Photoionization Loss of Mercury's Sodium Exosphere Measured by MESSENGER and THEMIS

National Aeronautics and Space Administration

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Summary

- Using MESSENGER **UVVS**, and ground observations from the **THEMIS** telescope we estimate how much of the sodium exosphere is lost by photoionization during Mercury's eccentric orbit around the Sun.
- We compare the estimated exospheric sodium loss (i.e. sodium ion production) to Na^+ measurements made by MESSENGER's Fast-Imaging Plasma Spectrometer (**FIPS**).
- **Peak loss rates of 3×10^{24} atoms/s to the exosphere occur at perihelion (0º TAA).**

Why is this Important?

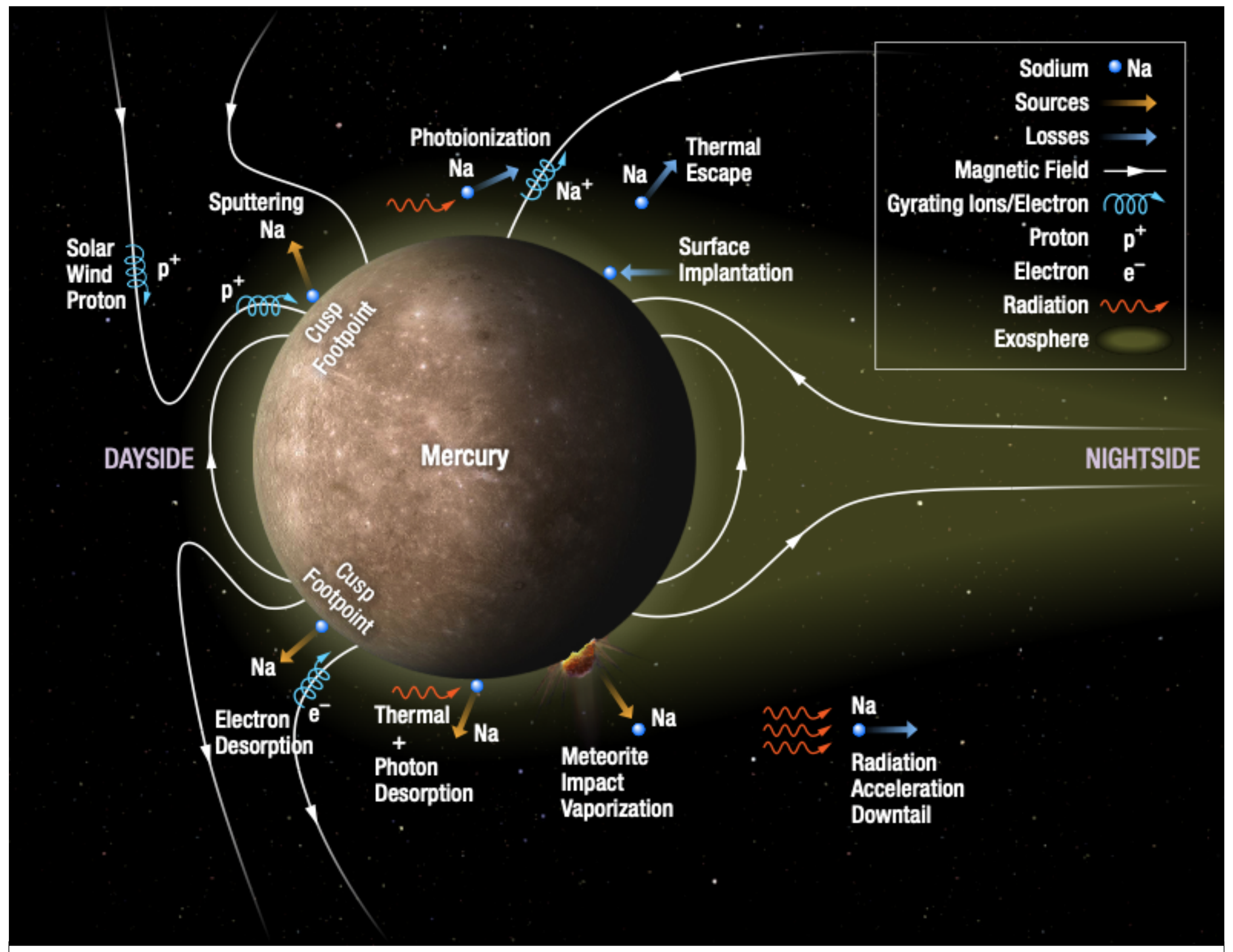

Figure 1. A schematic showing the various exospheric source and loss processes at Mercury.

- Photoionization is one of many loss or source processes at the exosphere at Mercury (Figure 1). It is vital to understand each process to understand the temporal and spatial variability, and the dynamics of the exosphere.

Observations

- MESSENGER Na^+ observations at Mercury's cusp show how Na^+ content varies with season.
- Calculation from observations of how much Na is photoionized to make Na+ in the exosphere: from MESSENGER UVVS (black), THEMIS (blue) using measurements of neutral sodium content on the dayside (in comparison to Na^+ FIPS data red and grey).
- UVVS observations (blue) of neutral sodium emission of sodium lost downtail on the nightside due to radiation acceleration – as well a model fit.

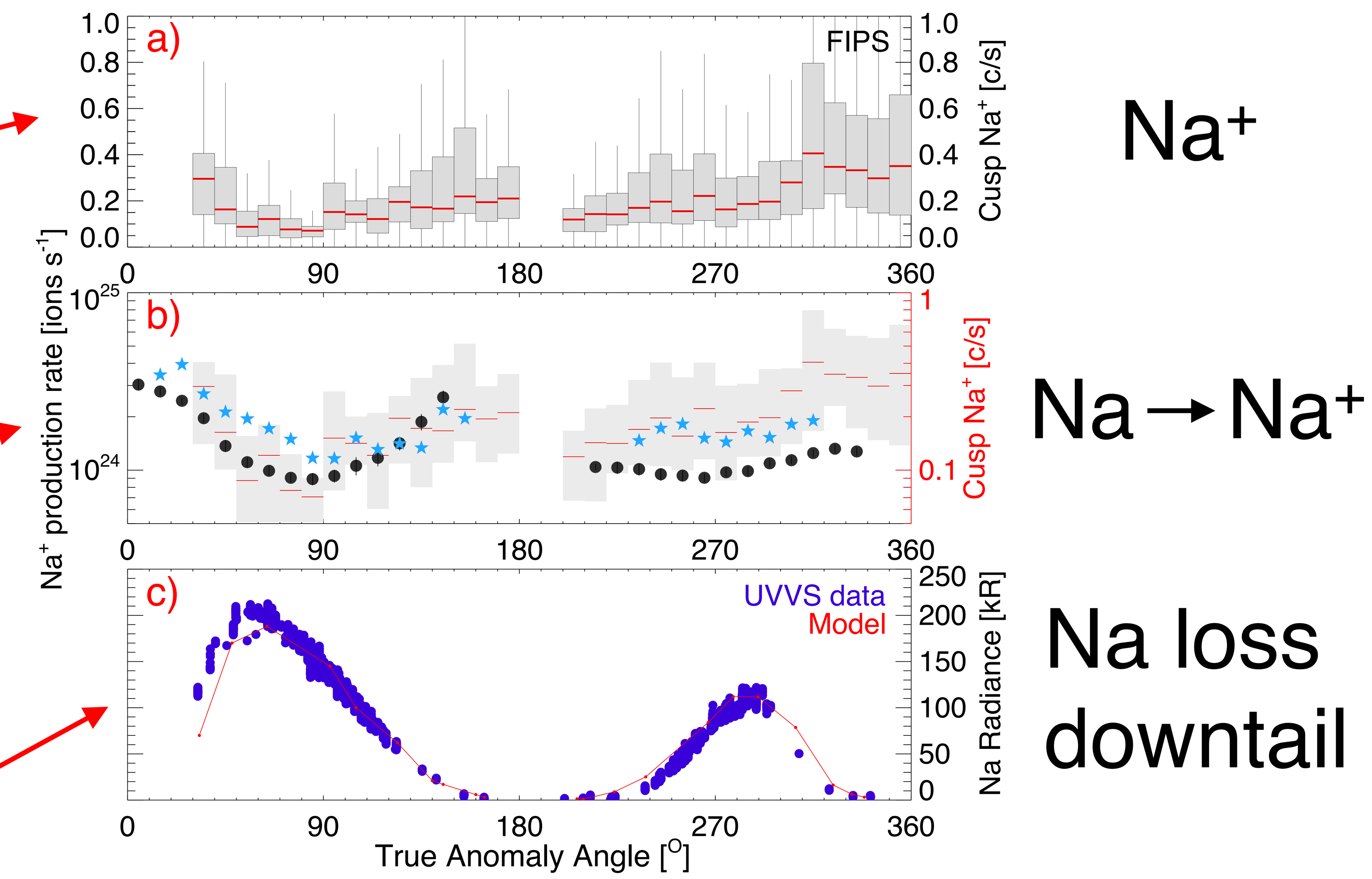

Figure 3. Sodium dependence on TAA. a) FIPS observed Na^+ count rate in the cusp binned in 10º TAA bins, b) shows the total dayside mass-loading calculated from measurements c) UVVS observed nightside emission at midnight local time at 0.25 R_M above Mercury's surface (blue) and a model of nightside emission fit to the data (red).

What does this mean?

a) Seasonal trend of Na^+ is dependent on photoionization of the variable neutral exosphere. Daily variation of Na^+ (i.e. variability in a TAA bin) is due to magnetosphere-exosphere coupling.

b) Plasma observations are correlated to neutral observations. Neutral variability due to radiation acceleration results in the number of Na^+ in the magnetosphere (i.e. if there is less neutral in the exosphere, then there is less atoms to photoionize).

c) Observations at high altitude on the nightside show that more neutral sodium is lost downtail due to radiation acceleration at 0-180º TAA, in comparison to 180-360º TAA. This is because there is an acceleration feedback loop when the planet is travelling away from the Sun (at 0-180º). We therefore observe much less ions at 60º.

Implications:

A peak exospheric loss rate due to photoionization of 3×10^{24} atoms/s is larger than peak loss of neutral Na due to radiation acceleration of 1×10^{24} atoms/s (Schmidt et al., 2010).

Peak photoionization loss rate would result in the total eradication of the dayside exosphere within ~4 hours (if other processes are "switched off"). This means photoionization is a significant loss process that is balanced by other source processes.

Modeling tends to underestimate the importance of photoionization: Leblanc and Johnson (2003) modeled the exosphere and found an exospheric loss rate due to photoionization of 3.5×10^{23} atoms s^{-1}, **10x less** than our maximum estimate from observations and **2.5x less** than our minimum estimate.