MESSENGER OBSERVATIONS OF MERCURY'S EXOSPHERE: DISCOVERIES AND SURPRISES FROM THE FIRST TWO FLYBYS. Ronald J. Vervack, Jr.[1], William E. McClintock[2], E. Todd Bradley[3], Rosemary M. Killen[4], Ann L. Sprague[5], Nelly Mouawad[4], Noam R. Izenberg[1], Mark C. Kochte[1], and Mark R. Lankton[2], [1]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723 (Ron.Vervack@jhuapl.edu); [2]Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO 80303; [3]Dept. of Physics, University of Central Florida, Orlando, FL 32816; [4]Dept. of Astronomy, University of Maryland, College Park, MD 20742; [5]Lunar and Planetary Laboratory, The University of Arizona, Tucson, AZ 85721.

Introduction: During the first two MESSENGER [1] flybys of Mercury, the UltraViolet and Visible Spectrometer (UVVS) channel of the Mercury Atmospheric and Surface Composition Spectrometer [2] (MASCS) conducted numerous observations of Mercury's exosphere. Previous observations made from both Mariner 10 [3–5] and ground-based telescopes [e.g., 5–10] have shown the existence of a tenuous exosphere that is highly variable on both spatial and temporal scales. Simultaneous, high-spatial-resolution measurements of several species made by the MASCS/UVVS during two flybys of Mercury by the MESSENGER spacecraft have provided an unprecedented glimpse into the structure of the exosphere and the processes behind it. Of particular note are the first detections of neutral magnesium, a species long predicted to be a significant component of the surface.

MESSENGER Observations: The workhorse on MESSENGER for measuring the distribution of neutral species in Mercury's exosphere is the UVVS component of the MASCS instrument. It is a scanning grating monochromator with three spectral channels — far-ultraviolet (FUV: 115-190 nm), mid-ultraviolet (MUV: 160-320 nm), and visible (VIS: 250-600 nm) — that provide a spectral resolution varying from 0.2 nm at UV wavelengths to 0.5 nm at visible wavelengths [2]. The instrument is equipped with a two-position aperture that subtends either 0.04°×1° or 0.04°× 0.05°. Its field of view and spectral resolution enable excellent observations of Mercury's exospheric emissions on both spatial and spectral scales.

The MESSENGER trajectories during the first two Mercury flybys and the UVVS observations in each case are illustrated in Figure 1. Observations occurred in four more or less distinct regions: (1) extended tail, (2) nightside (the "fantail"), (3) near dawn terminator, and (4) dayside.

During the extended tail observations on the inbound part of the trajectory, the UVVS line of sight was rocked back and forth about the Sun-Mercury line, sweeping out a region of space that is approximately three planet diameters tall. During both flybys, successful observations in the extended tail were obtained of the sodium (Na) doublet emission at 589.0/589.6 nm, whereas additional observations of emission by magnesium (Mg) at 285.2 nm and by calcium (Ca) at 422.7 nm were obtained during the second flyby.

Figure 2 compares the Na emission from the two flybys. In the tail these emissions exhibit a distinct high-latitude enhancement relative to the equatorial regions. Similar enhancements have been seen in ground-based observations of Na [11]. It is interesting to note that the overall emission at the northern latitudes is

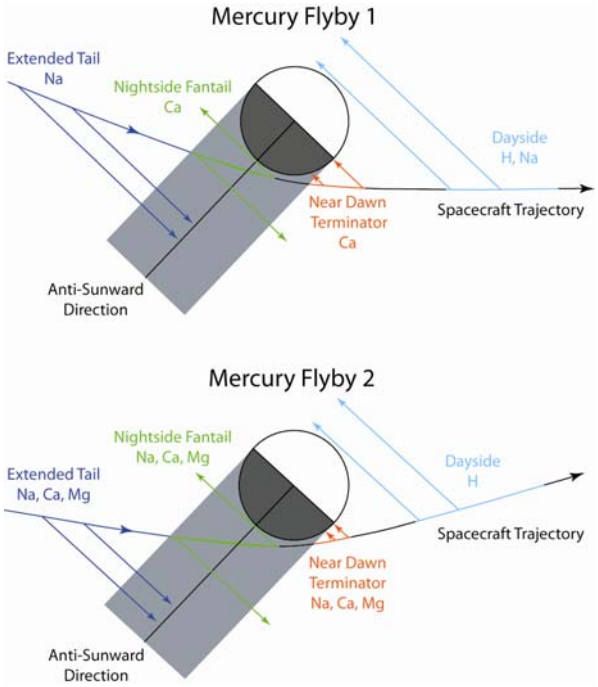

Figure 1. Illustration of the MASCS/UVVS observations during MESSENGER's first and second Mercury flybys. The spacecraft is moving from left to right in both flybys, and the view is looking down from the north. The four observation regions described in the text are indicated by color: extended tail (blue), nightside fantail (green), near dawn terminator (red), and dayside (cyan). The species observed in each region during each flyby are shown. Arrows indicate the line-of-sight direction for the observations. For the nightside fantail, observations start looking toward the dawn hemisphere and finish looking toward the dusk hemisphere. Black portions of the spacecraft trajectory are regions of no exospheric observations.

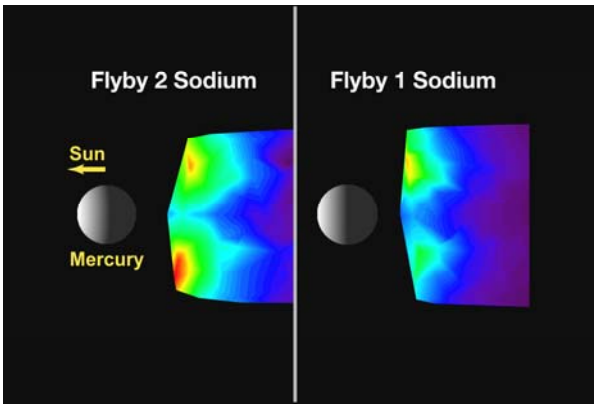

Figure 2. Comparison of Na emission in the extended tail region during MESSENGER's first and second Mercury flybys.

stronger relative to the south in the first flyby, whereas in the second flyby it is roughly the same in both the north and the south. These high-latitude enhancements are likely associated with variations in the solar-wind-sputtering source component of Na atoms. This result is consistent with MESSENGER magnetosphere observations, which suggest that the plasma flow during the first flyby was more focused in the north but more uniformly distributed during the second flyby [12–14].

Observations of Ca and Mg obtained simultaneously with the Na observations in the tail region during the second flyby show that the spatial distributions differ for each of the three species. In contrast to Na, Ca exhibits strong emission near the equatorial regions and less emission at higher latitudes, whereas Mg appears to be more uniformly distributed but may weakly trend with Ca.

Once the spacecraft entered Mercury's shadow, it executed a 180° roll in order to observe the daylit surface during the outbound trajectory. During this roll, the UVVS line of sight was initially pointed in the direction of the dawn hemisphere, rotated north, and finished viewing the dusk hemisphere near the equator. This roll, referred to as the fantail, provided observations of Ca emission during the first flyby and of Na, Ca, and Mg emission during the second flyby.

At the end of the fantail observations, the UVVS line of sight intersected the dark, nightside surface of the planet. As the spacecraft passed through closest approach and began its outbound leg, it emerged from Mercury's shadow. Although the line of sight still intersected the nightside surface, at least some part of the column between the spacecraft and surface was illuminated and resulted in measurable emission from Ca during the first flyby and from Na, Ca, and Mg during the second flyby. These observations continued until the line of sight crossed the dawn terminator, at which point sunlight reflected from the bright dayside disk precluded exospheric observations.

As with the tail observations, both the fantail and near-terminator observations show differing spatial distributions of Na, Ca, and Mg, including unexpected dawn-dusk asymmetries in Na and Ca that are not correlated. These distributions provide important insights into the processes that generate and maintain the exosphere.

As the spacecraft continued outbound, the UVVS line of sight moved beyond the daylit surface and exospheric observations resumed. Dayside Na and hydrogen (H, at the 121.6 nm Lyman α line) observations were conducted during both flybys. Background light scattered from the surface at Na wavelengths and background interplanetary medium emission at H wavelengths complicate the analysis of these emissions. Nevertheless, information about the dayside distribution of these two species was obtained. The H distribution in particular is consistent with the so-called "warm" component of the H distribution observed by Mariner 10 [4].

The UVVS observations are the first space-based data in over thirty years and, while they shed new light on the distribution of exospheric species, they are only two snapshots of the complicated Mercury exospheric system. A full understanding of the exosphere requires many observations spanning a variety of observing conditions such as will be provided by UVVS during the orbital phase of the MESSENGER mission.

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