Sodium Exosphere of Mercury

From ground-based to space observations - a unique view.

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MEARIM III

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Motivation

- High resolution spectroscopic data were taken around MESSENGER (MErcury Surface, Space ENvironement, GEochemistry, and Ranging) third flyby.
- Develop routines to reduce the spectroscopic data.
- Mapping sodium distibutions over for North-South and Terminator-limb directions.
- Study the time variability of sodium atoms over Mercury's surface.
- Study the asymmetries in sodium distribution over the planet.
- Compare groud-based data with space data.

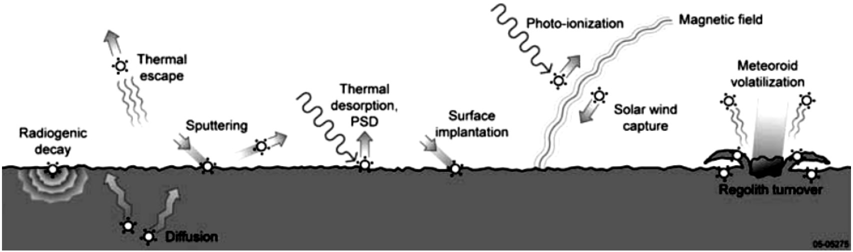
Outline

1. Introduction
2. Observations
3. Data reduction
4. Results
5. Future research

Introduction

- Mercury has a *surface-bounded exosphere:* mean distance for collision is larger than the atmospheric thickness ($P_{merc} = 10^{-12} P_{Earth}$).
- Very dynamic system: interaction between the surface and the surrounding space environment.
- Stuying the exosphere $\Longrightarrow$ composition of the surface $\Longrightarrow$ Evolution of Mercury.

Figure: Sources, sinks and interactions of the surface with the space environment (Domingue et al.(2007)).



Why Sodium?

- High cross section for resonance scattering.
- Strong emission lines in the visible.

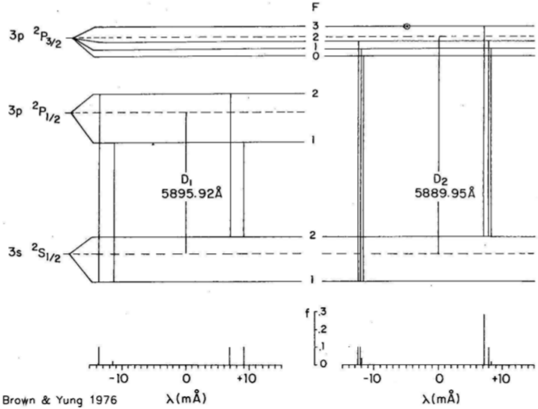
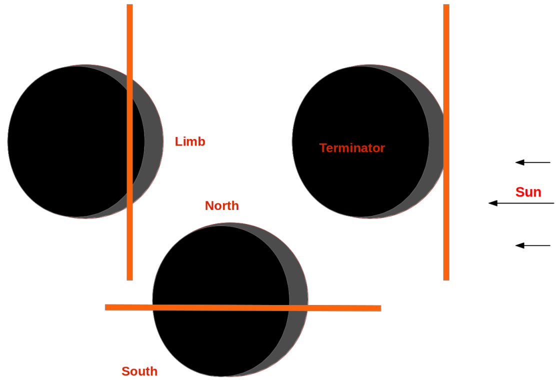


Figure: Energy level schematic for atomic sodium(Brown and Yung, 1976).

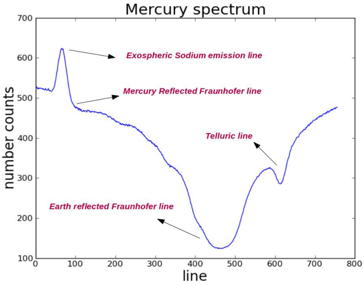
Observations

- Observations conducted with the 2.7 m telescope at the McDonald Observatory and a Cross Dispersed Echelle Spectrograph.
- Three days of observations: September 28, 29 and 30, 2009.

Figure: Slit orientation on the days of observations.



- Data reduction are written with IRAF CL scripts and Python programing language.
- Standard corrections: bias removal, comsic ray correction, flatfielding.



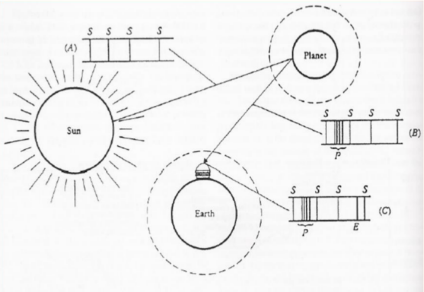
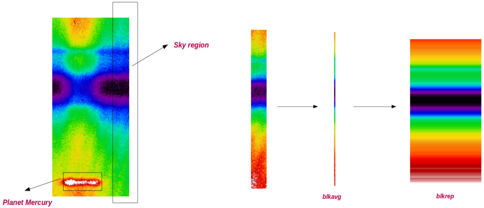
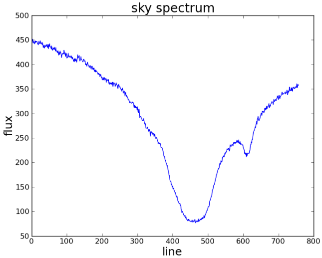


Figure: The different spectral features of the flatfielded images

Data reduction - Sky Subtraction

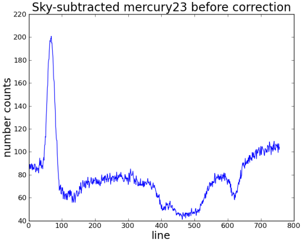
- Trim the sky from the end of the slit, and subtract it from the original spectrum

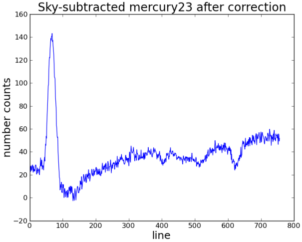




Data reduction - Illumination correction

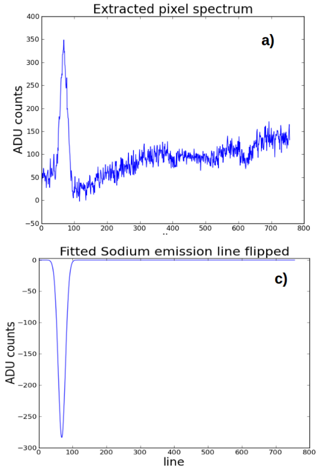
- Correction of the flatfield to account for the bad slit illumination.



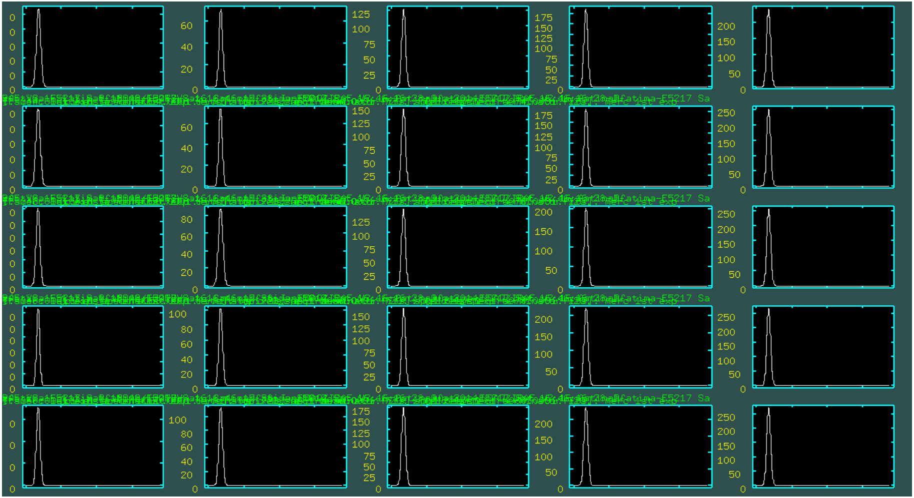


- Subtract the solar Fraunhofer line and extract the integrated line fluxes from the sodium lines in all the pixels along the slit.

Data reduction - Sodium Line Extraction



Data reduction - Sodium Line Extraction

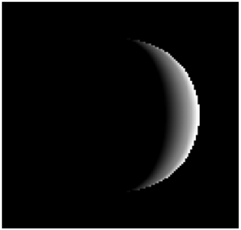


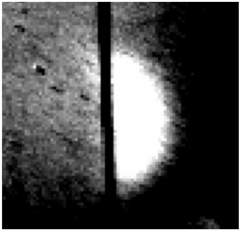
Data reduction - Flux Calibration

- The intensities were obtained in ADU units.
- No standard stars!
- The surface of the planet can be used as a standard calibration source:
- Calibration factor is needed:

$$calfac = \frac{Theoretical\ continuum\ flux_{max}}{Observed\ continuum\ flux_{max}} \quad (1)$$

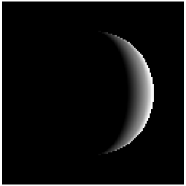
- SEEING!!!

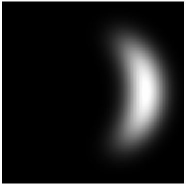




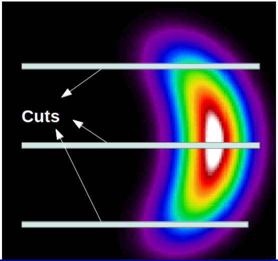
Data reduction - Flux Calibration

- Hapke reflectance model is convolved with gaussians of different widths.

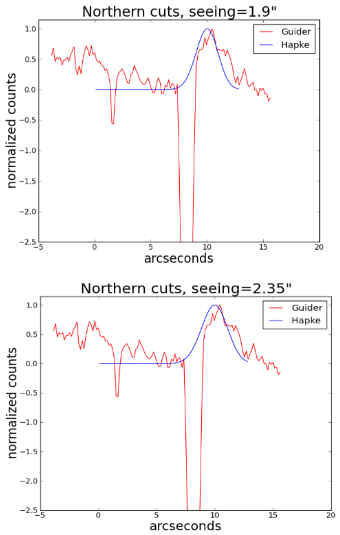




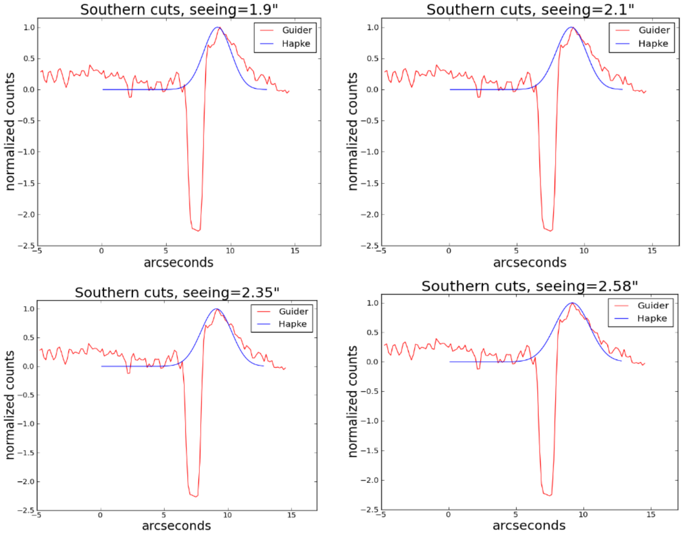
- Convolved profiles are compared to the observed ones.
- Seeing estimated from the best fit.

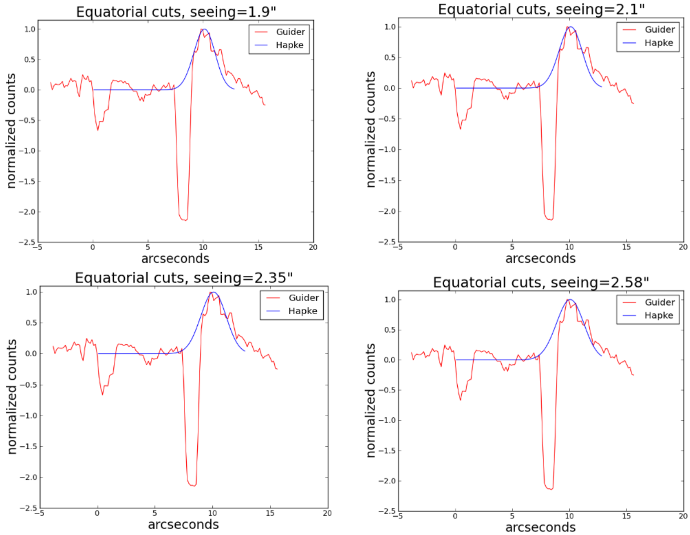


Data reduction - Flux Calibration



Data reduction - Flux Calibration




Equatorial cuts, seeing=1.9"
Guider
Hapke
normalized counts
arcseconds
Equatorial cuts, seeing=2.1"
Guider
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Equatorial cuts, seeing=2.35"
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Equatorial cuts, seeing=2.58"
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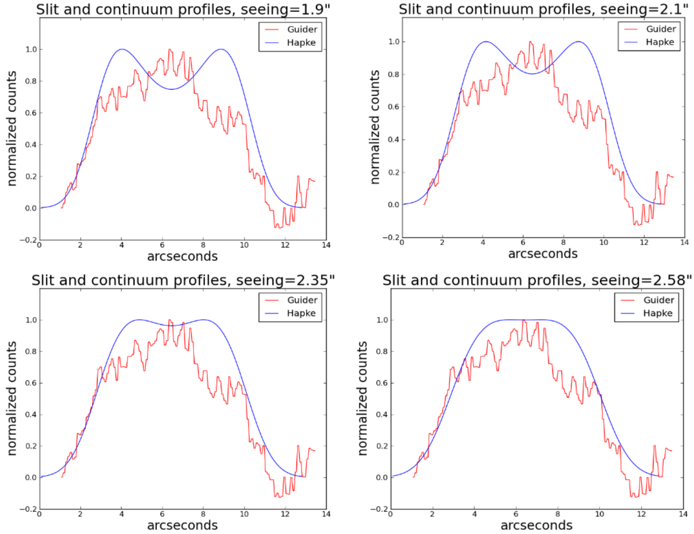
arcseconds

Data reduction - Flux Calibration



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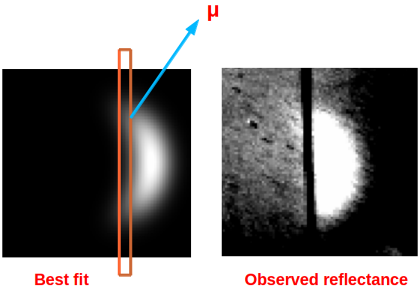

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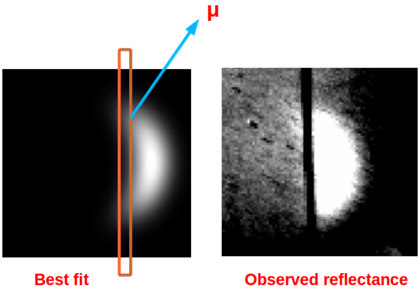
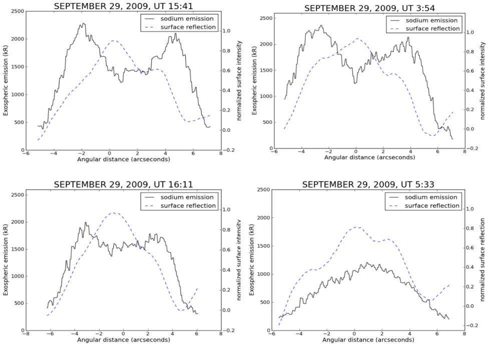


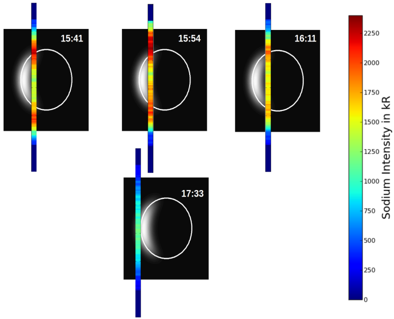
$$calfac = 4\pi \, \frac{\mu \times F_{1AU} \times dispersion}{R^2} \times \frac{1}{Cont_{max}} \quad [kR.counts^{-1}] \qquad (2)$$

$$I(Na)_{kR} = calfac \; I(Na)_{ADU} \qquad (3)$$

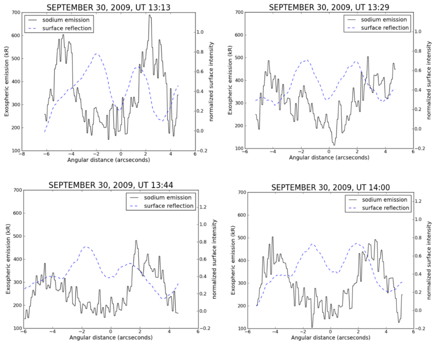
$$1 \quad Rayleigh = \frac{10^6}{4\pi} \; photons \; cm^{-2} \; s^{-1} \; sr^{-1} \qquad (4)$$

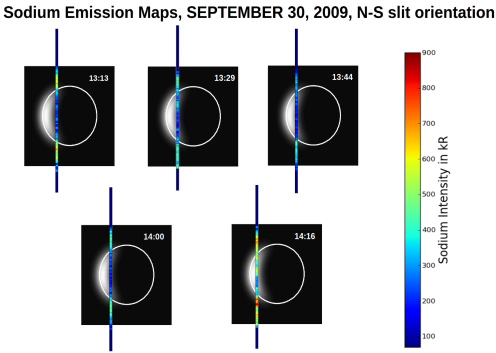


Sodium Emission Maps, SEPTEMBER 29, 2009



Results - Asymmetries & Variabilities





Results - Asymmetries & Variabilities

- Potter and Morgan, 1990
- Sprague. 1992
- Sprague et al. 1990, 1997
- Leblanc and Johnson(2003)

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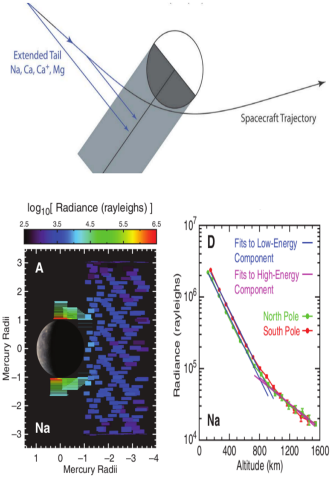
  $\Rightarrow$ Sputtering by solar wind particles yields the high altitude excesses!



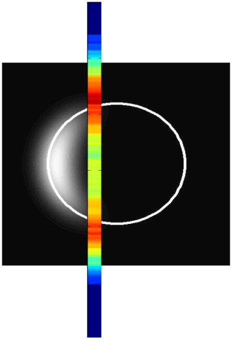
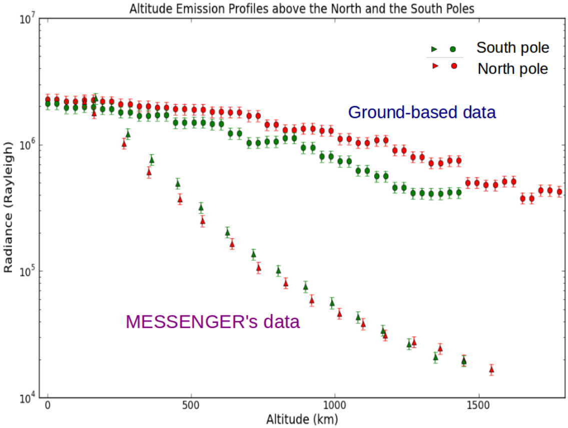
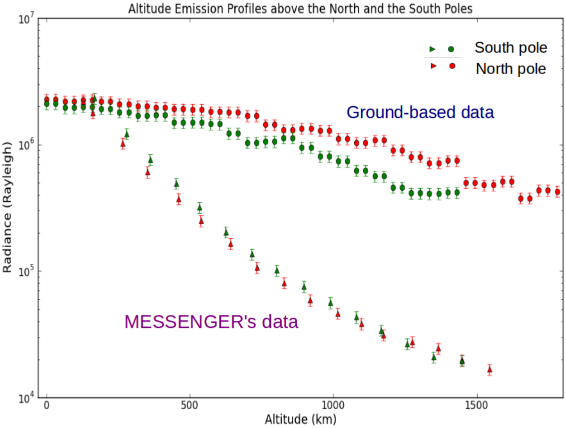


Figure: Altitude profiles from MESSENGER observations (vervack et al.(2009)); Generated sodium emission map.

Ground-based and space observations

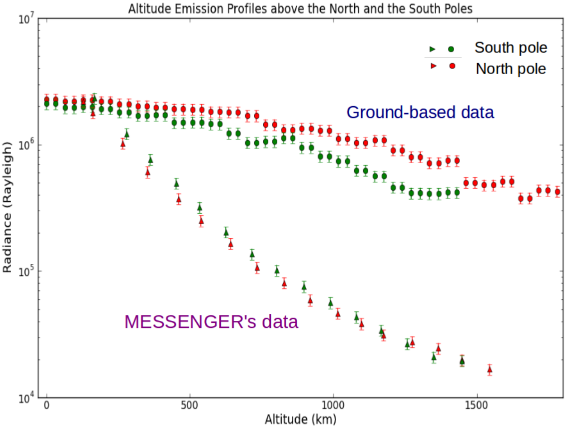


Ground-based and space observations



- Seeing contribution?

Ground-based and space observations



- Seeing contribution?
- Geometry of observations?

Future research

- Develop models (for both space and ground-based data) to better understand the processes responsible for the observed distribution.
- Doppler shift measurements and upper limits on flow velocity of sodium atoms to explain the UVVS data.


Thank you!
FG (simple) G band 4305 1024 1024 2006/11/08 19:15:00