EPSC Abstracts
Vol. 5, EPSC2010-373, 2010
European Planetary Science Congress 2010

MESSENGER Observations of Mercury's Exosphere

Matthew H. Burger (1,2), Rosemary M. Killen (1), Ronald J. Vervack, Jr. (3), William E. McClintock (4), Nelly Mouawad (5), Ann L. Sprague (6)

(1) Planetary Magnetospheres Laboratory, Solar System Exploration Division, NASA/Goddard Space Flight Center, Greenbelt, MD 20771, USA (2) Goddard Earth Sciences & Technology Center, University of Maryland, Baltimore County, Baltimore, MD 21228, USA (3) The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA (4) Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO 80303, USA (5) Department of Astronomy, University of Maryland, College Park, MD 20742, USA (6) Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721, USA. (Matthew.H.Burger@nasa.gov)

Abstract

Sodium, calcium, and magnesium have been observed in Mercury's exosphere during three flybys by the MESSENGER spacecraft. Each species shows a distinct spatial distribution, pointing to differences in the source and transport processes responsible for ejecting each exospheric component from the surface. We will present the observations of Mercury's neutral exosphere and highlight temporal variations and differences between the three observed species. We will also discuss the modeling effort that has been undertaken to understand the neutral sources.

1. Introduction

Mercury is surrounded by a surface-bounded exosphere known to contain hydrogen, helium, sodium, potassium, calcium, magnesium, and possibly oxygen. Mg was discovered during the second encounter of Mercury by the Mercury Atmospheric and Surface Composition Spectrometer (MASCS) on the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft [1]. We present observations of Mg during the second and third Mercury flybys (M2 and M3), and observations of sodium and calcium made on all three flybys. [2, 1, 3]. We have also developed a model of the exosphere to understand the observations. This model has been used to simulate the sodium exosphere during the first (M1) and second flybys [4, 5] We summarize their findings and discuss potential sources of exospheric neutrals.

2. Observations

Line emission due to resonant scattering of solar radiation was observed by the Ultraviolet and Visible Spectrometer (UVVS) component of the MASCS instrument. Emission features of Mg at 285.2 nm, Ca at 422.7 nm, and Na at 589.1 and 589.7 nm were measured spectroscopically. During M1 and M2 the observations we use were divided into two primary phases: On the approach to Mercury, MASCS scanned the tail region anti-sunward of the planet between $\sim$ 2 and 8 Mercury radii (R_M, where 1 R_M= 2440 km). The tail is formed by radiation pressure on atoms ejected from Mercury's surface. Differences in Mercury's position in its orbit between M1/M2 (which occurred at similar true anomalies) and M3 produced large changes in the radial extent of the Na tail (Figure 1).

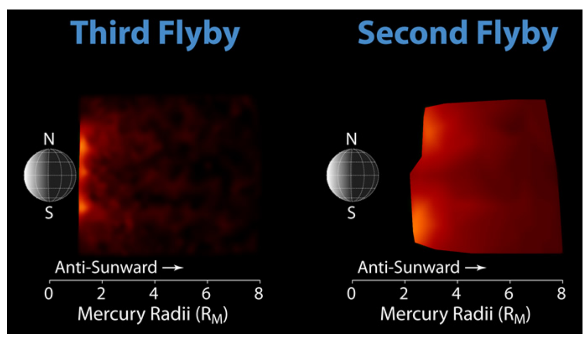

Figure 1: Comparison of sodium emission during M2 and M3 in the tail region. The scale for the M3 image is stretched by a factor of five relative to M2.

The second phase of the observations, designated the "fantail," occurred as MESSENGER passed through Mercury's shadow near the closest approach to the planet. The spacecraft executed a roll maneuver that allowed MASCS to measure latitudinal variations in the exosphere (Figure 2). The distributions of Na, Mg, and Ca showed significant differences in intensity and morphology, implying differences in the regions of the surface from which the material was derived and the mechanisms responsible for supplying each species to the exosphere.

During the third flyby an additional set of data was obtained: the vertical distribution of each species was mapped over the poles. As in the fantail, the morphology and brightness of each species varied independently and provided evidence of both individual source processes for each exospheric constituent and multiple source processes for each species [3].

3. Exospheric Modeling

We have developed a Monte Carlo model of Mercury's exosphere to track the trajectories of neutrals ejected from the surface until they are photo-ionized, escape from the system, or stick to the surface. This model has been used to understand the sources of sodium during M1 and M2 using both the MASCS data and ground-based observations [4, 5].

This work has found that the primary source of sodium in the tail region is photon-stimulated desorption (PSD) of Na atoms from the top few nanolayers of the regolith. On the dayside, Na is rapidly depleted due to the high UV photon flux; however, ion precipitation in regions of the surface open to the solar wind increases the diffusion rate of Na from the interiors of grains to their surfaces such that more sodium is available for photo-desorption. This produces an increased flux of sodium at high latitudes which was detected by MASCS during the fantail observations (Figure 2). During M1, [5] made ground-based observations of the dayside simultaneous with the MASCS observations of the sunlit portion of the anti-sunward tail. These complementary observations have allowed us to further constrain the sodium source rate and understand the interaction between exospheric sodium atoms and the surface. In addition, we have placed an upper limit on the impact vaporization rate that is comparable previous estimates [6, 7].

4. Summary and Conclusions

Even before beginning the orbital phase of its mission, MESSENGER has transformed our understanding of Mercury's exosphere. The three flybys have highlighted the exosphere's non-uniform nature: MASCS has observed temporal variability, spatial inhomogeneities in the surface flux, differences between exospheric species, and multiple source processes contributing to the production of single species. This has demonstrated the need for increased modeling effort to interpret the wealth of data anticipated after MESSENGER's orbital insertion.

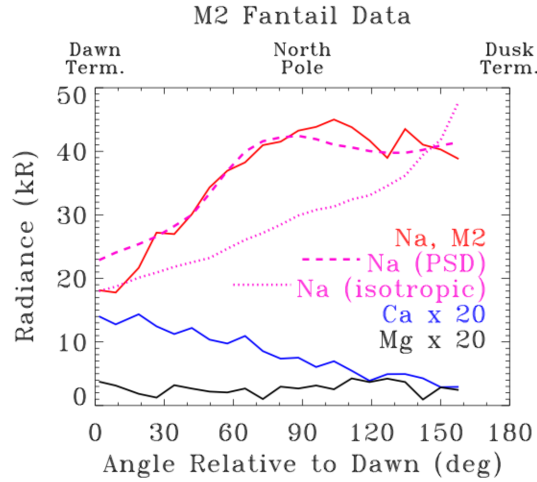

Figure 2: Comparison of Na (red), Ca (blue), and Mg (black) observations during M2. The magenta lines show model simulations of the Na exosphere. The dotted line indicates an isotropic sodium source. The dashed line shows a PSD source with the flux enhanced at high latitudes by ion precipitation.

References

[1] McClintock, W.E. et al.: MESSENGER observations of Mercury's exosphere: Detection of magnesium and distribution of constituents, Science, Vol. 324, pp. 610-613, 2009.

[2] McClintock, W.E. et al.: Mercury's exosphere: Observations during MESSENGER's first Mercury flyby, Science, Vol. 321, pp. 92-94, 2008.

[3] Vervack, R.J. et al.: Mercury's complex exosphere: Results from MESSENGER's third flyby, Science, in press, 2010.

[4] Burger, M.H. et al.: Monte Carlo modeling of sodium in Mercury's exosphere during the first two MESSENGER flybys, Icarus, in press, 2010.

[5] Mouawad, N. et al.: Constraints on Mercury's Na exosphere: Combined MESSENGER and ground-based data, Icarus, submitted, 2010.

[6] Morgan, T.H., Zook, H.A., Potter, A.E.: Impact-driven supply of sodium and potassium to the atmosphere of Mercury, Icarus, Vol. 75, pp. 156-170, 1988.

[7] Cintala, M.J.: Impact-induced thermal effects in the lunar and Mercurian regoliths. J. Geophys. Res., Vol. 97, pp. 947-973, 1992.