MERCURY ATMOSPHERIC AND SURFACE COMPOSITION SPECTROMETER OBSERVATIONS OF THE TAIL-REGION EXOSPHERIC SPECIES OF MERCURY DURING THE FIRST MESSENGER FLYBY.

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Introduction: MESSENGER [1] will fly by Mercury for the first time on January 14, 2008, with closest approach occurring at 19:04:42 UTC. MESSENGER will approach the planet from the night side, giving opportunity to observe species in the tail region. This flyby, along with the other two Mercury flybys, offers a better opportunity to observe the extended tail region than during the mission's orbital phase.

Dynamical modeling by Ip [2] and Smyth and Marconi [3] predicted that solar radiation pressure could push exospheric sodium in an anti-sunward direction, resulting in an extended tail of material being lost from the system. This phenomenon was first confirmed by Potter et al. [4], who observed sodium up to 40,000 km behind the planet. Subsequent ground-based observations have shown the sodium tail to completely disappear at other times in the Mercury year. Varying radiation pressure with planetary true anomaly implies a modulation effect on the pressure experienced by sodium throughout the Mercury year. However, ground-based observations have shown that sodium source production rates exhibit temporal variations [5], and thus the abundance of sodium in the tail at a specific planetary true anomaly may be the result of the combination of these effects. The cross-sectional extent of the tail region is related to the component of ejection energies normal to the Mercury-Sun line and has been studied using ground-based observations [5]. Thus characterization of the tail region gives insight into loss rates and production mechanism ejection energies for exospheric species.

The MESSENGER flyby offers the opportunity to observe the tail region with emphasis on sodium and hydrogen. Furthermore, observations of calcium, sodium, potassium, and sulfur are planned while the spacecraft is in the shadow of the planet. Of these species, sulfur is the only one that has not been previously observed in the Mercury exosphere. This flyby offers the possibility of characterizing the morphology and composition of species in the tail region for a planetary true anomaly of ~ 285°, which may yield further insight concerning the contribution of solar radiation pressure to the loss rate of species from the system and possibly information concerning production processes.

Instrumentation: The Mercury Atmospheric and Surface Composition Spectrometer (MASCS) consists of two channels fed by a common telescope: an UltraViolet and Visible Spectrometer (UVVS) and a Visible and InfraRed Spectrograph (VIRS) [6]. Exospheric measurements rely exclusively on the UVVS channel. The UVVS is a scanning grating monochrometer with three detectors: Far UltraViolet (FUV), Mid UltraViolet (MUV), and VISible (VIS). The grating scans over emission lines of exospheric species, producing a spectrum as a function of grating step or wavelength. The instrument is designed with the idea of measuring photons that have been resonantly scattered by the interaction of incident solar radiation with exospheric species.

Observations: Observations during the approach are broken into two categories, where the first consist of "tail sweep" observations that look along the extended tail region of the exosphere and the second are nightside exosphere observations that occur mostly while the spacecraft is in the shadow of the planet.

The tail sweep observations consist of alternately scanning the grating across hydrogen Lyman alpha with the FUV channel and the 589.0/589.6-nm sodium doublet with the VIS channel. Sixteen grating steps are used for the Lyman alpha observations, and 18 grating steps are used to scan across the sodium doublet with 1-s integration time per grating step. The spacecraft will be rotated back-and-forth around the spacecraft-Sun vector (spacecraft Y axis), which will result in scanning up and down in the +/- Z direction in the Mercury-fixed coordinate system. These observations begin when the spacecraft is ~ 24,000 km from Mercury along the Mercury-Sun line and end just as MESSENGER is beginning to enter the shadow of the planet at a distance of ~ 1800 km from Mercury along the Mercury-Sun line. Figure 1 shows the scan pattern of the instrument boresight as viewed from the spacecraft and projected in the plane defined by the Mercury-Sun vector and the Mercury Z axis. The extent of the coverage in the cross section of the tail region is ~ 3 Mercury diameters. Superimposed on the scan pattern are the projected fields of view for the sodium observations, which are over the 18 seconds needed to scan across the sodium doublet. The length of the projected field of view in the Mercury-Sun direction is primarily determined by the distance of the spacecraft from the plane. The height of the field of view is determined mostly by the raster scan rate in conjunction with the distance of the spacecraft from the plane. The spatial resolution of an observation ranges from ~ 900 to 40 km along the length of the tail at the beginning and end of the tail sweep observations, respectively. Typical spatial resolution along the Mercury Z axis direction is > 1000 km for scans crossing the Mercury-Sun line and < 100 km at the extreme raster scan ranges.

Nightside observations consist of looking for sulfur, sodium, calcium, and potassium by scanning the grating consecutively over each of the lines. For each line, 16 grating steps are used with an integration time of 0.25 s per grating step, giving a total time to complete the grating scan over all 4 lines of ~ 16 s. These observations occur for altitudes from ~ 500 km above the planet surface and continue down to the surface of the planet. The projected field of view for a grating scan over a single species is ~ 10 km in length along the Mercury-Sun line and a maximum height in the Mercury Z axis direction of ~ 5 km.

Detection limits: Detection limits may be determined in order to set an upper limit for each species. The detection limit may be calculated with a specified SNR and noise. The off-axis angle, which is calculated as the angle between the MASCS UVVS boresight and a vector from MASCS to the terminator, is > 25°, implying a minor contribution to the signal from the solar continuum reflected from the dayside of the planet. Therefore the background counts arise primarily from detector dark counts. The detection limit is calculated by specifying an SNR and estimating the noise as the Poisson noise from the signal and the detector dark counts. The detection limit in counts is converted to the detection limit in Rayleighs by dividing by the radiometric sensitivity. Table 1 shows the predicted detection limit for each of the planned observations for an SNR = 5. The column abundances are determined with the assumption that the species are optically thin and will be different if the species are optically thick.

Conclusions: This flyby will produce the first in situ observations of sodium, calcium, potassium, and sulfur. Furthermore, the observations of sodium at a planetary true anomaly = 285° are useful as another data point in the ground-based observation campaign to characterize the behavior of the sodium tail as a function of planetary true anomaly [7]. Knowledge of the composition and morphology of the tail region leads to better understanding of the loss rate of exospheric species associated with the tail region and the energy of production processes. Finally the results of these observations will be used to plan tail observations for the other two Mercury flybys.

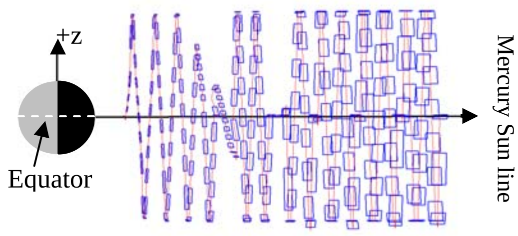

Figure 1. Projected fields of view of the UVVS atmospheric slit during the tail sweep observations. The Mercury-Sun line points anti-sunward.

Species	**Detection limit (Rayleighs)**	**Detection limit column abundance (10^6 atoms /cm^2)**
H (Lyman alpha)	169	20200
S	1015	$3.38*10^6$
Na (330 nm)	148	2000
K	149	1990
Ca	174	7.75
Na (589.0+589.6) nm	609	10.3

Table 1. Detection limits for SNR = 5 based on the integration time of the observation and the assumed detector dark counts. Column abundances are determined assuming that the species are optically thin.

References:
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