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

Mercury's orbit is 0.385 AU from the Sun with an eccentricity (e) of 0.2.

The diameter of Mercury is 2440 km.
One sidereal day = 59 Earth days
One year = 88 Earth days
One diurnal day = 176 Earth days

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

⇒ 3/2 resonance

Inversion of Sun apparent motion

1st year

1st rotation

3rd rotation

2nd year

2nd rotation

10 October 2007

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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
**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
All-sky ion camera
• Instantaneous viewing
• Energy: $\sim$0-3 keV
  $\Delta E/E \sim 7\%$
• Angle: 2 Pi
  $\Delta \Phi \sim 22.5^\circ$
• Mass: 1 (H) - 132 (Xe)
  $\Delta M/M > 50$

Planetary Ion Camera PI K. Torkar (IWF, Graz) from SERENA mass spectrometers package PI S. Orsini (IFSI, Roma)
PI: E. Flamini (ASI)
Co-PI: G. Cremonese (INAF)

- 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)
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?
## Observed Mercury's exosphere

<table>
<thead>
<tr>
<th>Species</th>
<th>Subsolar column density (cm(^{-2}))</th>
<th>Near surface subsolar density (cm(^{-3}))</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>0.1 - 10 \times 10^{11}</td>
<td>\sim 10^4</td>
<td>From Earth</td>
</tr>
<tr>
<td>K</td>
<td>0.5 - 3 \times 10^9</td>
<td>\sim 10^2</td>
<td>From Earth</td>
</tr>
<tr>
<td>Ca</td>
<td>1.1 \times 10^8</td>
<td>?</td>
<td>From Earth</td>
</tr>
<tr>
<td>H</td>
<td>3 \times 10^9</td>
<td>\sim 23 (hot) 230 (cold)</td>
<td>Mariner 10</td>
</tr>
<tr>
<td>He</td>
<td>3 \times 10^{11}</td>
<td>\sim 6 \times 10^3</td>
<td>Mariner 10</td>
</tr>
<tr>
<td>O</td>
<td>3 \times 10^{11}</td>
<td>\sim 4.4 \times 10^4</td>
<td>Mariner 10</td>
</tr>
</tbody>
</table>

**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:
  \[ \text{Na/K} = 80-190 \gg \text{Moon (6), solar (20)} \] (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)
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H and He: thermal desorption and surface accommodation

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)

⇒ 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)

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

From Potter et al. (2006)

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

![Graph showing emission lines](EMMI_10-28-2006): slit N° = 6 Na (D2, D1)

- Terrestrial wavelength
- Doppler(Earth)
- Doppler$_{helio}$(Mercury)+Doppler(Earth)
Observations with TNG

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"

Na/D Measured by EMMI/NTT/ESO

October 28, 2006

CFHT, Mauna Kea, Hawaii
3.58-m telescope

Campaigns
June 2006 (CFHT)
October 2006 (NTT)

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

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

- Photo ionization
- Photo Stimulated Desorption
- Solar Wind sputtering
- Micro-Meteoritic Impact
- Thermal Desorption
- Neutral loss
- Absorption of neutral and magnetospheric ion
- Meteoroid gardening
- Diffusion
- Meteoritic supply + solar wind implantation

Adapted from Morgan and Killen (1997)