



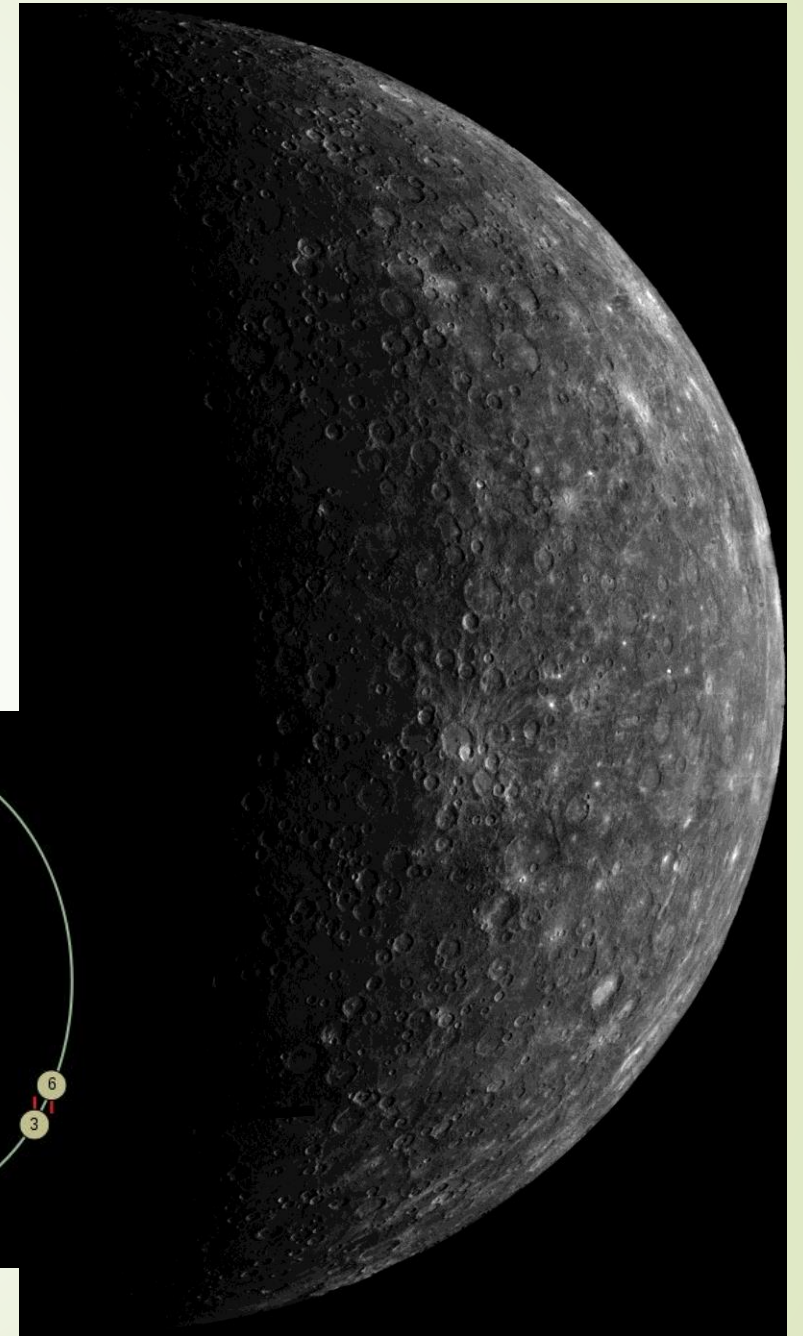
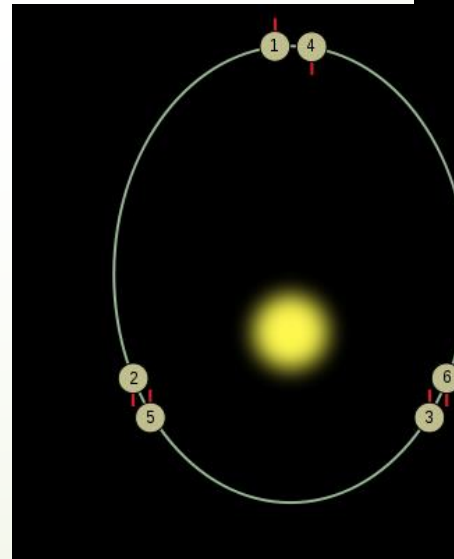
Measuring Mercury EXOSPHERE from Earth

With a Solar Telescope!

Mercury

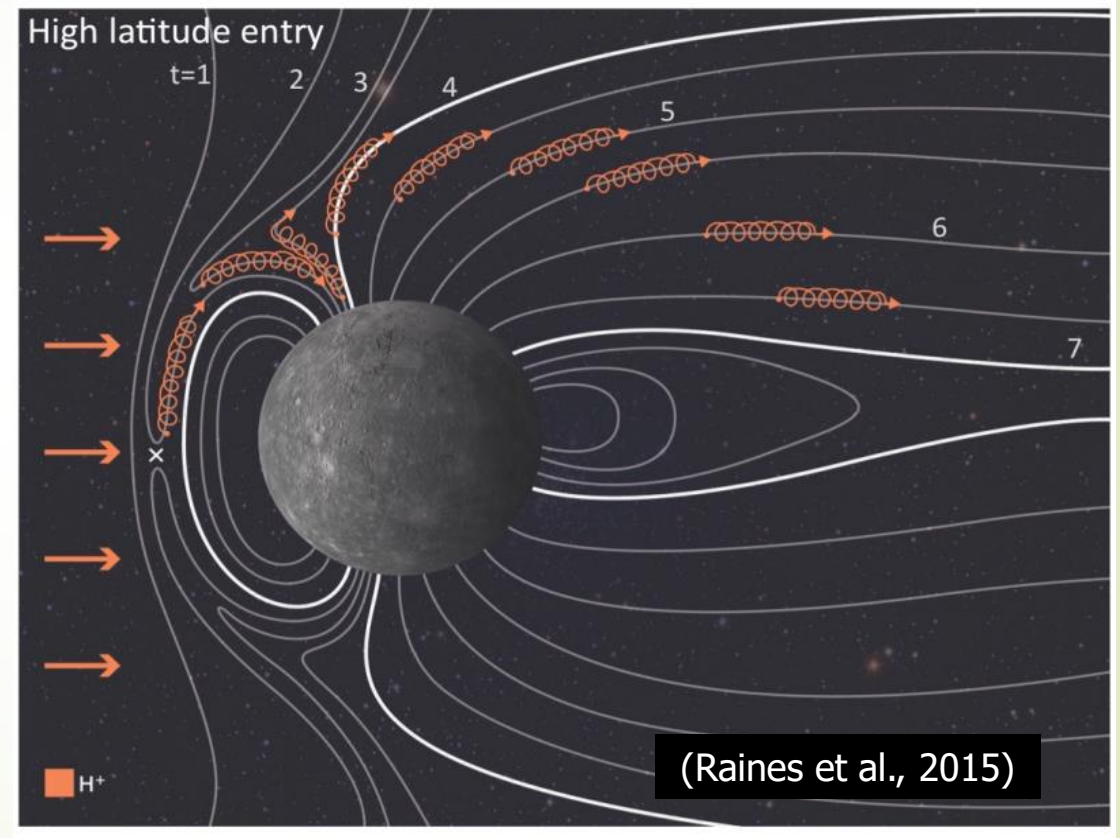
- Closest planet to the Sun
 - a difficult target to observe

Parameter	Mercury	Earth
Mean orbital axis (AU)	0.387	1
Eccentricity	0.206	0.017
Inclination to ecliptic	7°	0°
Sidereal orbital period (Earth day)	87.97	365.26
Sidereal rotation period (Earth day)	58.64	1
Diurnal period (Earth day)	176	0.5
Spin axis obliquity to orbit	0.1°	23.4°
Mass (10^{24} kg)	0.33	5.97
Radius (km)	2440	6374
Density (g/cm^3)	5.43	5.52
Uncompressed density (g/cm^3)	5.4	4.4
Surface gravity at equator (m/s^2)	3.82	9.81
Escape velocity (km/s)	4.25	
Maximum surface temperature (K)	700	279
Minimum surface temperature (K)	90	
Magnetic field moment	$3 \cdot 10^2 \text{ nT R}_M^3$	$3 \cdot 10^4 \text{ nT R}_E^3$
Magnetic axis inclination to spin axis	10°	17°

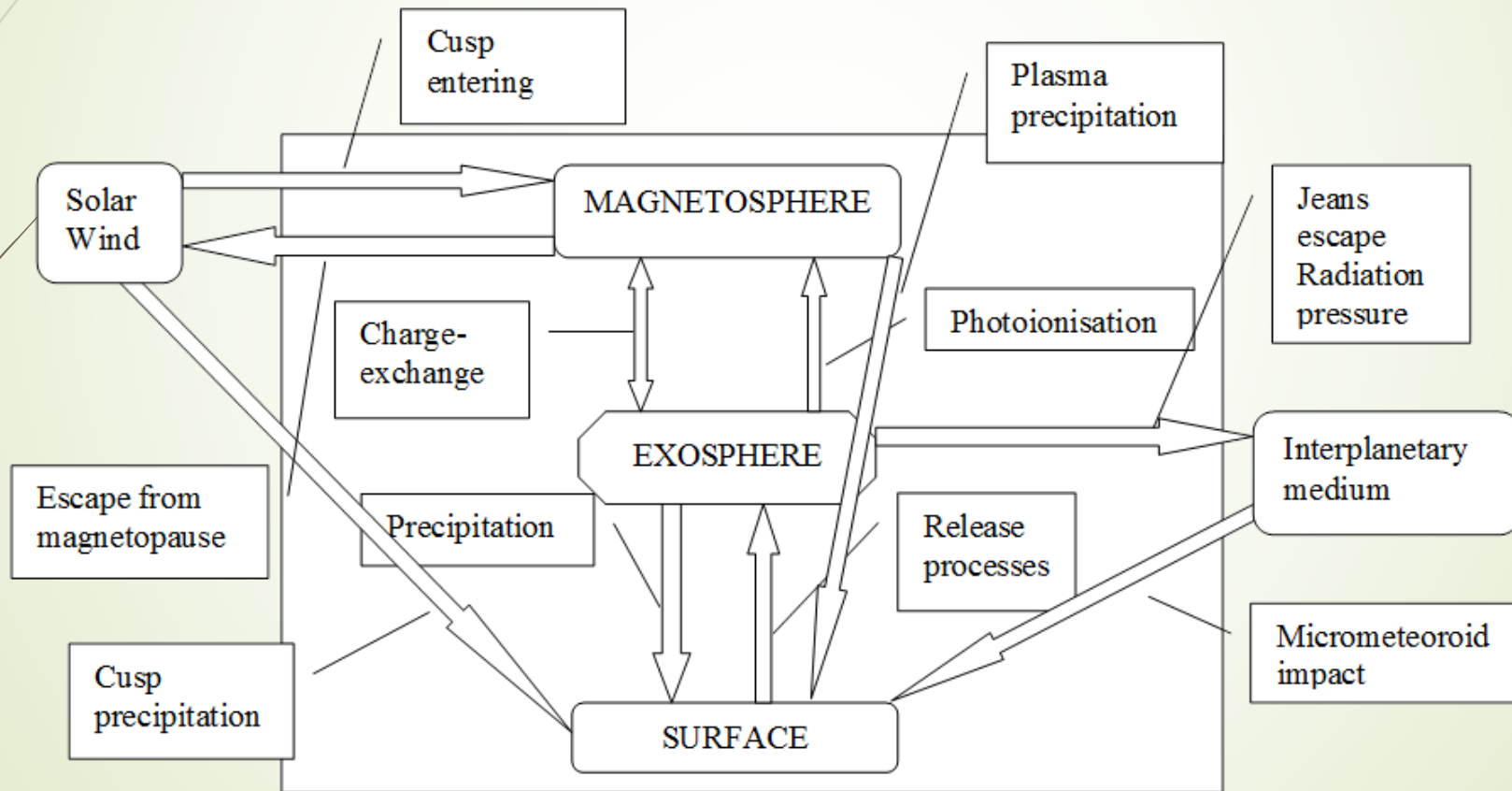


Mercury Exosphere

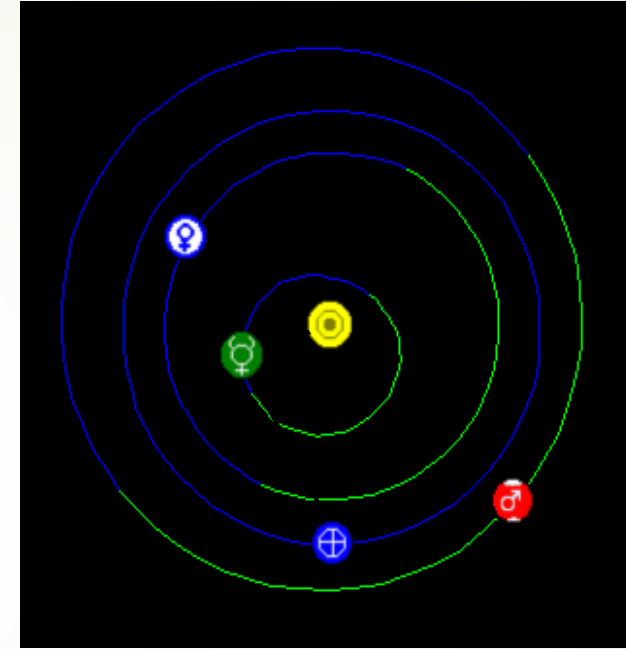
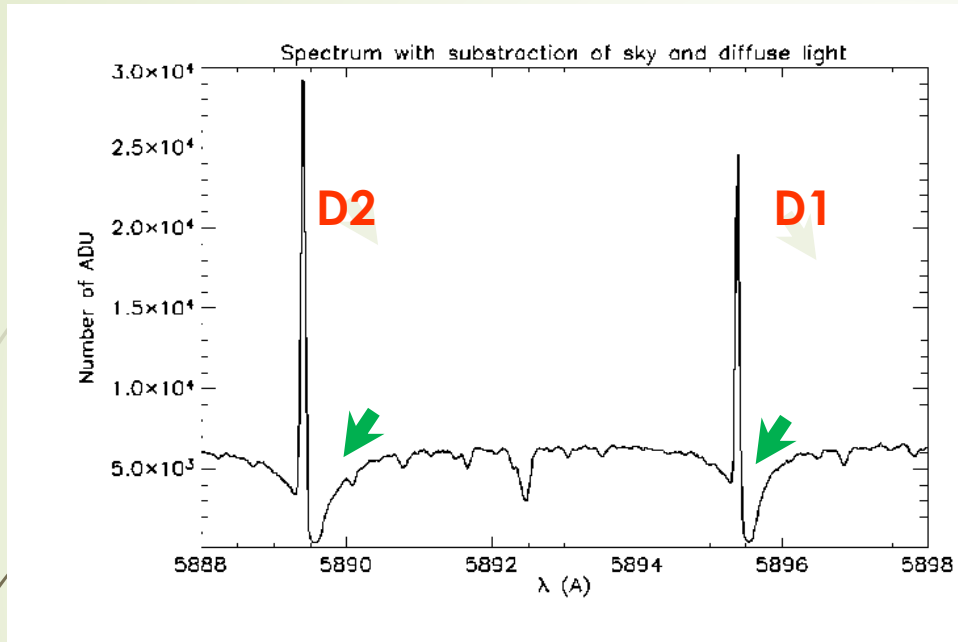
- ▶ Exosphere: part of the atmosphere that is NOT gravitationally bound
- ▶ Needs to be replaced!
 - ▶ Sun (direct radiation, particles)?
 - ▶ Planetary and/or Interplanetary Magnetic field?
 - ▶ Interplanetary environment (micro-meteoroids)?
- ▶ Composition:
 - ▶ H, O, He (by Mariner 10)
 - ▶ Na, K, Ca (From Earth)
 - ▶ Mg, Al, Mn (by MESSENGER) + Others upper limits



Why the Exosphere?



Emitted and reflected photons



Reflected **SOLAR spectrum** → **In Absorption**
(relative doppler Mercury from Earth + Sun from Mercury)

Na from **MERCURY EXOSPHERE** → **In Emission**
(relative doppler: Mercury from Earth)

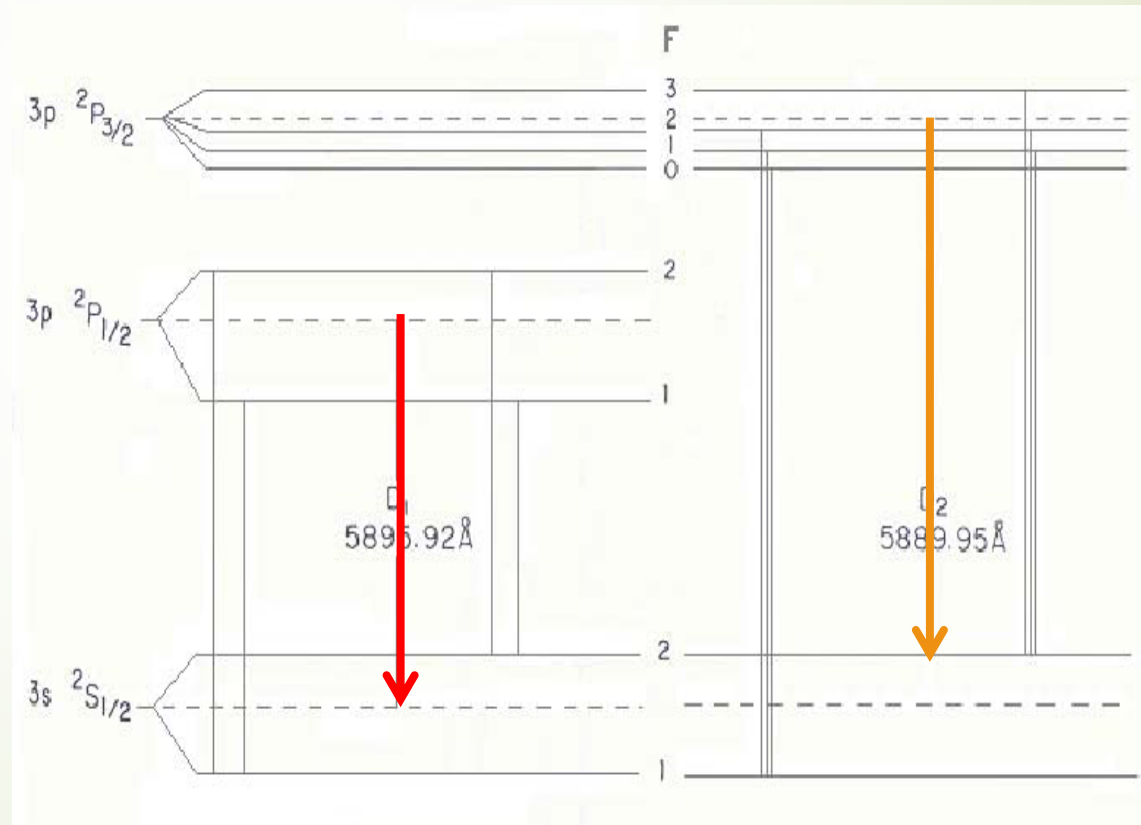
Resonant Scattering

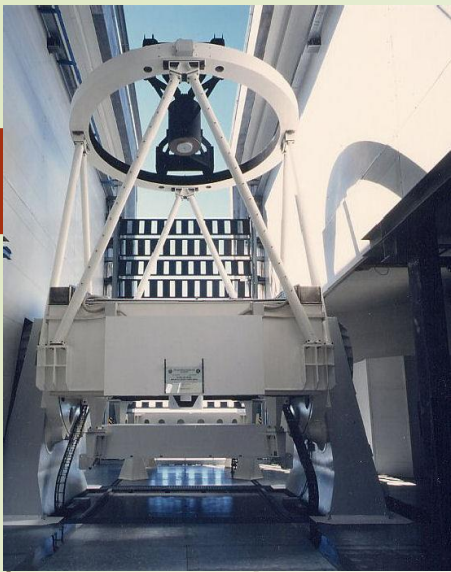
1. Excitation by solar photons
 2. De-excitation and photons emission
- Na D lines = 5890-5896 Angstrom

→ Emission only observable in the sunlit zone

- $2P_{1/2} \rightarrow 2S_{1/2}$ transition = **D1**
- $2P_{3/2} \rightarrow 2S_{1/2}$ transition **D2**

→ The D lines are in a region relatively free of telluric lines.

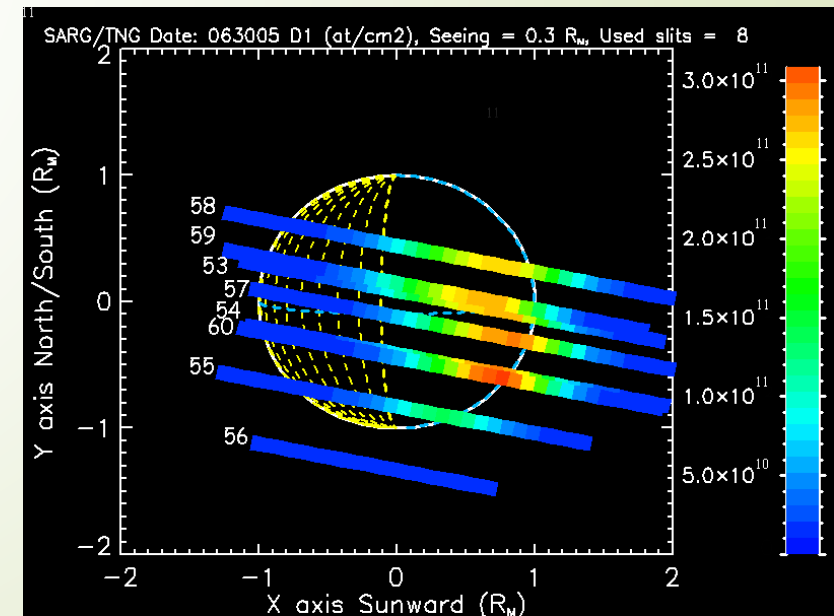




Observing with TNG

M1 diameter	3.58m	Spectrograph resolution	115000
Focal length	38.5m (F/11)	Slit length and width	26.7 x 0.40 arcsec
M2 diameter	0.875m	Pixel dimension and scale	0.022 A, 0.16 arcsec
M2 baffle diam.	1.165m	CCD dimension	2K x 4K pixels
Scale	5.36 arcsec/mm		
Vignetting-free field	25 arcmin diameter		

Slit Number	Obs.Time (UT)	Theoretical Position	Final Position	Seeing Sigma	Calibration Factor
HYNB0053	20:16	0.0	+ 0.3	1.1	1.99
HYNB0054	20:19	- 2.0	- 1.4	1.1	2.75
HYNB0055	20:22	- 4.0	- 2.8	1.0	12.07
HYNB0056	20:26	- 6.0	- 4.5	1.2	35.52
HYNB0057	20:30	+ 1.0	- 0.4	1.0	2.20
HYNB0058	20:33	- 1.0	+ 1.5	1.2	2.12
HYNB0059	20:37	0.0	+ 0.5	1.0	2.11
HYNB0060	20:40	- 3.0	- 1.5	0.9	2.62





Observing with THEMIS

F/16 Ritchey-Chretien 0.9 m solar telescope

Helium filled telescope tube

Very low level of scattered light

MTR mode for multiline spectropolarimetry

Spectral range 400 to 1000 nm at :

R ~ 220,000 *Slit: 0.5" & 120 " long*

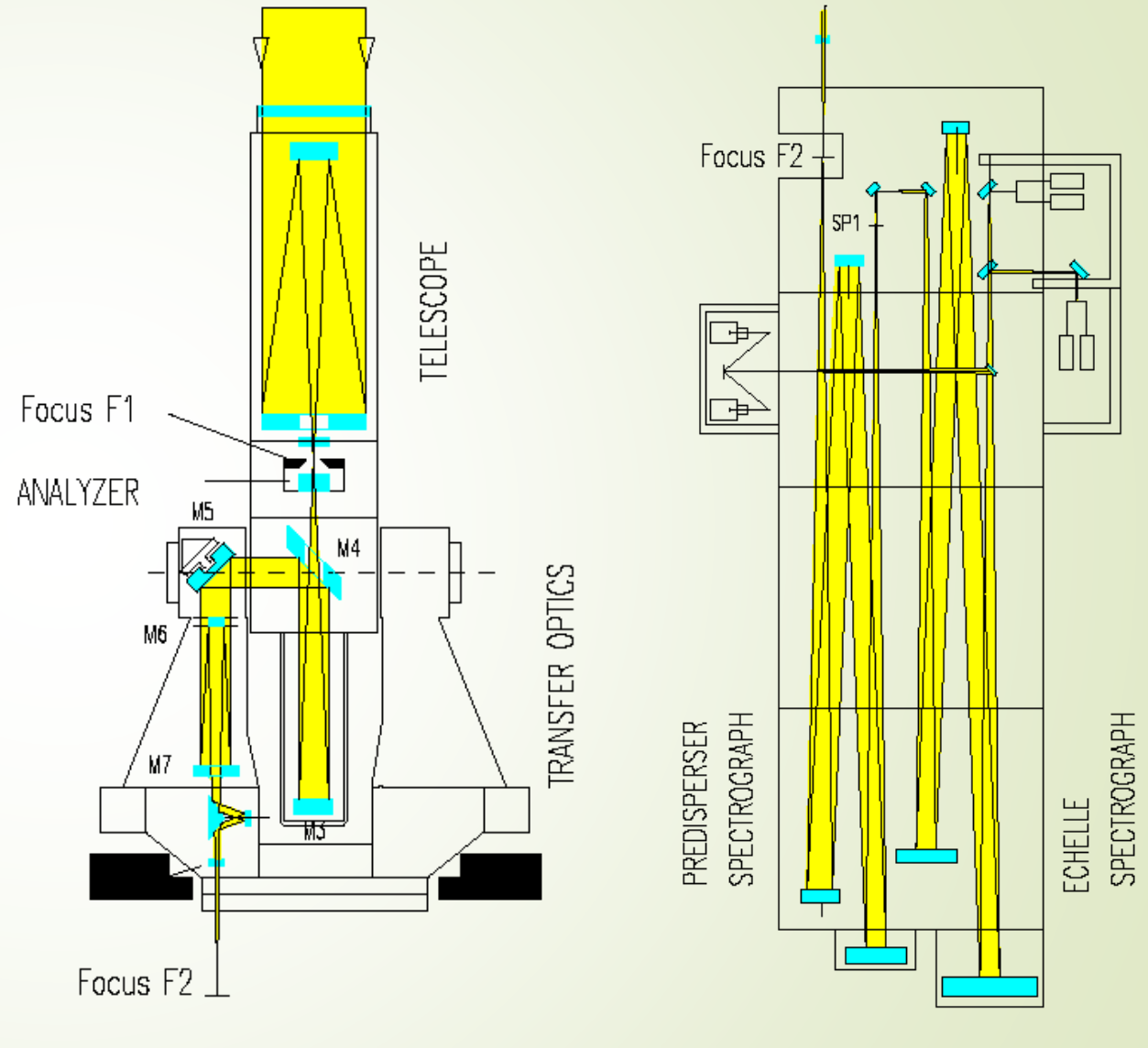
R ~ 400,000 *Slit: 0.25" & 70 " long*

Spectral resolution 0.027 Å to 0.016 Å

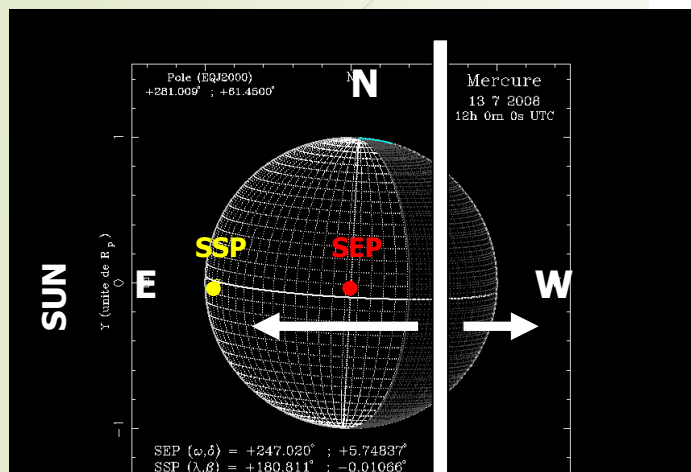
Spectral dispersion 10.2 to 6 mÅ

Two individual cameras: Na D1 at 5896 Å

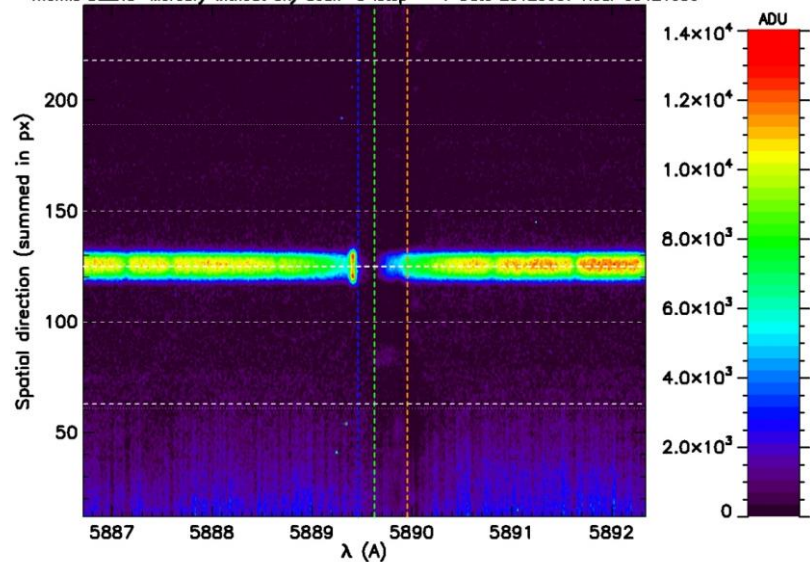
Na D2 at 5889 Å



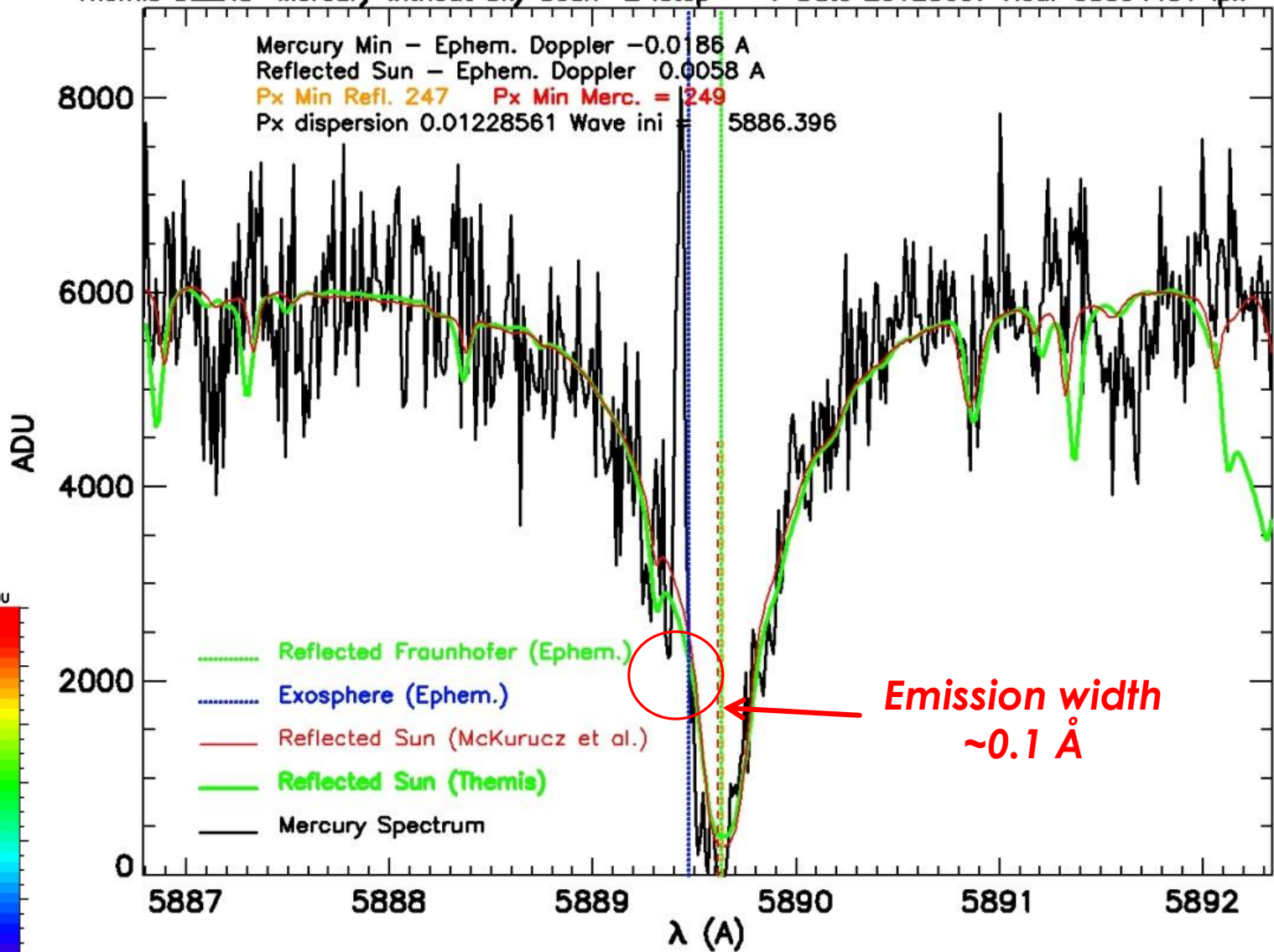
THEMIS data



Themis D2_Na Mercury without Sky Scan 3 Istep = 7 Date 20120607 Hour 09421636



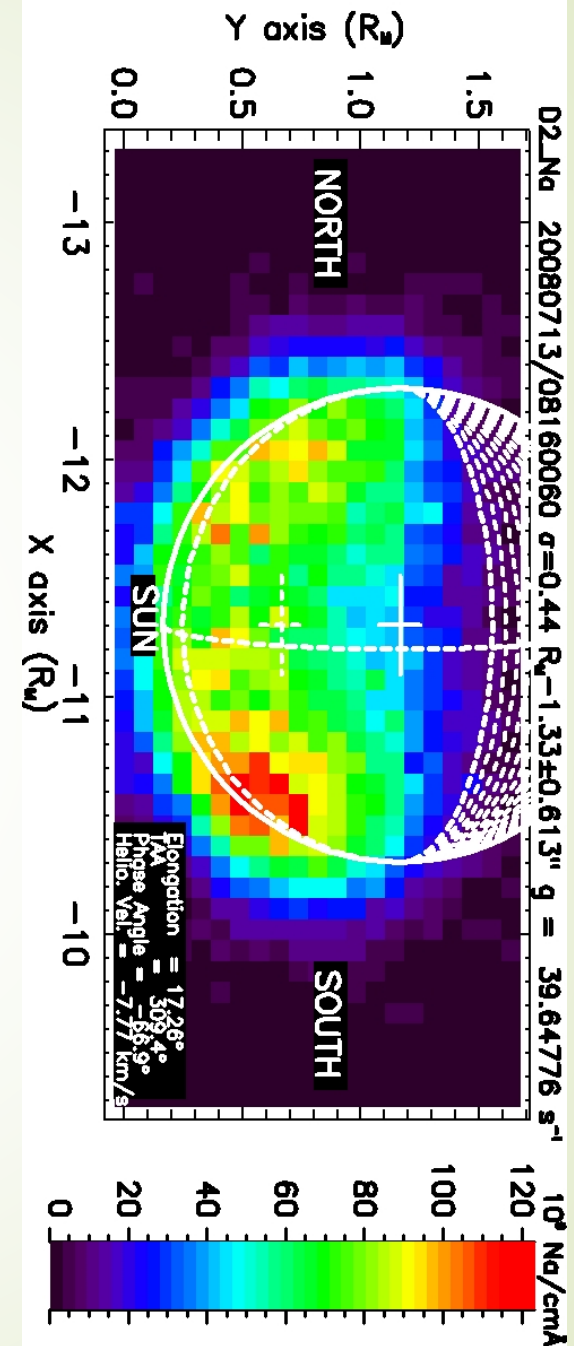
Themis D2_Na Mercury without Sky Scan 2 Istep = 7 Date 20120607 Hour 08394451 ipx = 126



THEMIS observations

- The slit is oriented in the N-S axis of Mercury and is moved E-W to scan the whole disk of the planet
- The scans result in a data-cube with both the 2D spatial dimensions and the wavelength
- In about 40 to 120 minutes a complete scan of Mercury exosphere is obtained
- Advantage of working all day long (i.e. up to 12 hours/ day in summer time) with no fear of solar light

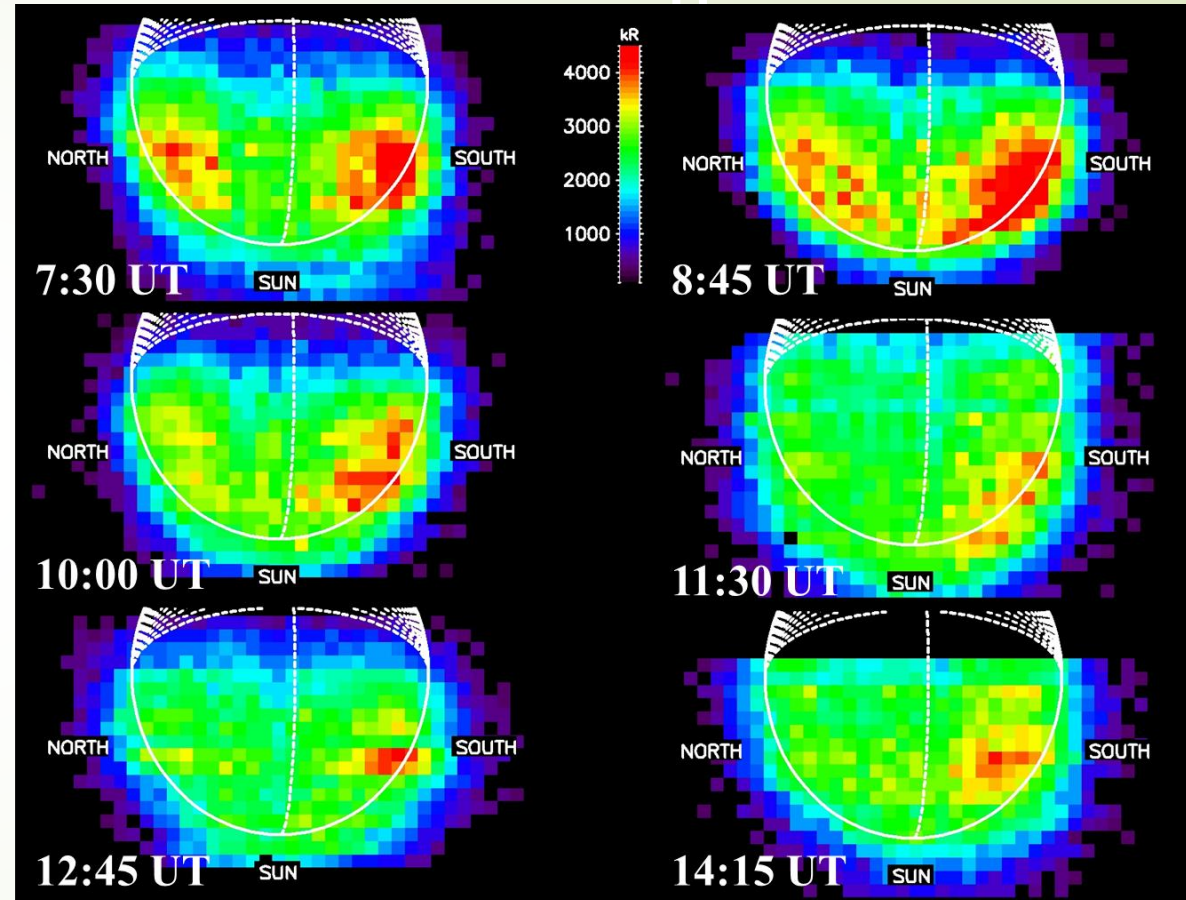
→ Possibility to study **exospheric dynamics** (peaks variability in intensity and position)



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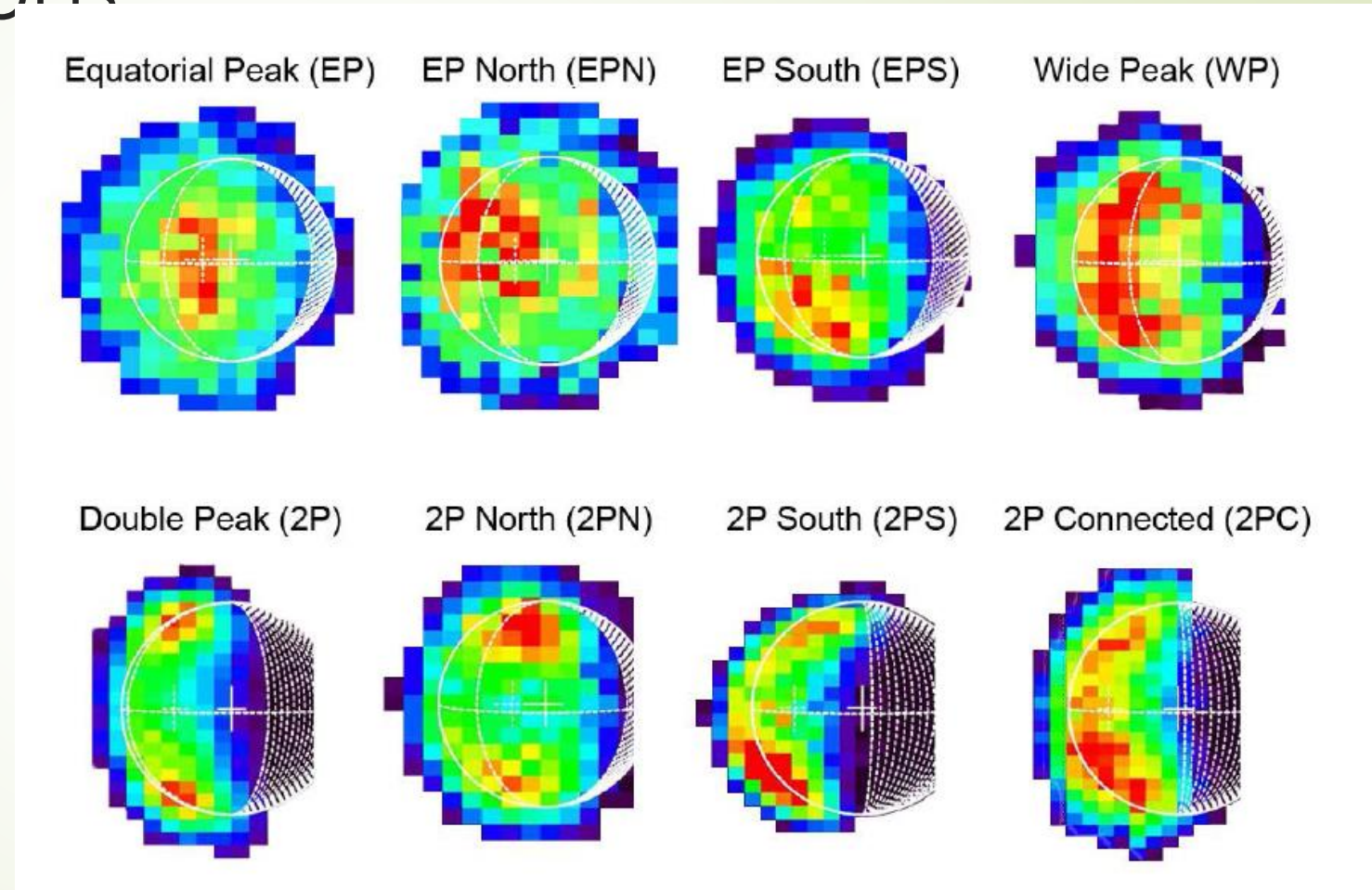


(Leblanc et al 2009)

THEMIS observations

Statistical analysis: identification of **8 different Na exospheric patterns**

→ Possibility to make statistical analysis and Na correlate exospheric patterns with local IMF

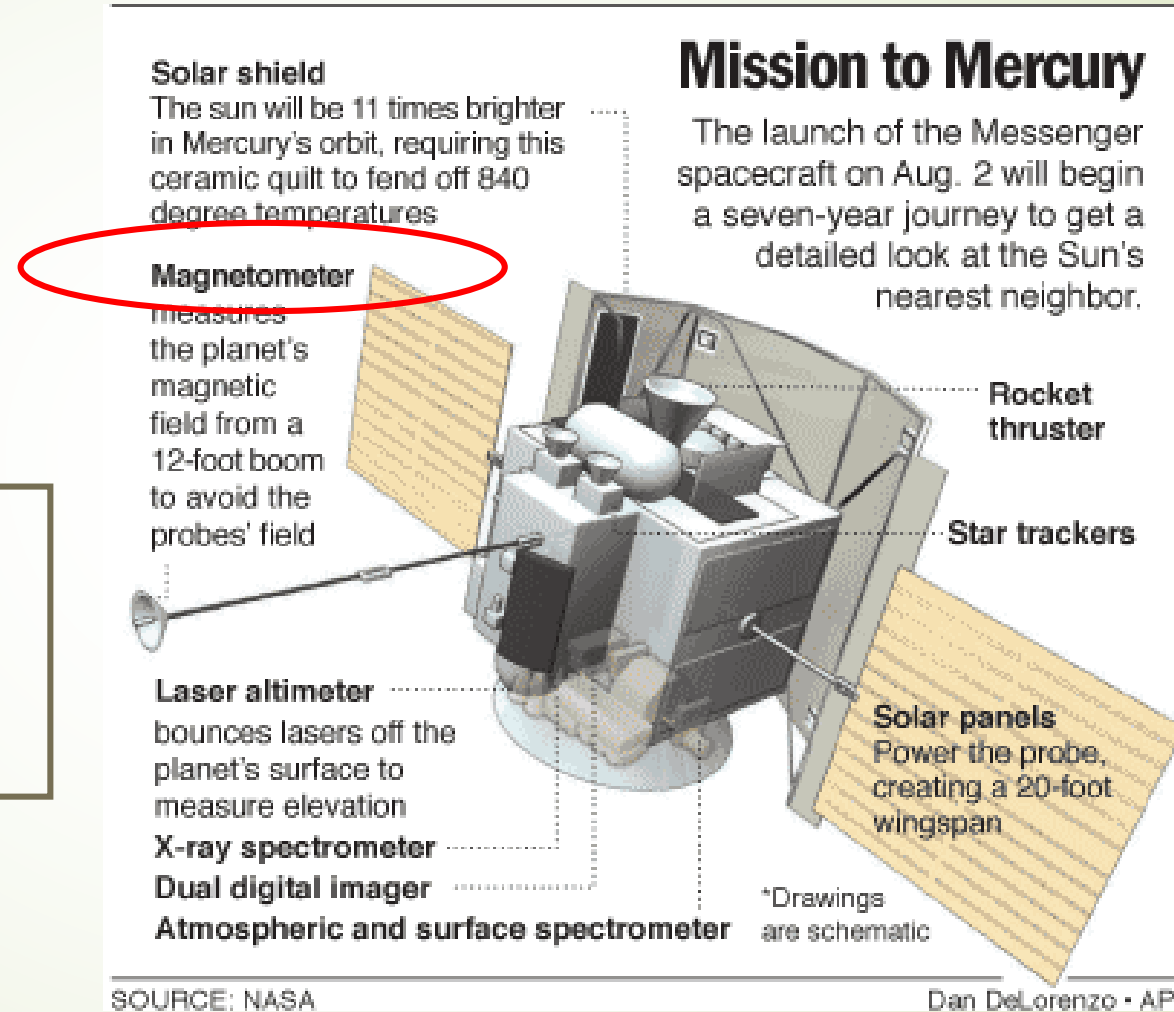


(Mangano et al 2015)

Messenger mission

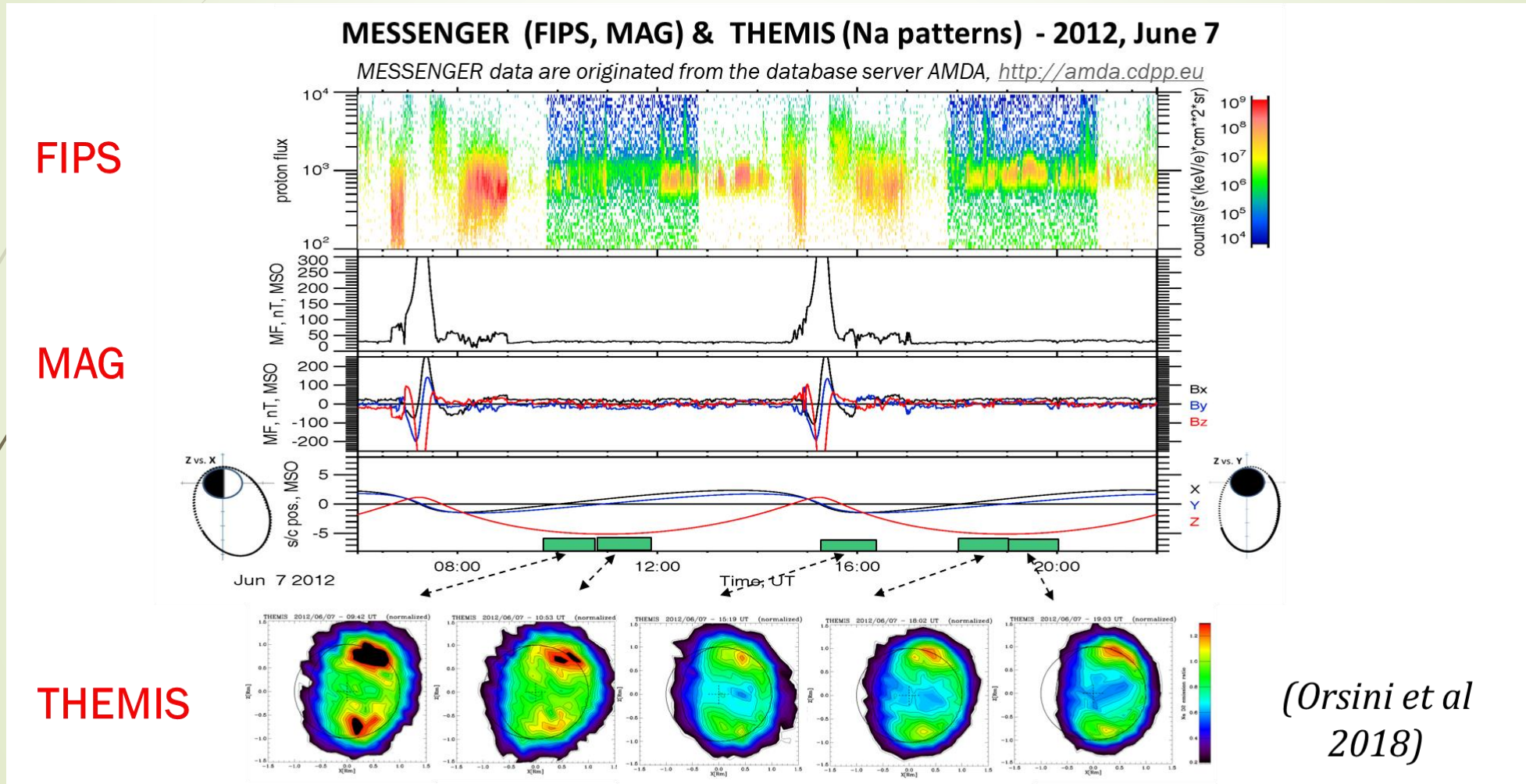
Mercury **S**urface,
Space
Environment,
Geochemistry,
and **R**anging

'Discovery' mission by NASA
Lift-off: 3 August 2004
Flybys: 2008 (2), 2009 (1)
In orbit: 18 March 2011
End of Mission: 30 April 2015

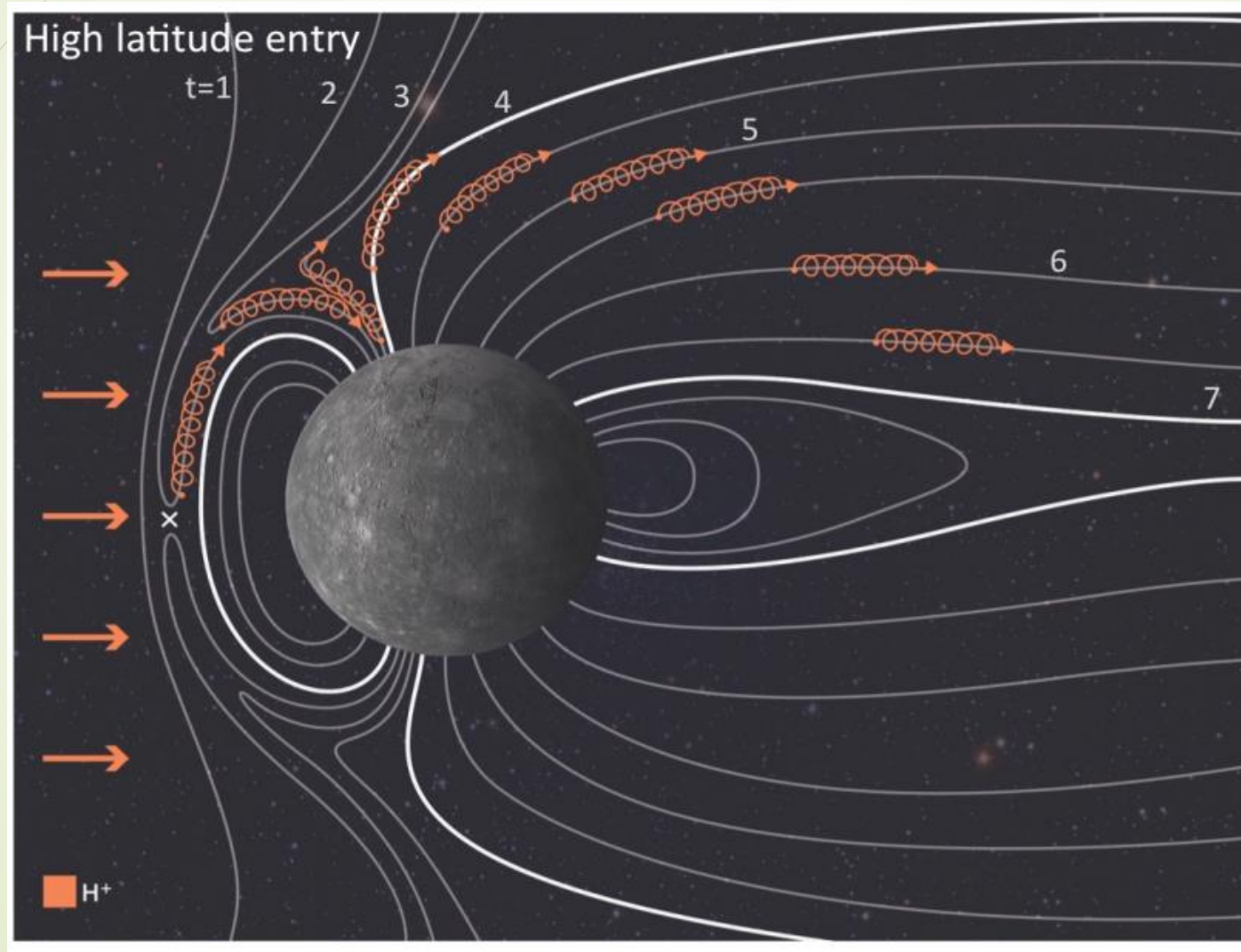


Standard exosphere situation

→ 7 June 2012



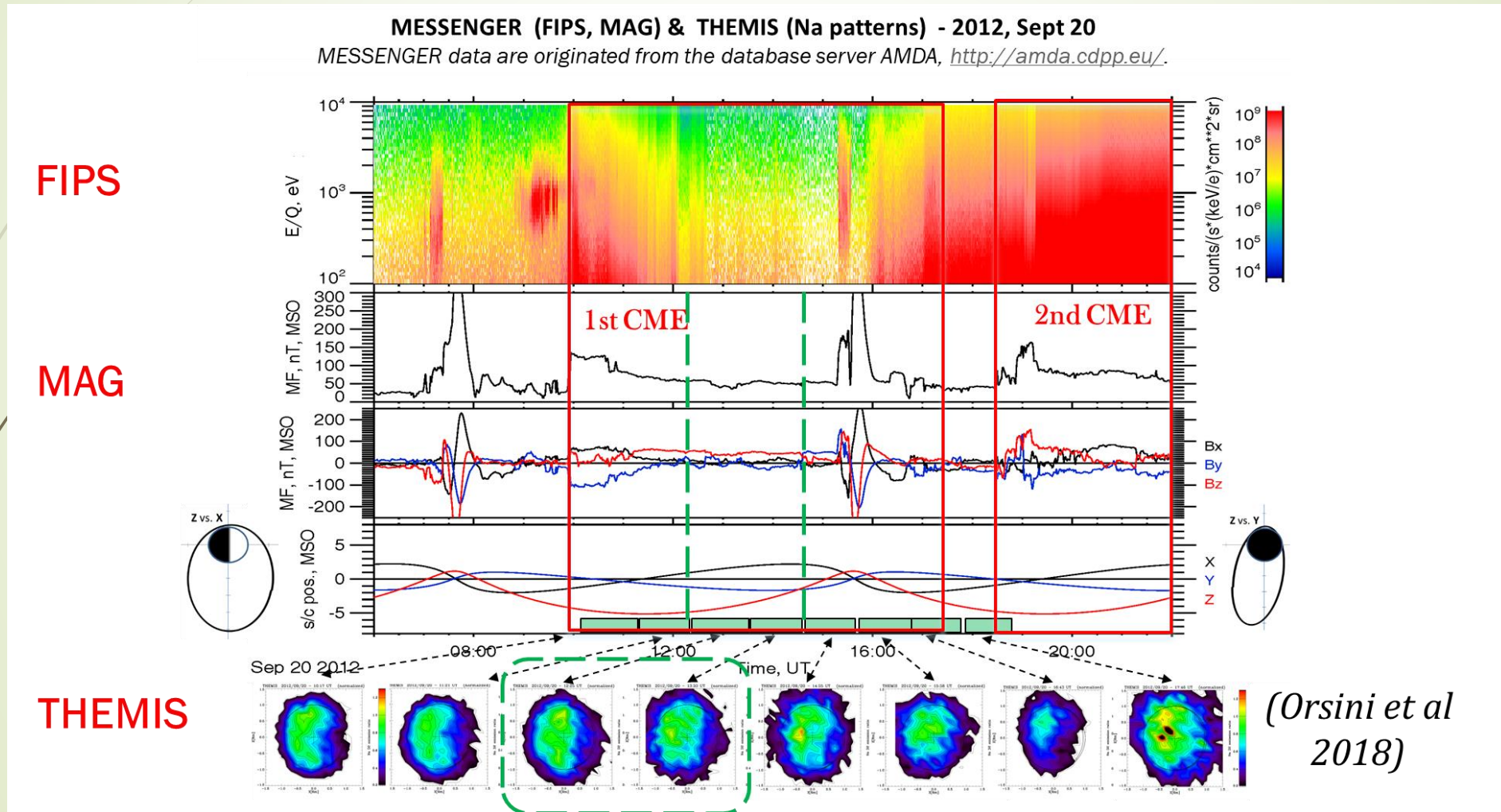
Mercury Exosphere



(Raines et al., 2015)

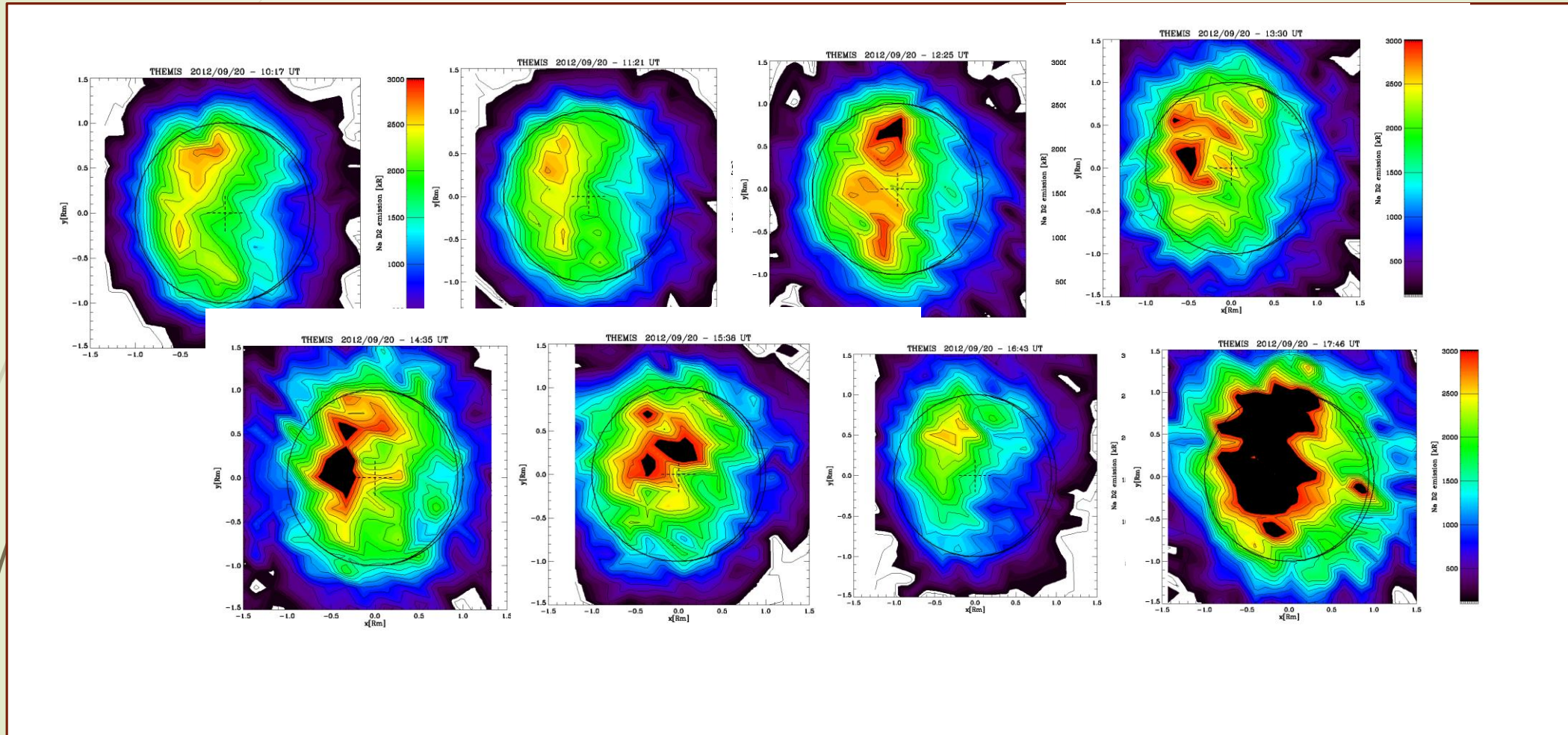
CME-exosphere interaction

→ 20 September 2012



CME-exosphere interaction

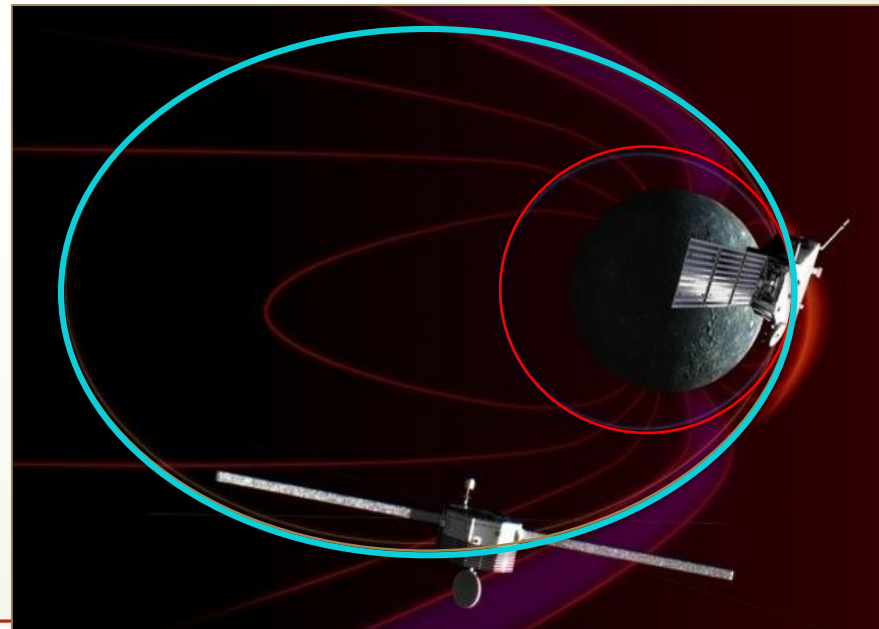
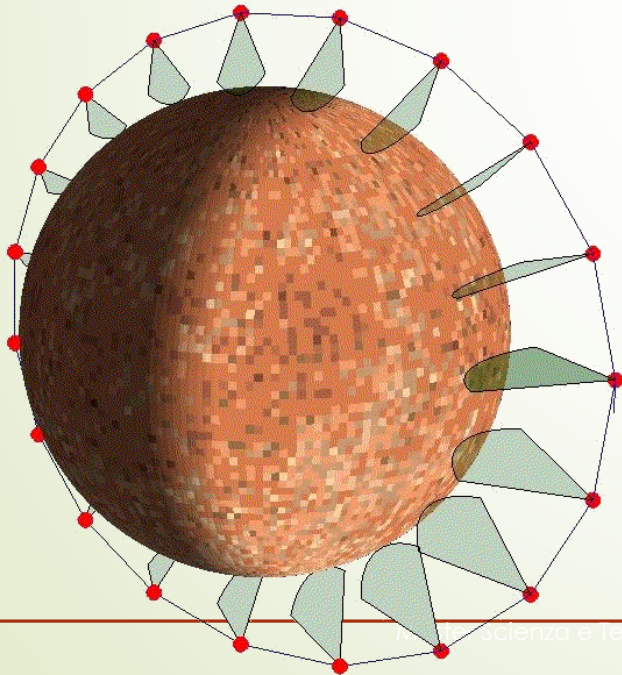
→ 20 September 2012



Upcoming: **BepiColombo**

MPO in close-by orbit:

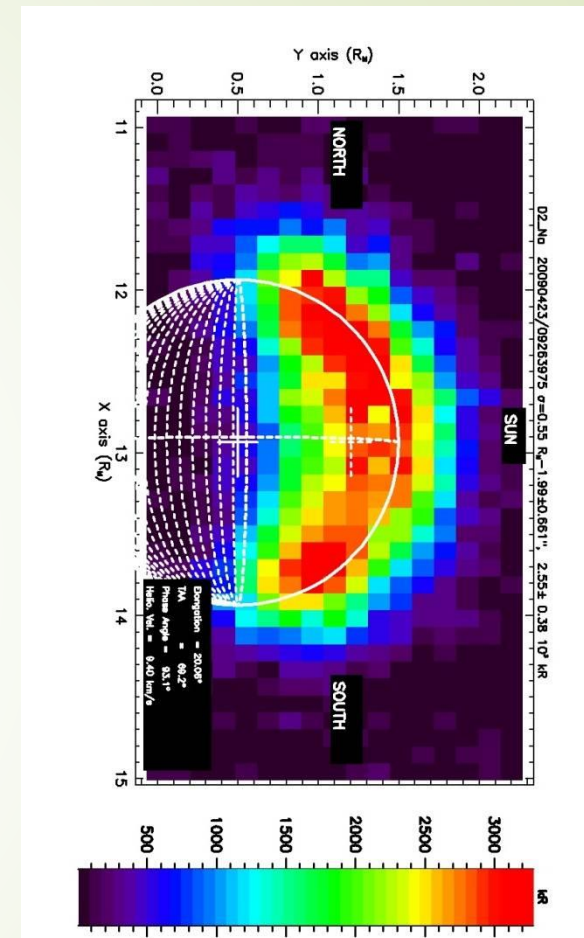
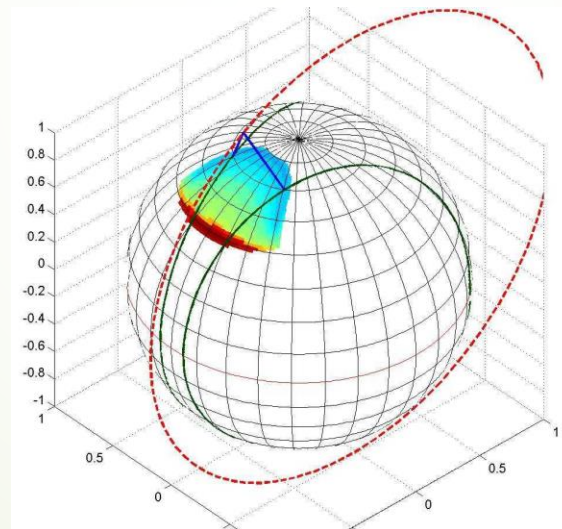
The SERENA instrument suite will measure the ions and neutral atoms characteristics



Upcoming: **BepiColombo**

Comparing the two observations

Complementing the information about the Exosphere





Some Literature



- ▶ McClintock, William E., et al. "Observations of Mercury's exosphere: composition and structure." *Mercury. The View after MESSENGER. Edited by Sean C. Solomon* (2018): 371-406.
- ▶ Killeen, Rosemary M., et al. "Understanding Mercury's Exosphere: Models Derived."
- ▶ Orsini, Stefano, et al. "Mercury sodium exospheric emission as a proxy for solar perturbations transit." *Scientific reports* 8.1 (2018): 1-10.
- ▶ Mangano, Valeria, et al. "THEMIS Na exosphere observations of Mercury and their correlation with in-situ magnetic field measurements by MESSENGER." *Planetary and Space Science* 115 (2015): 102-109.
- ▶ Killen, Rosemary, et al. "Processes that promote and deplete the exosphere of Mercury." *Space science reviews* 132.2-4 (2007): 433-509.
- ▶ Milillo, A., et al. "Surface-exosphere-magnetosphere system of Mercury." *Space Science Reviews* 117.3 (2005): 397-443.
- ▶ Massetti, Stefano, et al. "Short-term observations of double-peaked Na emission from Mercury's exosphere." *Geophysical Research Letters* 44.7 (2017): 2970-2977.
- ▶ Leblanc, François, et al. "Short-term variations of Mercury's Na exosphere observed with very high spectral resolution." *Geophysical research letters* 36.7 (2009).