MERCURY'S ATMOSPHERE

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OUTLINE

Introduction

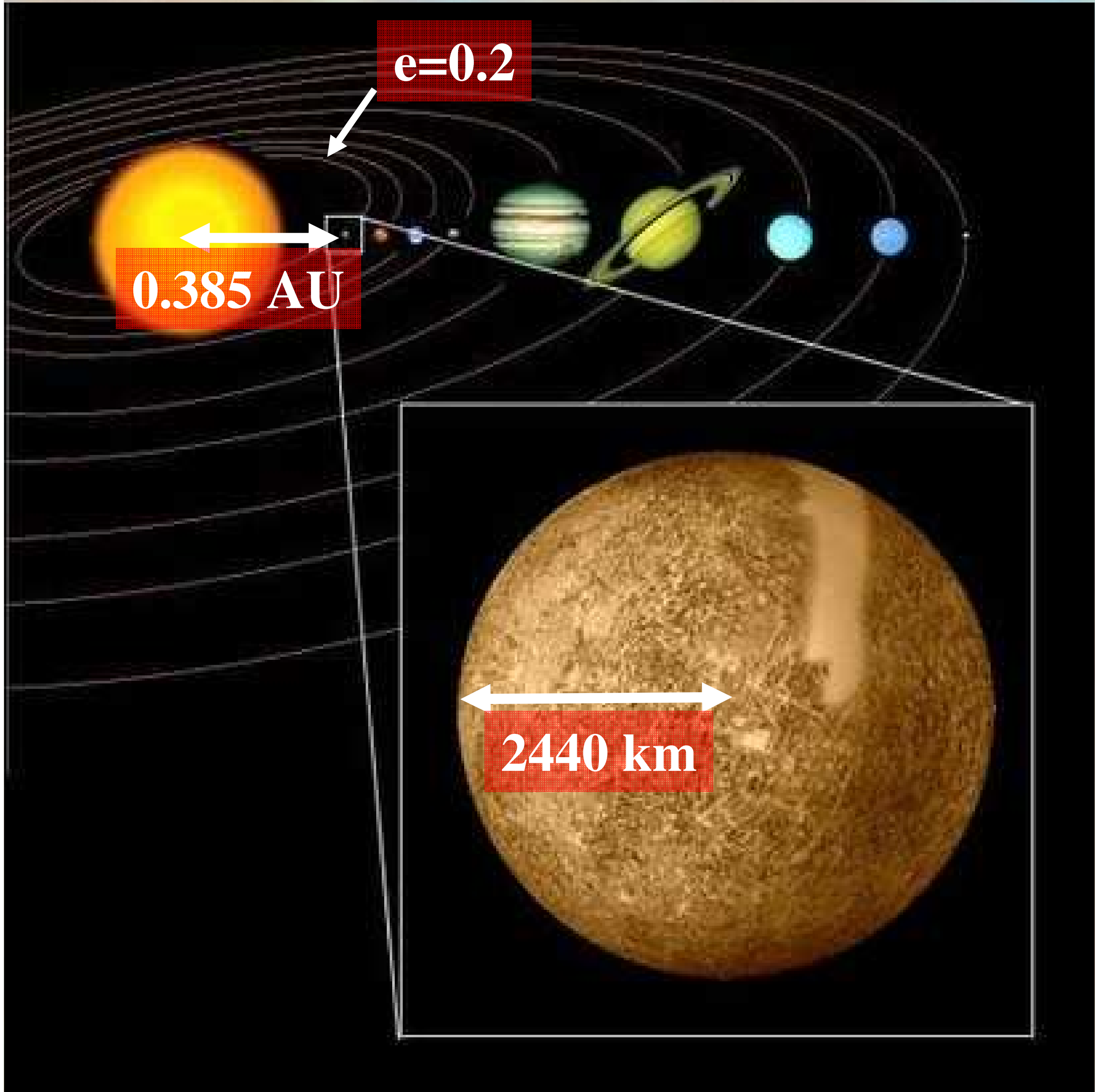
I Why Mercury is an interesting object?

II Mercury's exosphere

- Identified species
- Energetic, spatial and temporal distributions

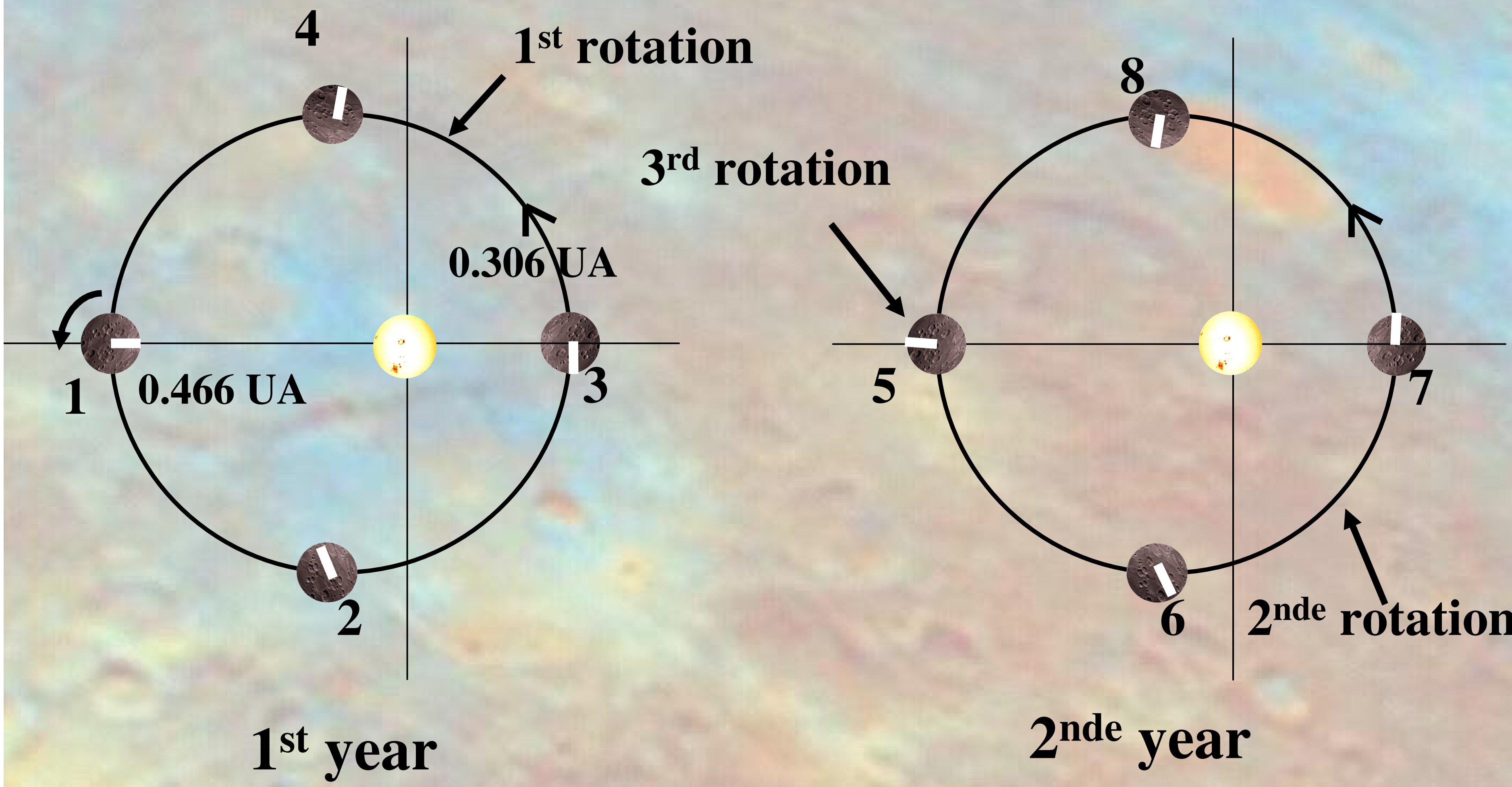
III Ground based observations with TNG, NTT, CFHT and THEMIS

Conclusion

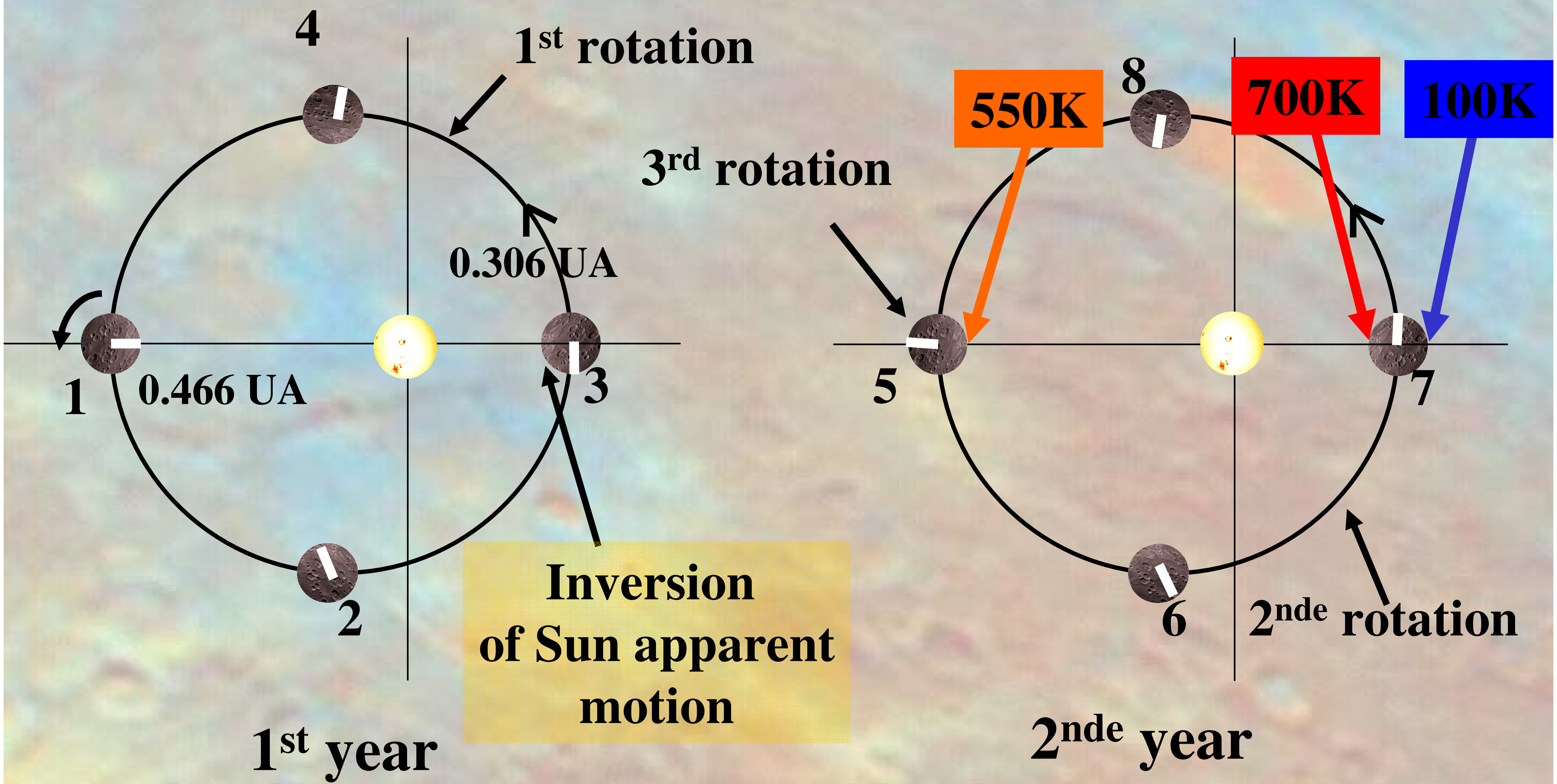


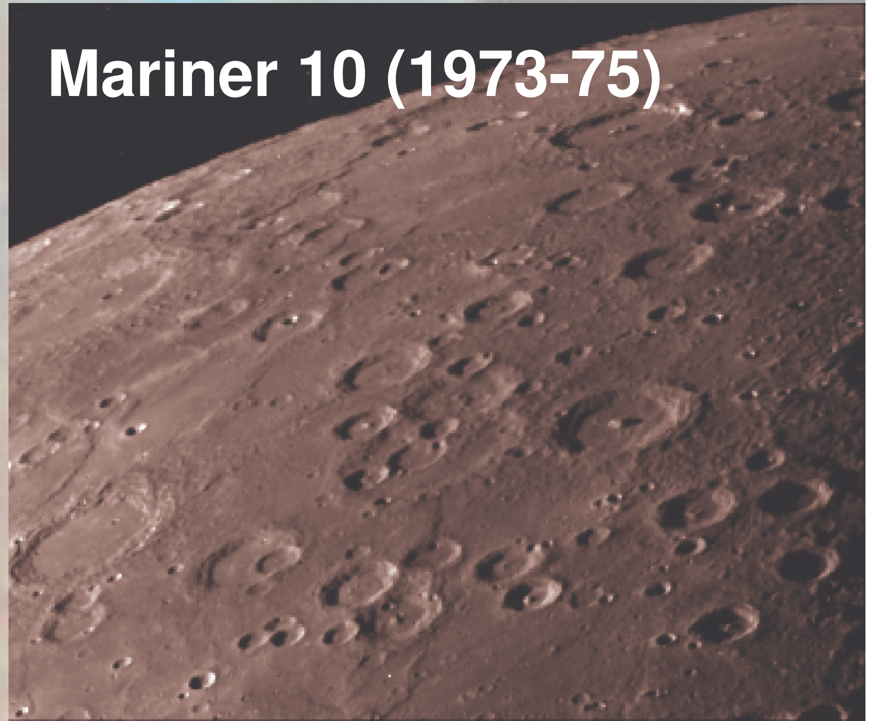
Mercury "end member" among the terrestrial planets

One sideral day = 59 Earth days
One year = 88 Earth days ⇒ **3/2 resonance**
One diurnal day = 176 Earth days

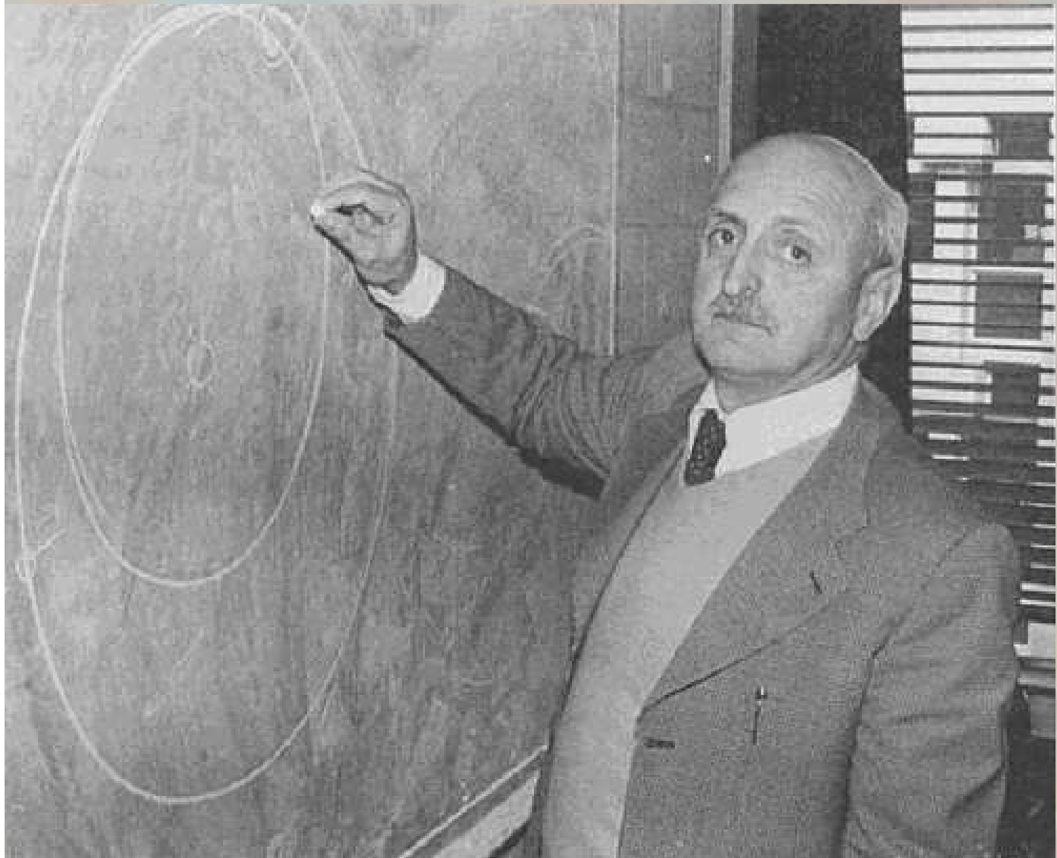


One sidereal day = 59 Earth days
One year = 88 Earth days $\Rightarrow$ **3/2 resonance**
One diurnal day = 176 Earth days

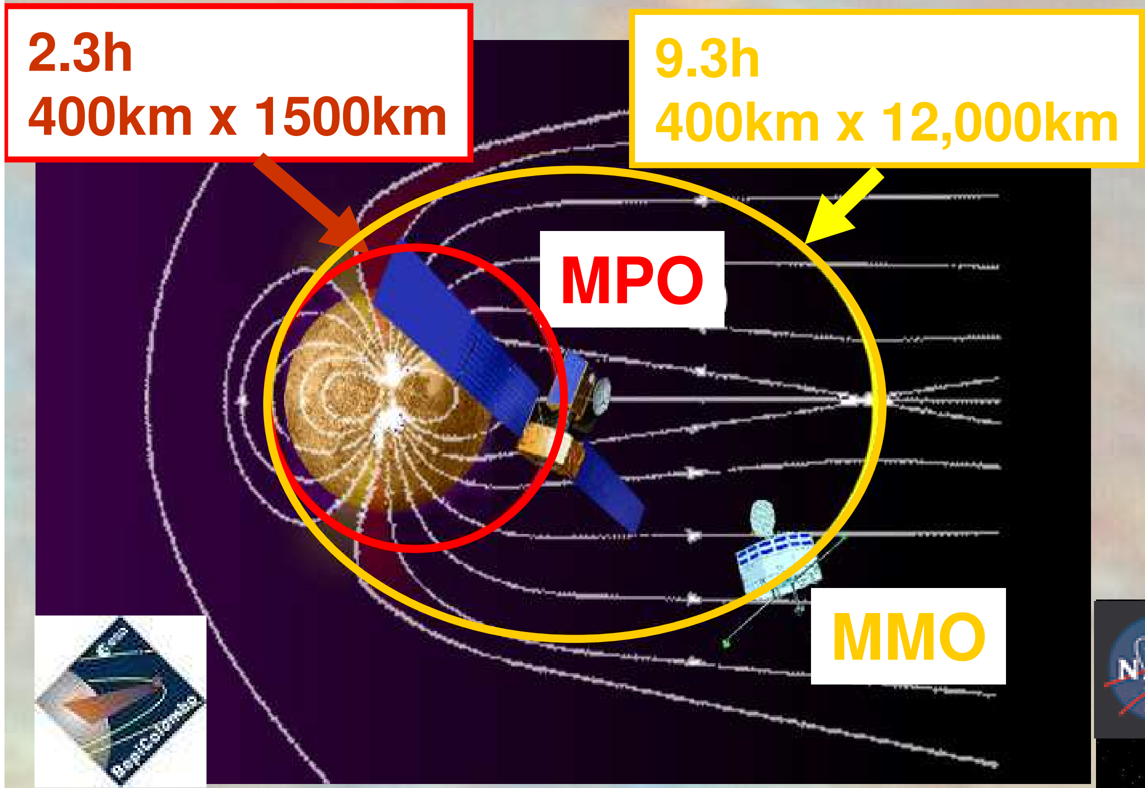




Only ONE Space Mission made three Flybies NASA Mariner 10



G. Bepi-Colombo, an italian mathematician and engineer, suggested that Mariner 10 could flyby 3 times Mercury

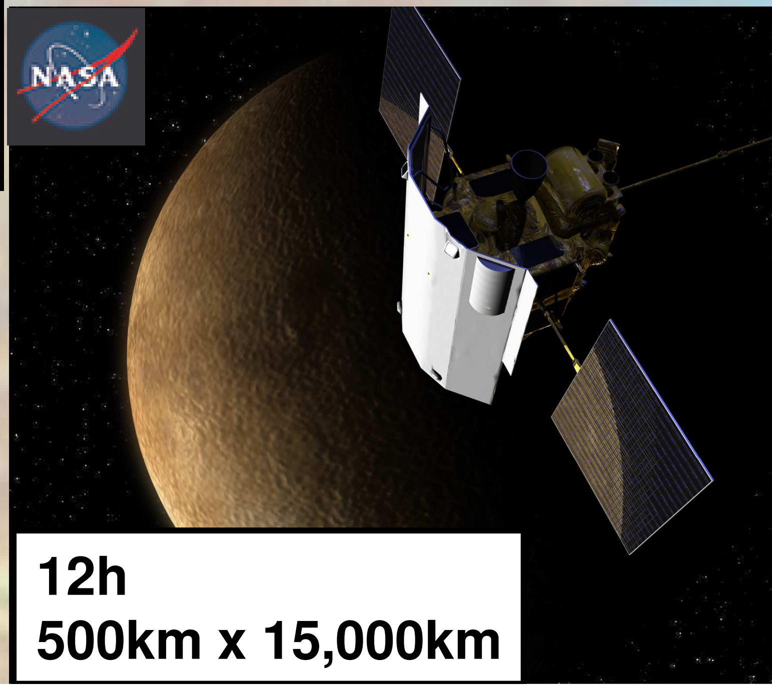


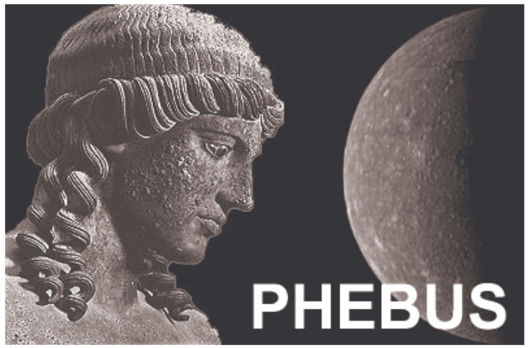
Bepi Colombo
an ESA/JAXA mission

To be launched in 08/2013
for an arrival in 08/2019

Messenger
a NASA mission

Launch 08/04/2004
First flyby 01/14/2008
Arrival in 2011

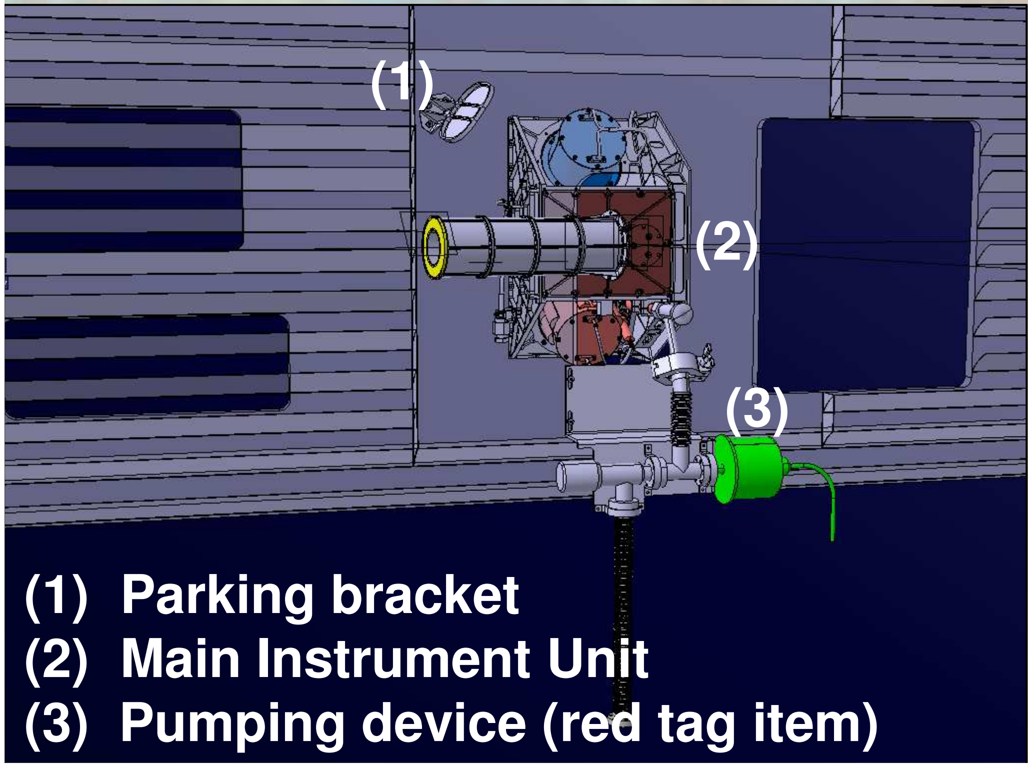




The BepiColombo UV Spectrometer

PHEBUS is a double UV spectrometer

- Extreme UV range : [55-155nm]
- Far UV range : [145-315nm]
- Near UV lines : 404 (K) and 422 (Ca) nm



-Mean detection limit

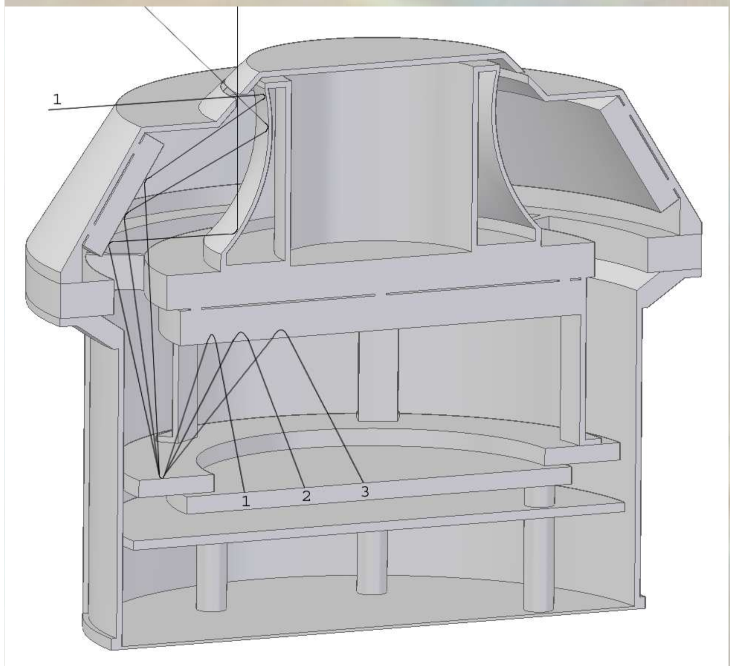
EUV range : ~ 0.1 Rayleigh

FUV range : ~ 0.2 Rayleigh

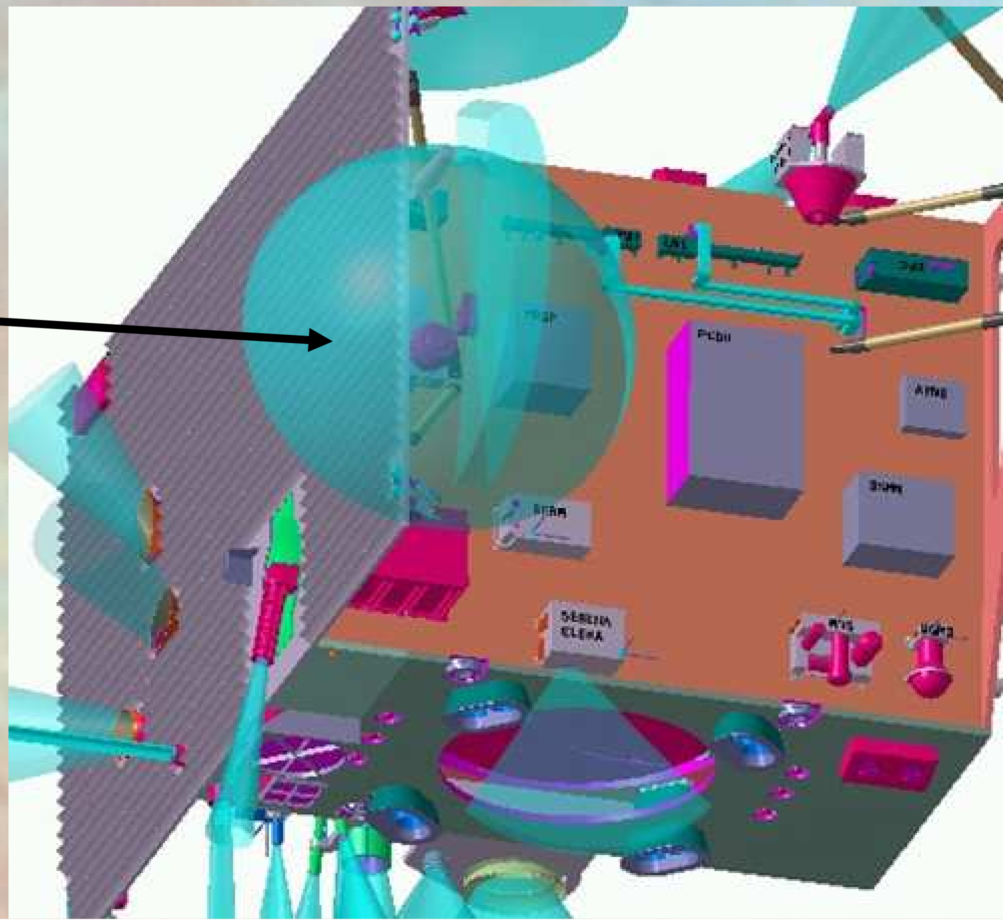
- Spectral resolution (FWHM)

EUV range : 0.5 nm

FUV range : 0.8 nm



Planetary Ion Camera PI K. Torkar (IWF, Graz) from SERENA mass spectrometers package PI S. Orsini (IFSI, Roma)

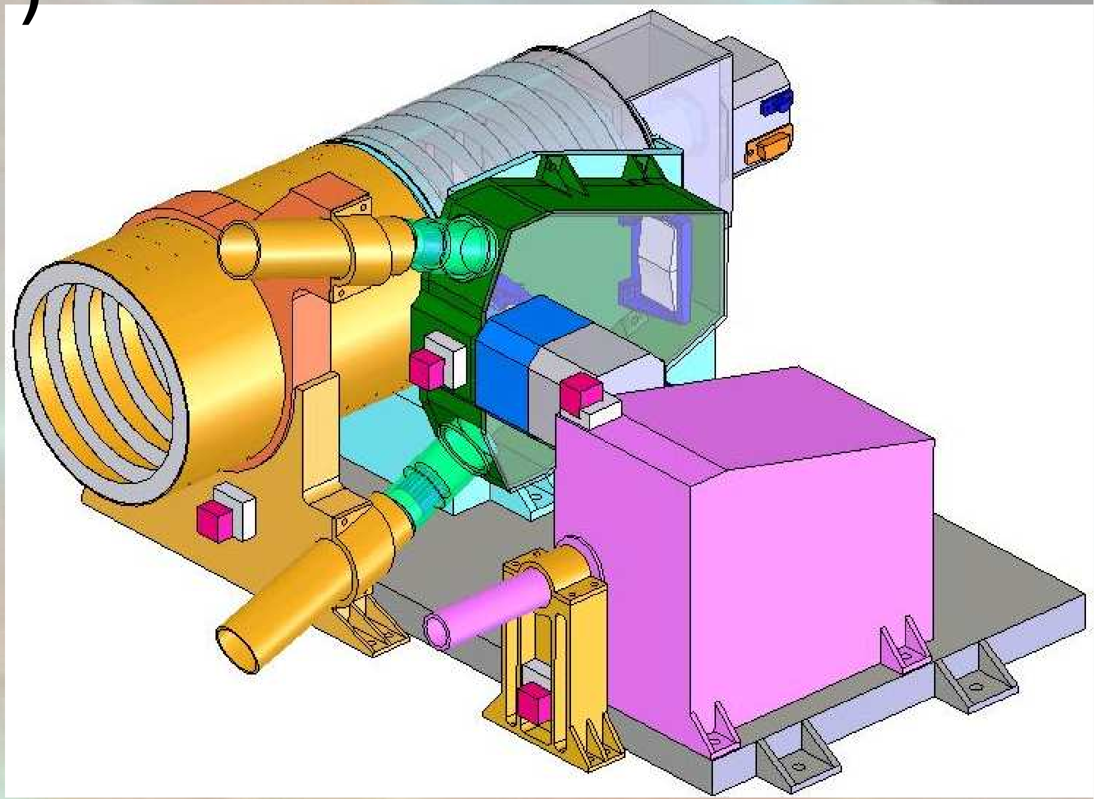


All-sky ion camera

- **Instantaneous viewing**
- **Energy: ~0-3 keV**
  $\Delta E/E$ ~7%
- **Angle: 2 Pi**
  $\Delta\Phi$ ~22.5º
- **Mass: 1 (H) - 132 (Xe)**
  $\Delta M/M > 50$

PI: E. Flamini (ASI)
Co-PI: G. Cremonese (INAF)

SYMBIO-SYS



- Surface geology
- Global tectonics
- Surface age
- Surface composition
- Geophysics

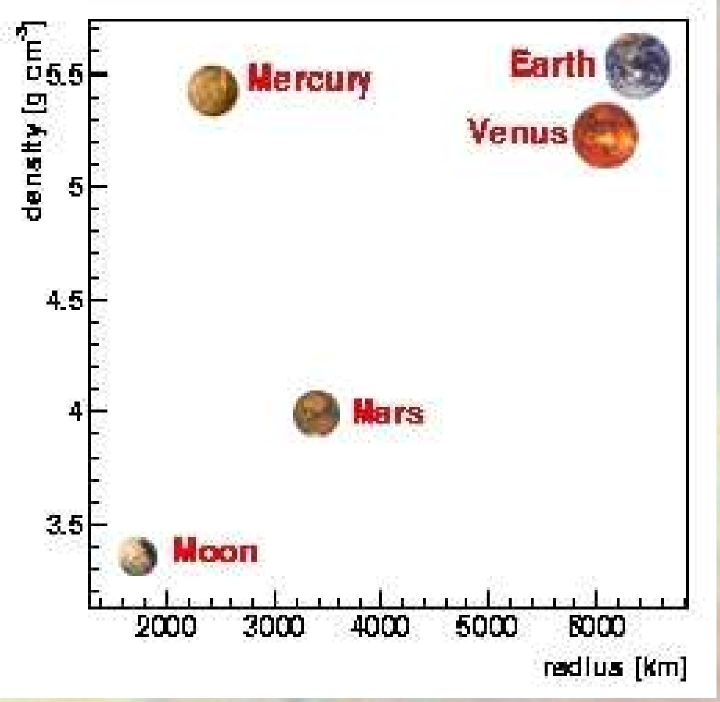
•Low Resolution Color Imaging and Stereo Channel (50 m/pixel at 550, 700, 880 nm)
•High Resolution Imaging Channel (5 m/pixel, filters: 1 panchromatic, 3 interference filters (550, 700, 880 nm)
•Visible and near-Infrared Hyperspectral Imager (100 m, Spectral range: 400 – 2000 nm)

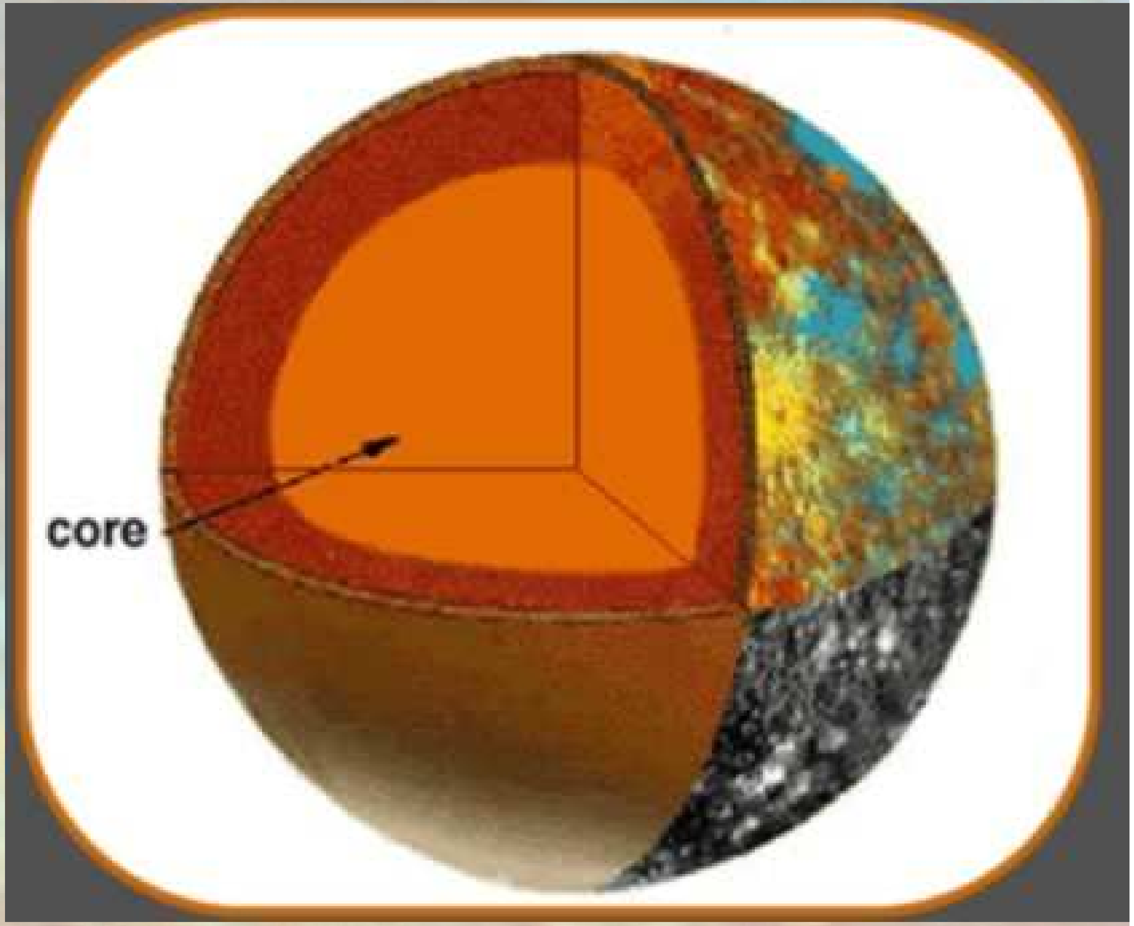
I Why Mercury is an interesting object?

Origin & evolution of a planet close to the parent star

Mercury as a planet:

Geology, core,
Composition?

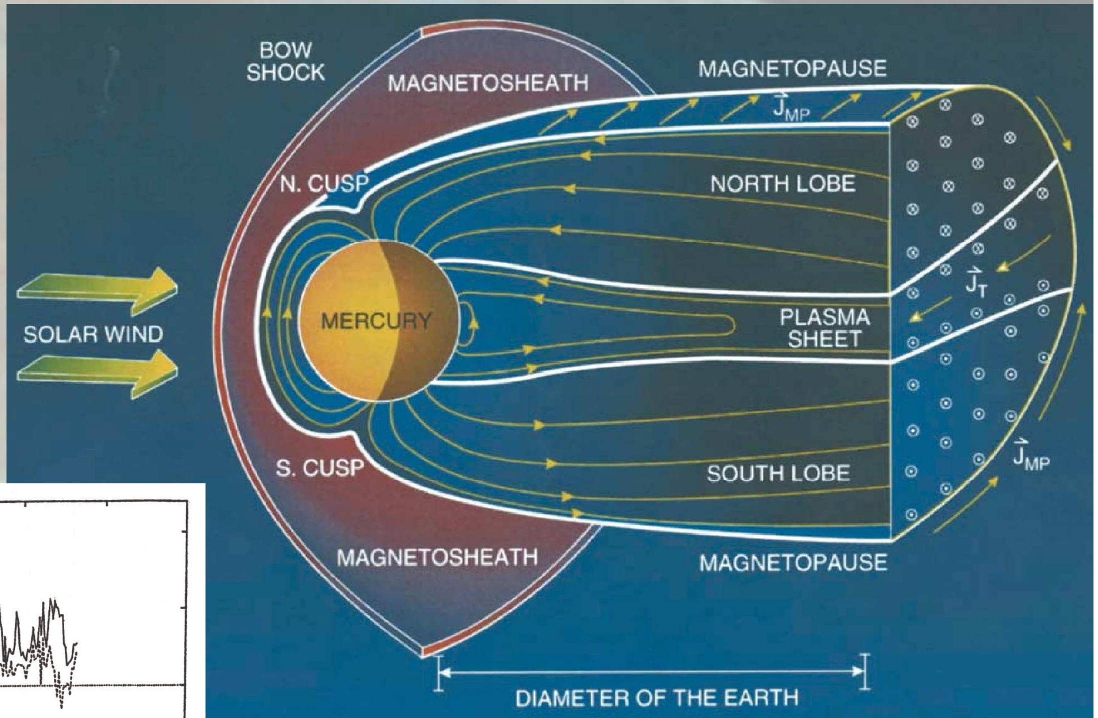


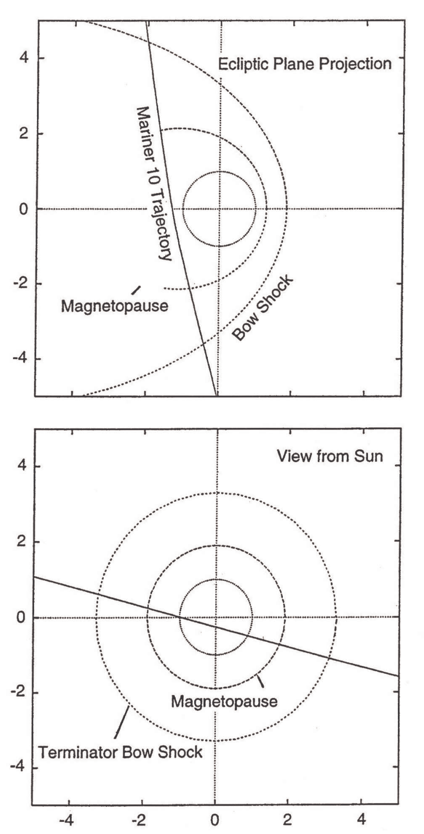


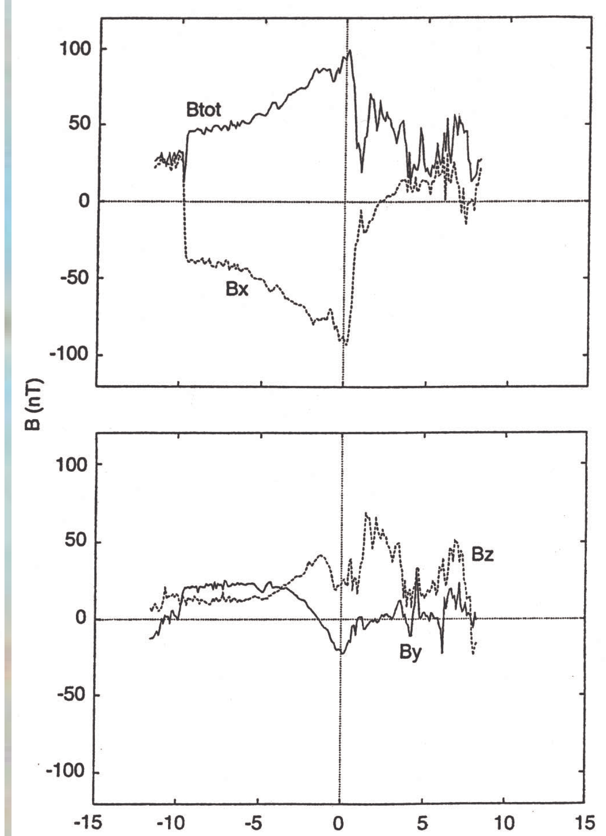
MARINER-10 flyby

→ An intrinsic magnetic field

Origin of Mercury's magnetic field?







Magnetosphere

Main currents - Structure, Interaction with solar wind Relation to exosphere?

II Observed Mercury's exosphere

Known Species

Species	Subsolar column density (cm^{-2})	Near surface subsolar density (cm^{-3})	Remarks
Na	$0.1 - 10 \times 10^{11}$	$\sim 10^4$	From Earth
K	$0.5 - 3 \times 10^9$	$\sim 10^2$	From Earth
Ca	1.1×10^8	?	From Earth
H	3×10^9	~ 23 (hot) 230 (cold)	Mariner 10
He	3×10^{11}	$\sim 6 \times 10^3$	Mariner 10
O	3×10^{11}	$\sim 4.4 \times 10^4$	Mariner 10

Mariner 10 Solar Occultation (Broadfoot et al. 1976)

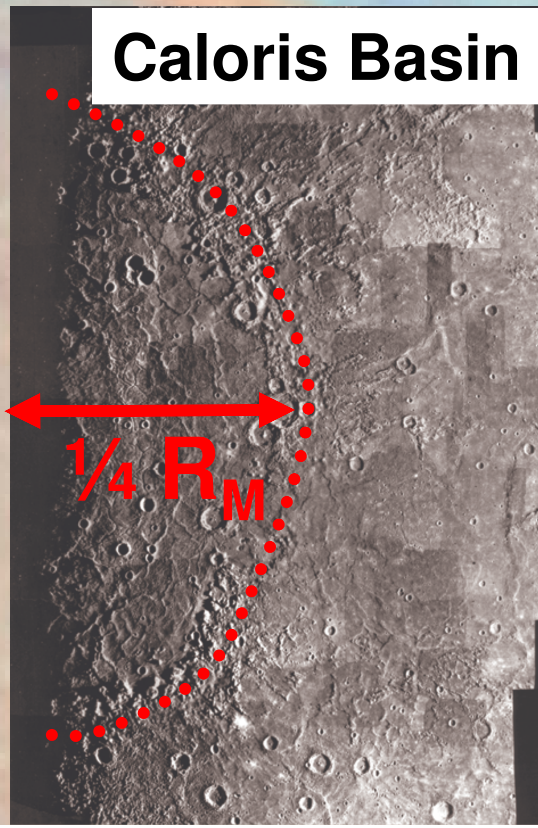
At terminator: neutral density < 10^7 cm^{-3}

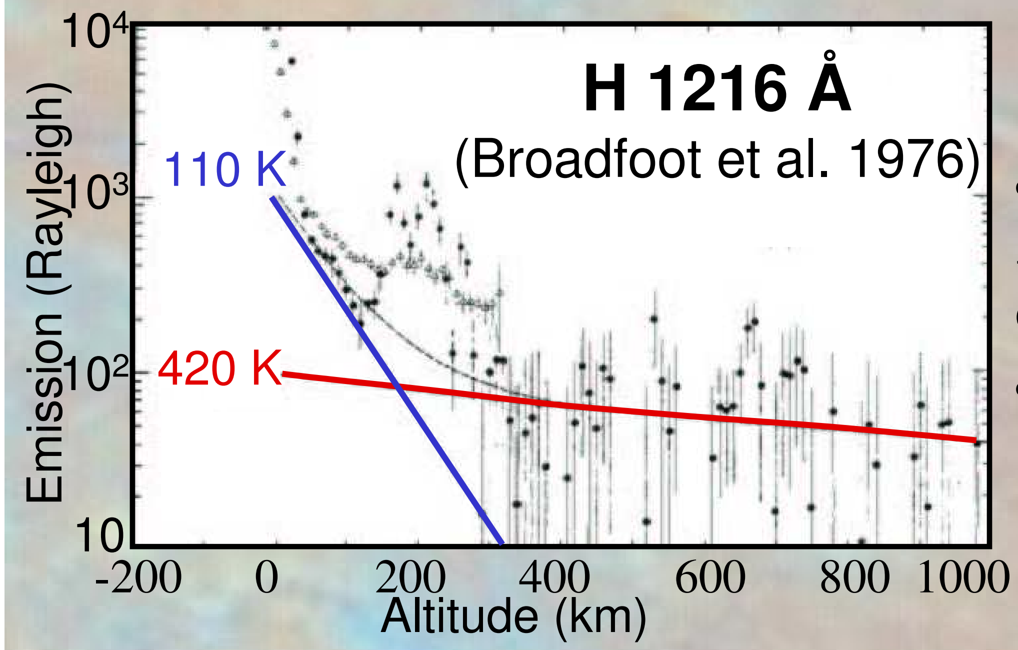
Mariner 10 Radio Occultation (Fjelbo et al. 1976)

Electronic density around Mercury < 10^3 cm^{-3}

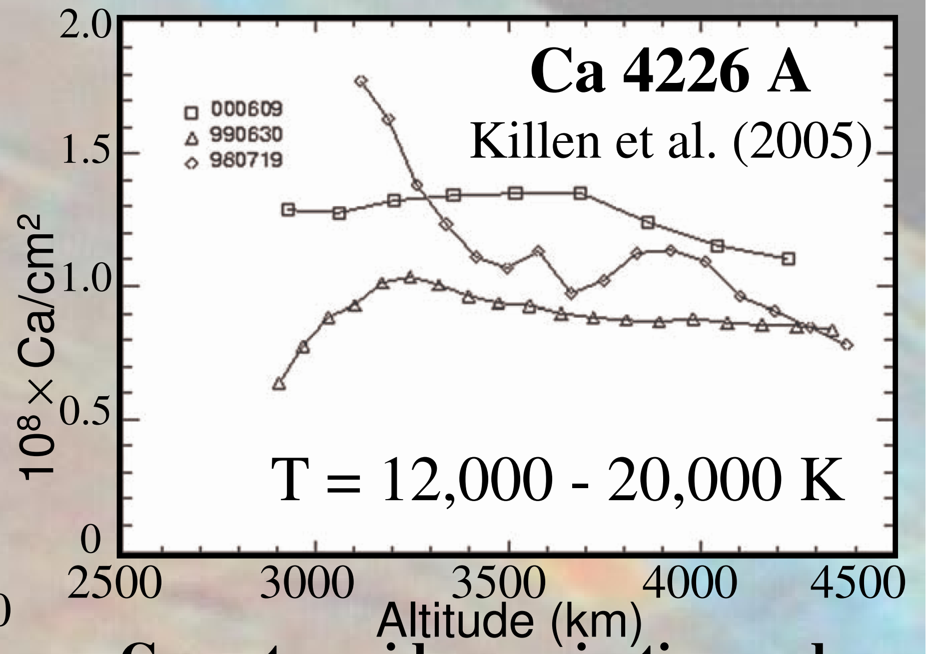
Since Mariner 10: discovery of Na, K, Ca components

- **1985: First Spectroscopic observation of Na (Potter et al. 1985)**
- **1986: observation of K:**
  Na/K = 80-190 >> Moon (6), solar (20) (Potter and Morgan 1988)
- **Suprathermal component in Na line (Killen et al. 1999)**
- **Sporadic spots of Na emission at high latitudes (Potter and Morgan 1990, 1997)**
- **Local enhancement on Caloris of K emission (Sprague 1990)**
- **First detection of Ca (Bida et al. 2001)**



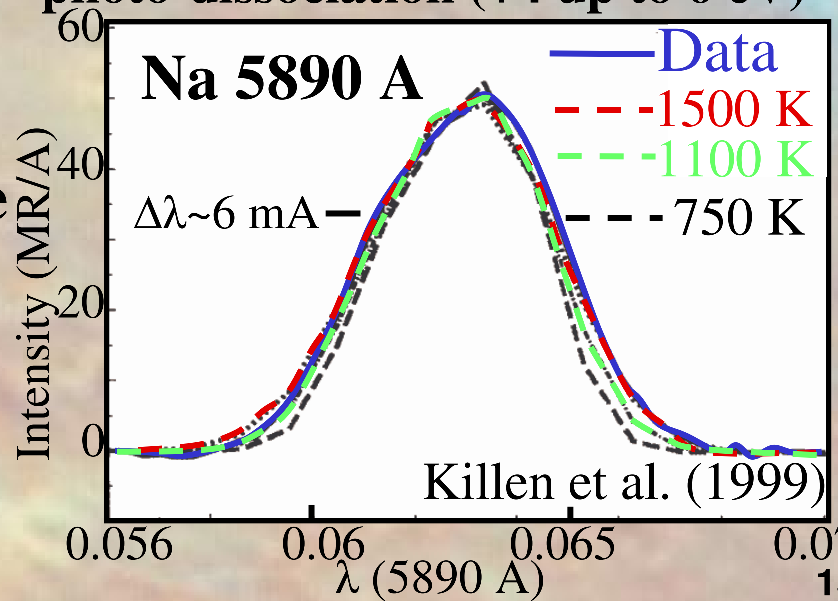


H and He: thermal desorption and surface accomodation



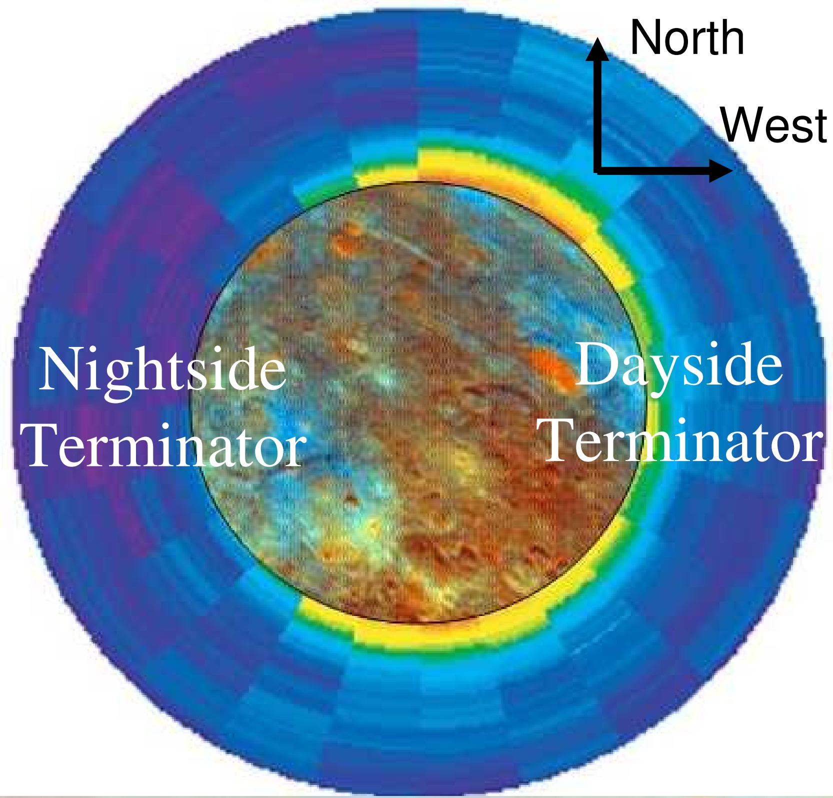
Ca meteoroid vaporization and photo-dissociation (+4 up to 6 eV)

Na: hotter than surface temperature
⇒ Energetic processes (?)

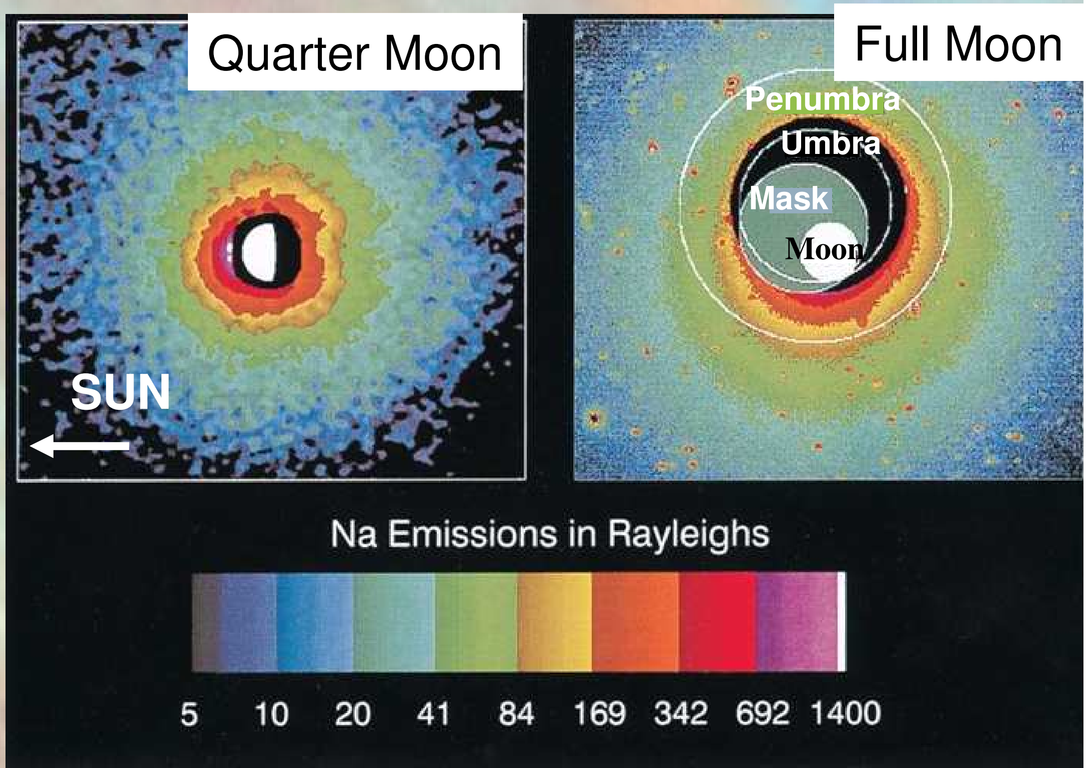


Different energy distributions?
⇒ Different release mechanisms?

A complex spatial structure

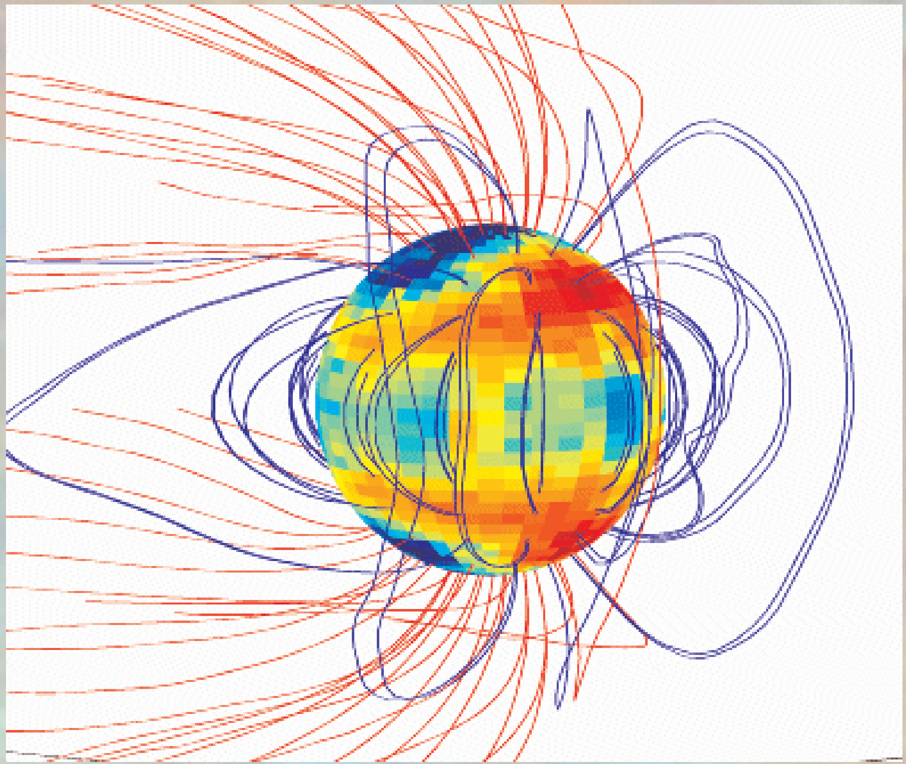


Observation of the D1 +D2 Na emissions in the Lunar exosphere (Mendillo et al. 1997)

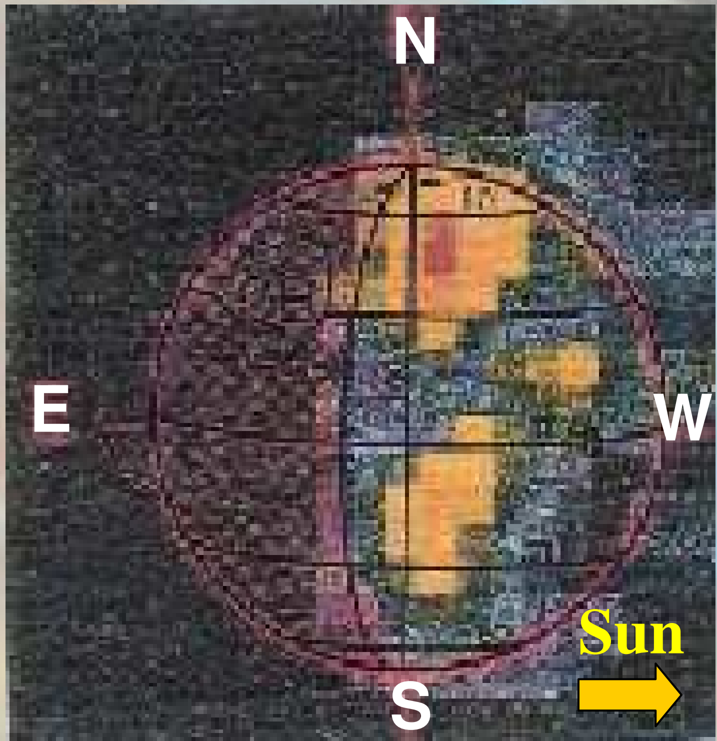


Occultation of the Solar Na D2 line by Mercury's exosphere (Schleicher et al. 2004)

Solar Wind sputtering



Solar Wind Proton impact
(Kallio and Janhunen 2003)



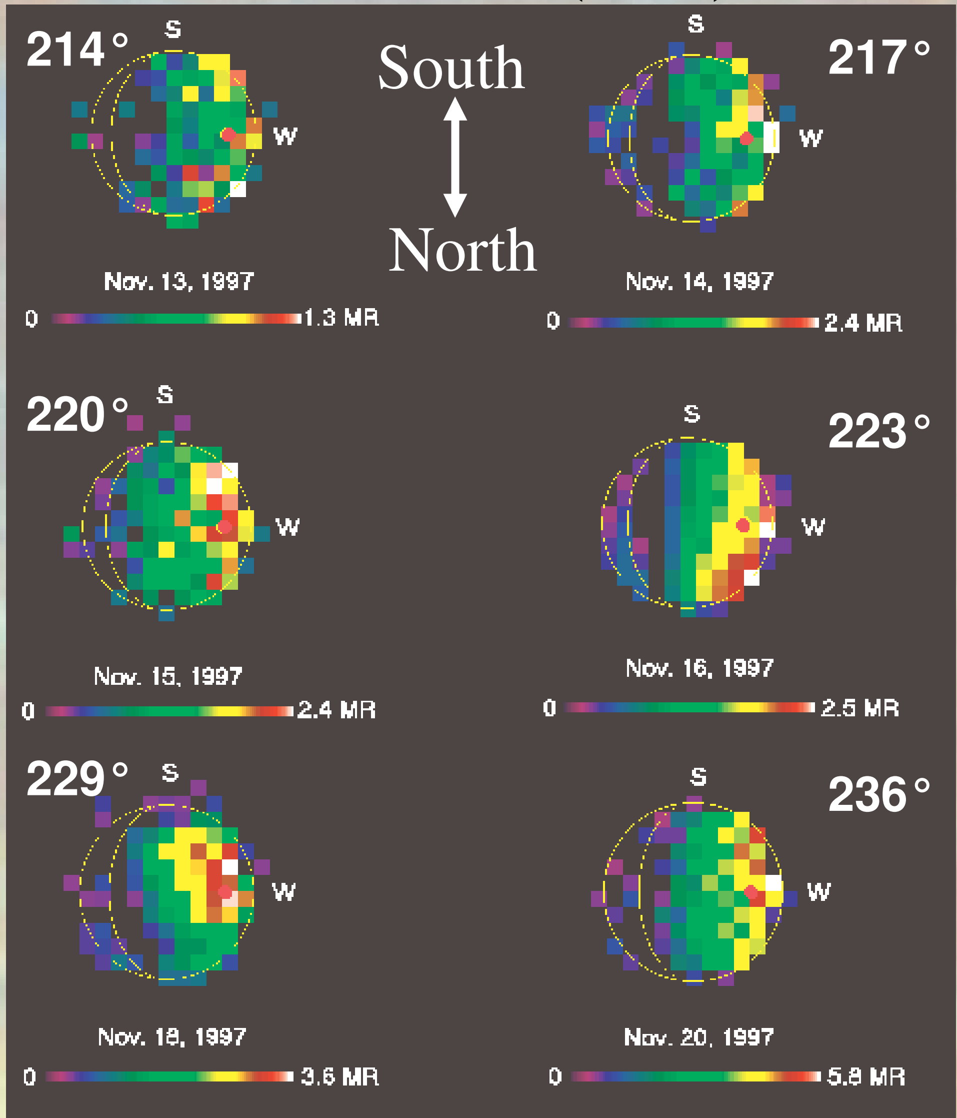
Observations of the Na D lines
(Potter and Morgan 1997)

⇒ High latitude peaks in Na emission could be due to solar wind magnetospheric penetration

⇒ High variability related to high variability of IMF orientation (Potter and Morgan 1990)

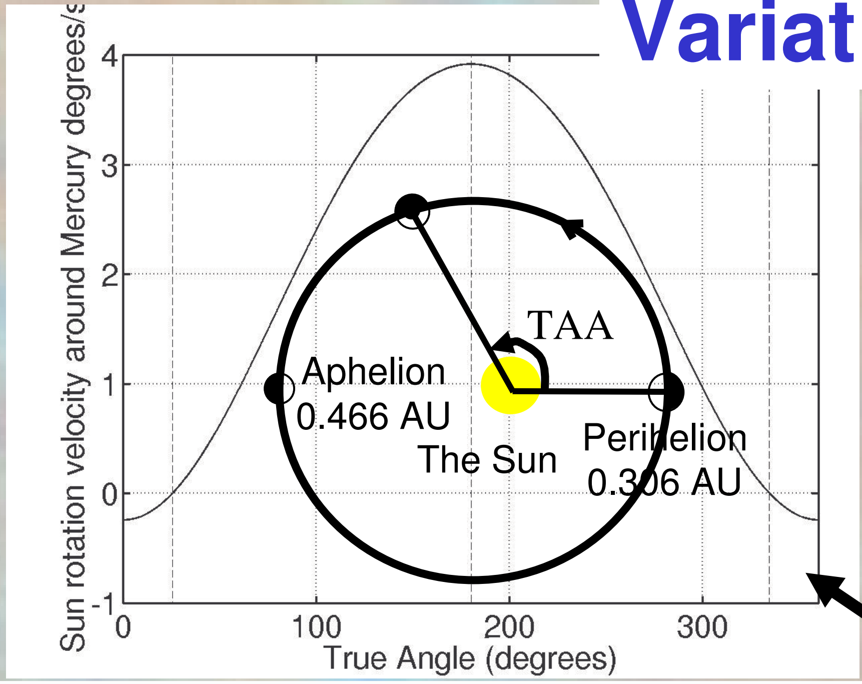
"Short" term variation

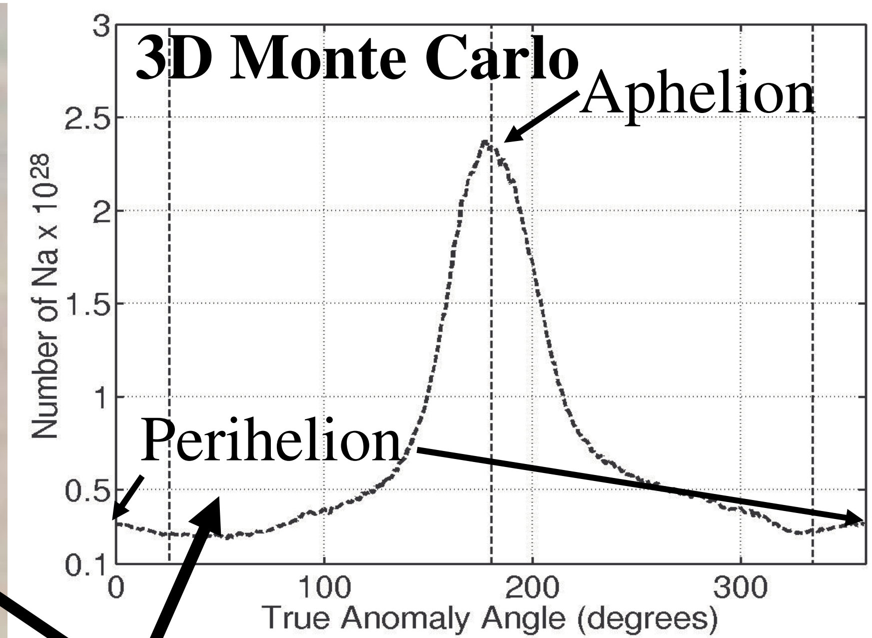
Potter et al. (1999)

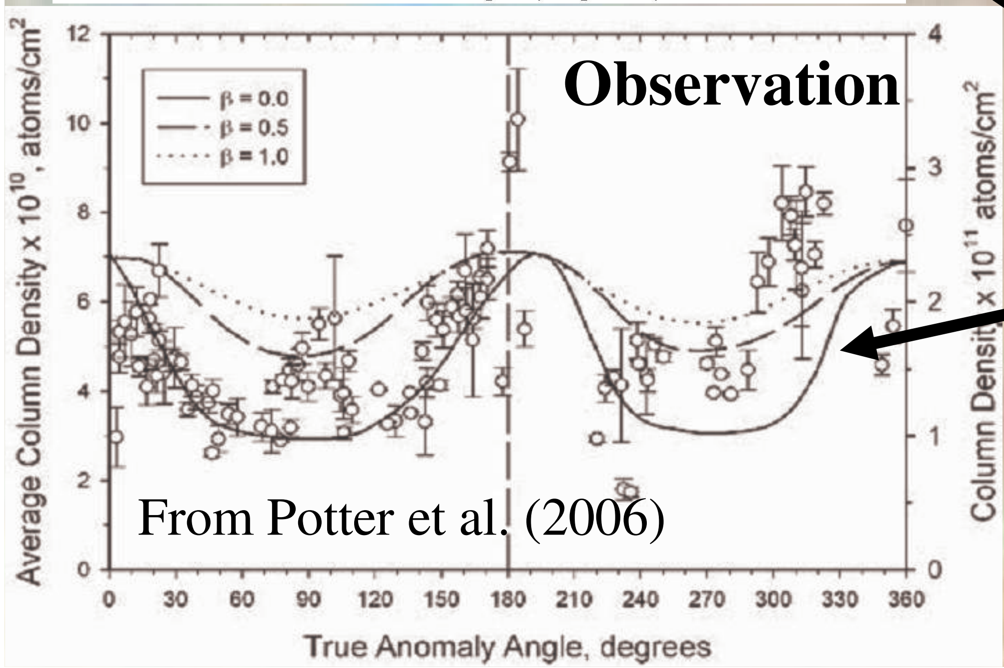


- Is it a CME encounter with Mercury?
- Is it a solar wind and UV variation inducing this observation?
- Role of Caloris?
- Other mechanisms?

Variation with respect to TAA







Driven by Mercury's rotations?

Driven by the solar radiation pressure?

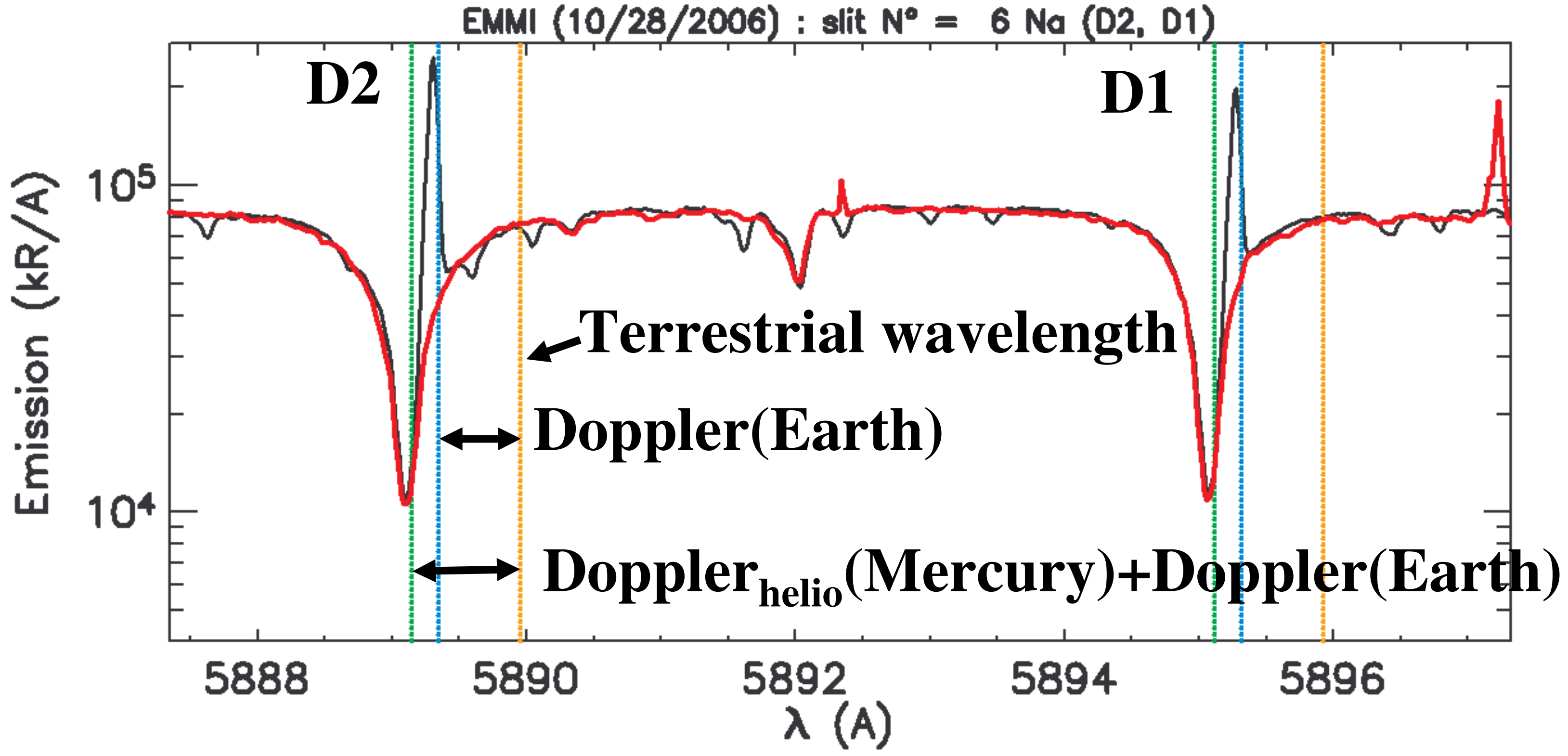
Driven by the distance to the Sun?

III Ground based observations

Mercury close to Sun → Observation only at dawn and dusk (< 1h)

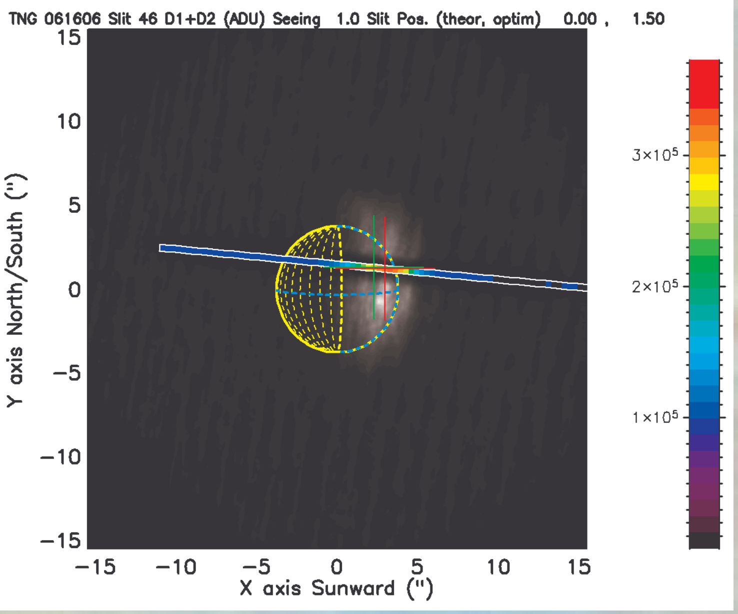
⇒ Airmass > 4 ⇒ Seeing between 2 to 4'' (~½ R_M)

- **Only Na, K and Ca (with Keck) identified from ground based**
- **Emission varies by a factor 20 because of Solar flux vs Doppler_{helio}**
- **Absolute intensity calibration with Mercury's surface**

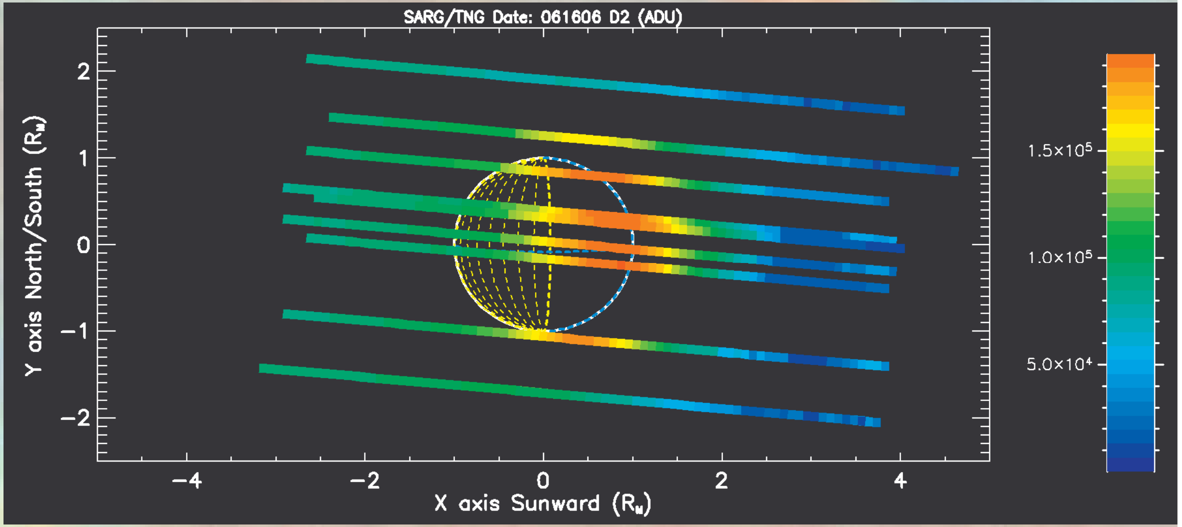


Observations with TNG

Fundación Galileo Galilei - INAF
Telescopio Nazionale Galileo
28º45'28.3" lat. N - 17º53'37.9" long. W - 2387.2m a.s.l.



SARG high efficiency spectrograph
Filter on D1 and D2
R=115,000
0.4" width 26.7" long

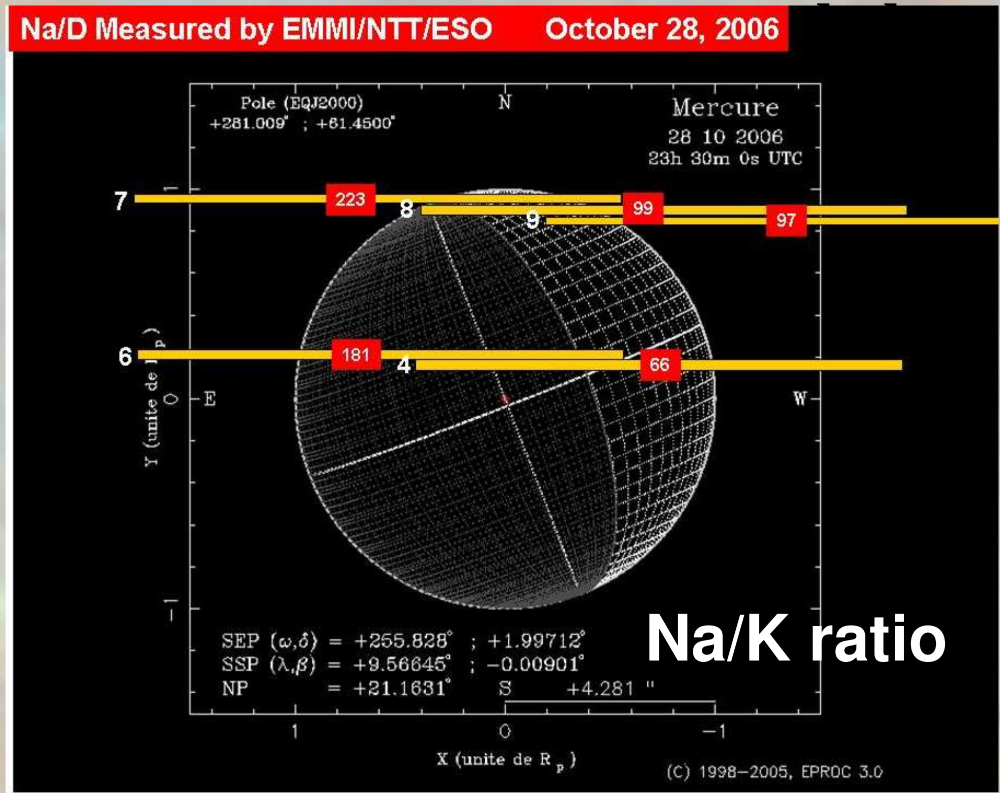


Campaigns in 2002 (3 days), 2003 (3 days), 2005 (3 days), 2006 (4 days)

TNG, La Palma, Canarias
3.58-m telescope

Observations of Na/K with EMMI/NTT & CFHT/ESPADONS

- **ESPaDOnS** echelle spectrograph
  370 -1050 nm at R=68,000 1.6''



CFHT, Mauna Kea, Hawaii
3.58-m telescope

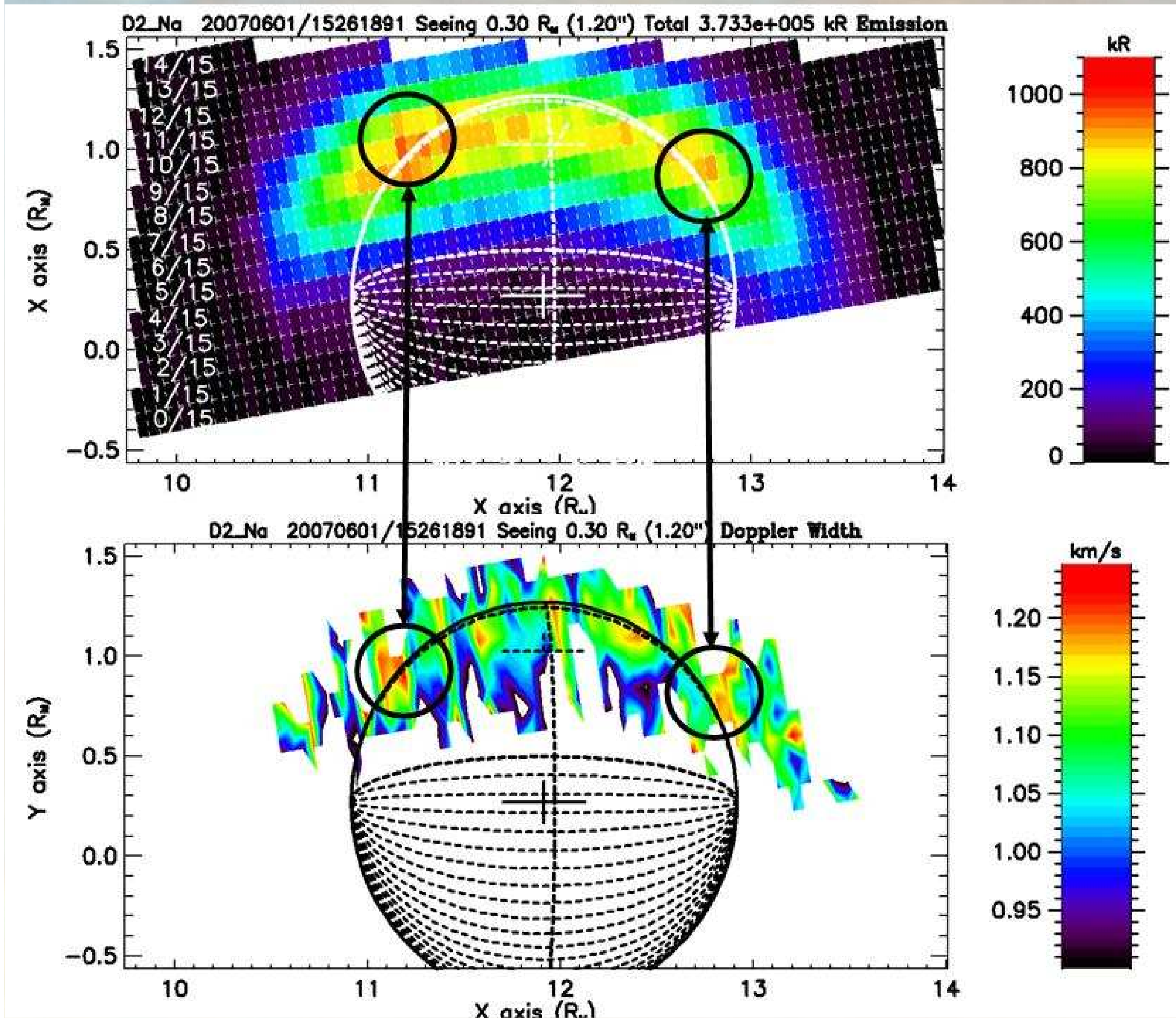
Campaigns
June 2006 (CFHT)
October 2006 (NTT)

NTT, La Silla, Chile
3.58-m telescope

EMMI with echelle spectroscopy
385 - 855nm at R=75000,
Slit: 0.8'' × 10''

Observations of Na with THEMIS

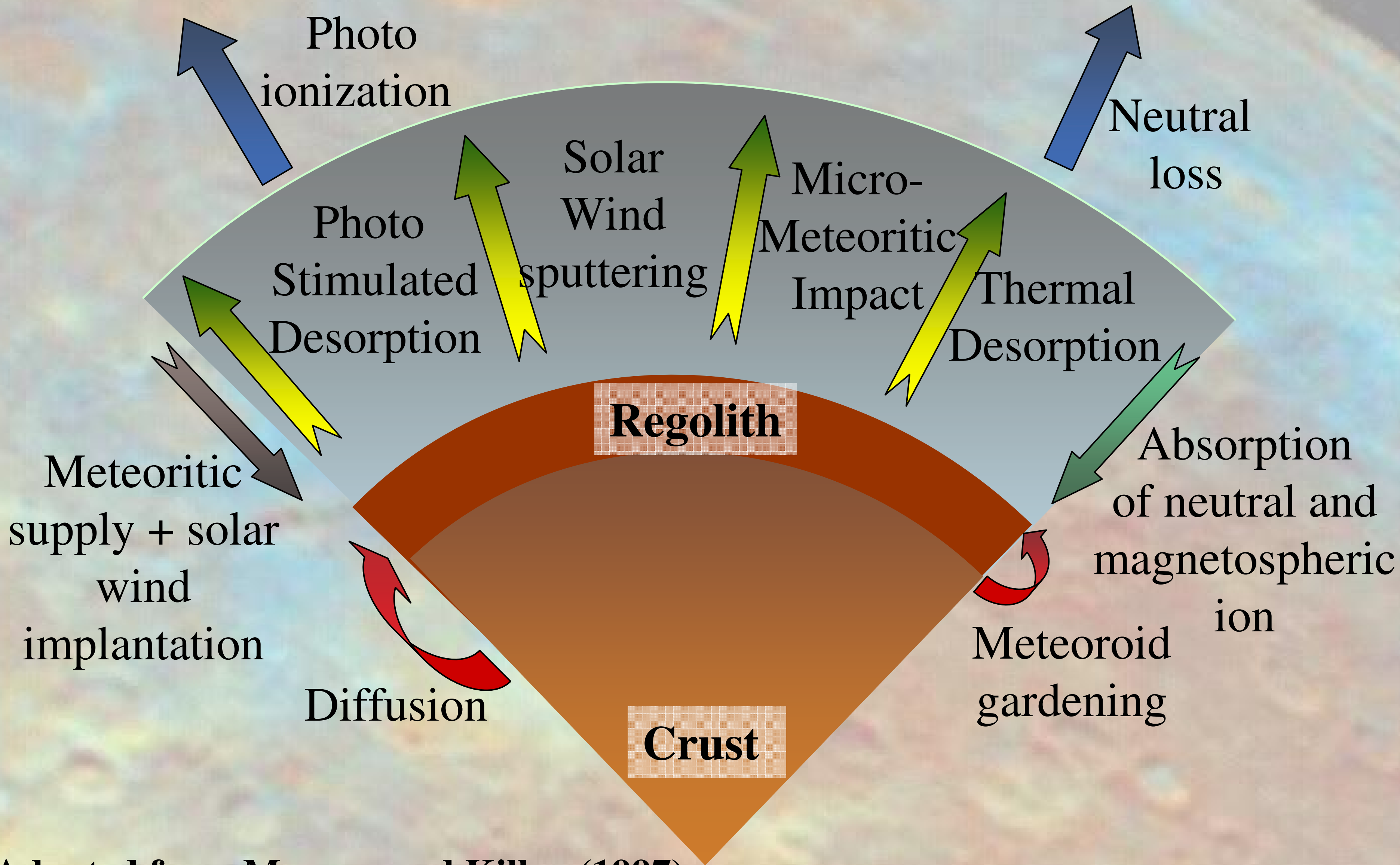
THEMIS with spectrograph, with up to 6 wavelengths simultaneously



THEMIS, Tenerife, Canarias 0.90-m Solar telescope

Spectral range 400 to 1000 nm at R=900000 (600000 avec camera), Slit: 1'' & 2' long

In summary



Adapted from Morgan and Killen (1997)