Comparing Observations of the Abundance of Sodium in Mercury’s Exosphere

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**Motivation**

- Mercury is highly vulnerable to the Sun
  - Its exosphere is most likely dependent on the amount of radiation the planet receives
- MESSENGER is one of the first satellites to obtain data about the exosphere from orbit
- We can compare this new data to ground based data to see if there are any corresponding trends
- Discovering how the exosphere is influenced by the Sun can give us an insight into:
  - The chemical composition of Mercury
  - How the planet might have formed
  - How our Solar System might have formed
  - What other planets might be like in other systems at similar distances as Mercury is from the Sun
OUTLINE

- Background on Mercury and the solar influence on its exosphere
- Variables of interest
- Observations from Earth
- Observations from MESSENGER
- Comparison of the two data sets
- Observed trends
Mercury

- General Facts
  - Smallest planet, 6% Earth
  - 1 year = 88 Earth days
  - 1 day = 176 Earth days
  - Highly eccentric orbit
  - Magnetic field present
  - Virtually no atmosphere

- Highly influenced by the Sun
  - High energy particle collisions
  - Radiation pressure
MERURY’S ATMOSPHERE

- No sustainable atmosphere
- Thin Exosphere
  - H, He, O, Ca, Mg, K Na
  - Resembles comet tail
- Source of Exosphere
  - Sputtering
  - PSD
  - Thermal Evaporation
  - Impact evaporation
**Determine Solar Influence by Variation in Observed Na**

- Search for increase in Na density:
  - D1 and D2 (yellow) spectrum 580 nm
- How does it change with respect to:
  - Time of Day
  - Change of season
GROUND BASED OBSERVATION METHOD

Observation Slit
SPRAGUE ET AL. OBSERVATIONS

Sprague et al. 1997

- Sprague et al.’s conclusions:
  - Na column density varies with local time
  - Did not account for True Anomaly
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<th>Phase Angle</th>
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<th>Heliocentric Distance (km)</th>
<th>Slit Rot. (°)</th>
<th>Epoch</th>
<th>Dec (°)</th>
<th>g02</th>
<th>g01</th>
<th>Total Rad. Accel. (au/s²)</th>
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**Sprague et al. 1997**

**Physical and Geometric Parameters for Mercury Observations**

**UT Date**

**Frame #**

**UT Time**

**Alt Mass**

**Slit Offset**

**Phase Angle**

**Heliocentric Distance (au)**

**Heliocentric Distance (km)**

**Slit Rot. (°)**

**Epoch**

**Dec (°)**

**g02**

**g01**

**Total Rad. Accel. (au/s²)**

**Total Rad. Accel. (km/s²)**

**Sub-Earth Long. Time**

**Sub-Earth Lat.**

**Sub-Solar Long. Time**

**Solar Activity**

**Helioc. Mag.**

**Flux at Mercury**

**Calibration Factor**

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**Note:** The table above represents physical and geometric parameters for Mercury observations as documented in Sprague et al. 1997. The parameters include UT Date, Frame #, UT Time, Alt Mass, Slit Offset, Phase Angle, Heliocentric Distance (au), Heliocentric Distance (km), Slit Rot. (°), Epoch, Dec (°), g02, g01, Total Rad. Accel. (au/s²), Total Rad. Accel. (km/s²), Sub-Earth Long. Time, Sub-Earth Lat., Sub-Solar Long. Time, Solar Activity, Helioc. Mag., Flux at Mercury, and Calibration Factor.
**Determine Local Time**

\[
Local \ Time = \text{Mod} \left\{ \left[ \text{Subsolar Point} - \left( \text{SubEarth Point} + \arcsin \left( \frac{-x}{\sqrt{1 - y^2}} \right) \right) \right] \times \frac{24}{360} + 12.24 \right\}
\]
Column Density (cm$^{-2}$)

Na Density vs Local Time

Local Time (hrs)
NEW PARAMETERS OF INTEREST

- True Anomaly
  - Used to determine seasonal variability of Na density
Na Column Density vs TA

Column Density (cm$^{-2}$)

True Anomaly (deg)
The MESSENGER Mission

- Takes vertical profile scans of Mercury’s exosphere
- Uses UVVS
- Records Na Column density for:
  - Local time
  - Seasonal variability
- 8 Mercury years of data (2 Earth years)
COMPETING FACTORS

- **Sunlight Exposure vs Radiation Pressure**
  - Greater photon intensity closer to the sunlight means more Na vaporization, but…
  - Being closer to the sun means more radiation pressure that disperses the exosphere

![Diagram showing the relationship between sunlight exposure and radiation pressure with True Anomaly values of 0° and 180°, indicating low and high intensity and pressure states.](image-url)
CONCLUSIONS

- Increases in Na density depends on:
  - True Anomaly
  - Local time
- Both ground based and MESSENGER data are same order of magnitude
- Overall: Data show similar trends!
**Future Work**

- Conduct an analysis of outliers in Sprague data
  - Attempt to account for difference in D1 and D2 spectra
- Compare to other ground based data that used different observation techniques
  - Potter et al.
REFERENCES AND IMAGES

- Image slide 1: http://nssdc.gsfc.nasa.gov/image/spacecraft/messenger.jpg
- Images slide 4:
  - http://www.8planets.co.uk/wp-content/themes/8planets/images/moon_surface_apollo_11_lg.jpg
  - http://undsci.berkeley.edu/images/us101/mercury.gif
- Image slide 5:
- Image slide 5:
  - http://upload.wikimedia.org/wikipedia/commons/2/2f/Fraunhofer_lines.svg
REFERENCES AND IMAGES CONT.

- Image slide 14: Cassidy, Timothy. PowerPoint presentation