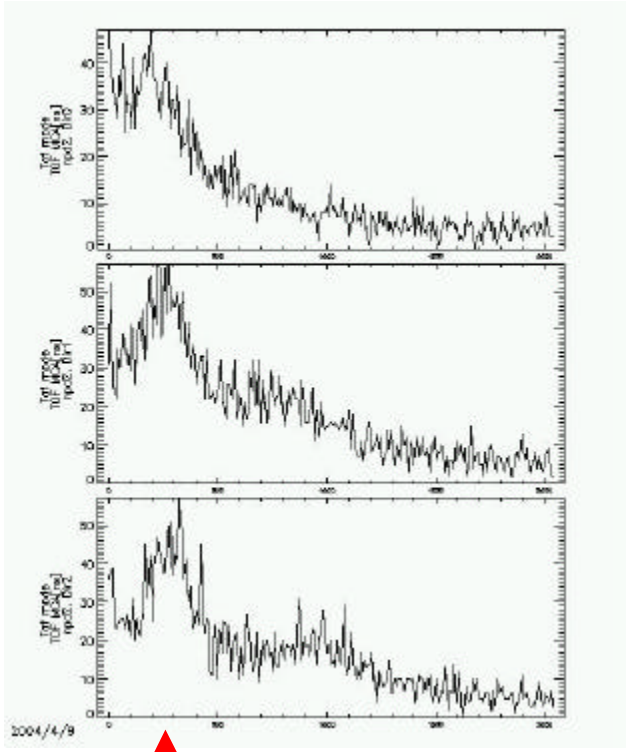


Mars eclipse



Unexplained neutral beams (2)



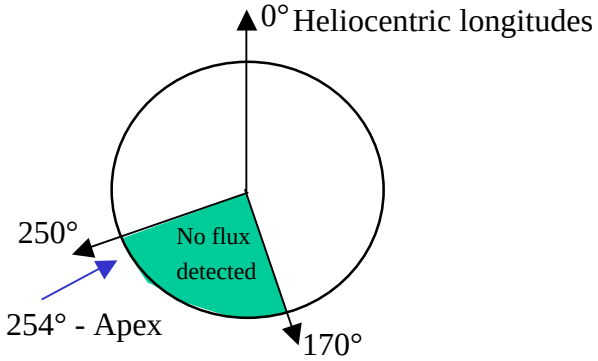


Neutral beams observed

Unexplained neutral beams (3)

- Mass: **hydrogen** (very short TOFs)
- Beam energy: **810 eV**
- Flux: (2 - 45) $\cdot 10^4$ **cm^{-2} sr^{-1} s^{-1} (extreme cases removed)**
- Energy spreading (FWHM): **> 100%** (TOF and angular spreading)
- Distribution: **no flux** detected from **170° - 250°** heliocentric longitude
- Variability: **strongly variable** either temporal or directionally

- Origin: Unknown…..Yet, there are indirect indications that there may be a second neutral beam entering heliosphere (IMAGE/LENA, ACE, ISEE-3, Wind, SOHO).
- All instrument anomalies known by April 21 2004 have been ruled out.



Summary

- **ASPERA-3 makes measurements in all plasma domains crossing all respective boundaries: bow shock, induced magnetosphere boundary (solar wind plasma void), photoelectron boundary.**
- **High energy electron measurements allow photoelectron mass spectroscopy.**
- **First ENA occultation measurements have been conducted.**
- **Strong hydrogen ENA albedo has been detected**
- **Unexplained neutral beams (heliospheric origin?) have been observed during the cruise phase and at Mars.**