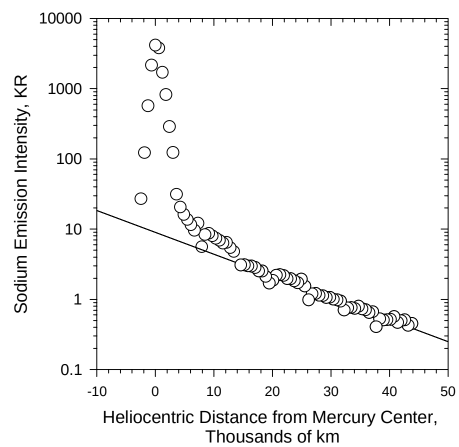
THE DISTANT SODIUM TAIL OF MERCURY. A. E. Potter[1], R.M. Killen[2], and T.H. Morgan[3], [1]National Solar Observatory, P.O. Box 26732, 950 N. Cherry Avenue, Tucson, AZ 85726-6732 apotter@noao.edu, [2]Southwest Research Institute, P.O. Drawer 28510, 6220 Culebra Road, San Antonio, TX 78228-0510, [3]NASA HQ, 300 E Street SW, Washington, DC 20546-0001.

Introduction: Models of the sodium atmosphere of Mercury predict the possible existence of a comet-like sodium tail [1,2]. Detection and mapping of the predicted sodium tail would provide quantitative data on the energy of the process that produces sodium atoms from the planetary surface. Previous efforts to detect the sodium tail by means of observations done during daylight hours have been only partially successful because scattered sunlight obscured the weak sodium emissions in the tail [3]. However, at greatest eastern elongation around the March equinox in the northern hemisphere, Mercury can be seen as an evening star in astronomical twilight. At this time, the intensity of scattered sunlight is low enough that sodium emissions as low as 500 Rayleighs can be detected.

Observations: We used the 1.6 meter McMath-Pierce Solar telescope at the National Solar Observatory, Kitt Peak, Arizona to observe Mercury after sunset against a dark sky on June 03 and 04, 2000 and again on May 24 and 25, 2001. About eight observations at various positions downstream of Mercury were possible during the 30-40 minutes that Mercury could be observed. Images of the planet or adjacent regions of the sky were placed on a 10 arc sec by 10 arc sec image slicer at the entrance slit of the stellar spectrograph. Spectra of the sodium D lines were recorded on an 800 x 800 element Texas Instruments CCD at a resolution of about 150,000. At this resolution, sodium emission from terrestrial twilight glow is clearly separated from Mercury sodium emission. The resulting spatial-spectral images were analyzed to yield a 10 arc sec by 10 arc sec images of the sodium D emission with 1 arc second pixels. The general procedure for calibration of the data and extraction of the images has been previously described [4].

Results: Sodium D_2 emission was detected along the antisunward direction from Mercury for a distance of about 40,000 km. Observations on May 25, 2001 were directed towards determining the downstream profile of the emission. The intensity of the sodium D_2 in the antisunward direction for May 25, 2001 is plotted in Figure 1.

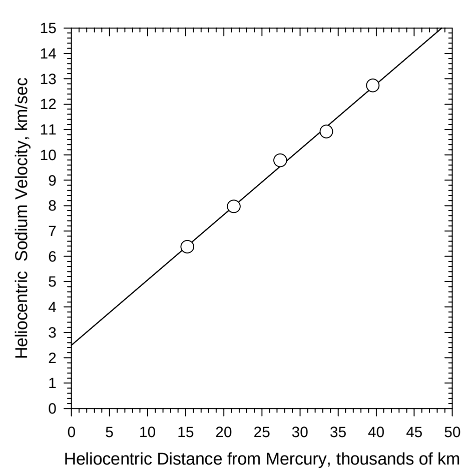
Figure 1. Emission intensity in the Mercury sodium tail, May 25, 2001



The Mercury phase angle on this date was 116.1^o, so that the sodium tail was viewed at an angle of 63.9^o to the line of sight. The observed apparent distances were divided by the sine of the phase angle to obtain heliocentric distances. The decay of sodium emission with distance results from photoionization of the sodium and lateral spreading of the sodium cloud.

Velocities of sodium atoms in the tail were measured from the Doppler shift of the emission lines. The observed shift is the vector sum of the initial Mercury-Earth shift and the additional shift resulting from solar radiation acceleration on the sodium atoms. Results are shown in Figure 2, where the heliocentric

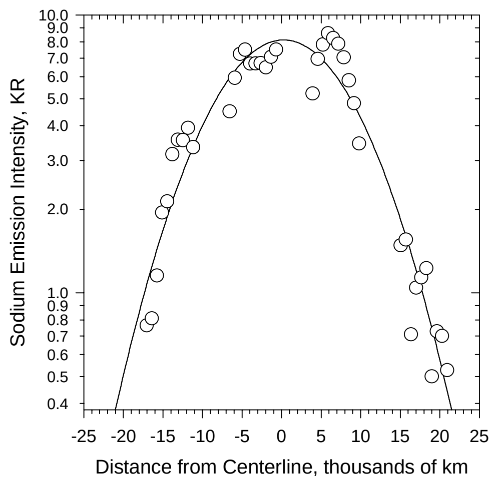
Figure 2. Heliocentric sodium velocity in the Mercury tail



velocity due to radiation acceleration is plotted against heliocentric distance.

Observations of the sodium tail were also accomplished on Jun 04, 2000. The Mercury phase angle on this date was 93.8° so that the tail was viewed at a near-right angle of 86.2°. This angle precluded the accurate measurement of heliocentric Doppler shifts in the sodium emission line caused by solar radiation pressure. However, these observations yielded information on the cross-sectional distribution of sodium in the tail. Results are shown in Figure 3, where the sodium emission intensity is plotted normal to the axis of the tail at a downstream heliocentric distance of about 17,500 km. At this distance, the tail has expanded to a diameter of nearly 40,000 km.

Figure 3. North-south cross-section of sodium tail June 04, 2000, 17,500 km downstream.



Discussion: The fact that an extended sodium tail can be detected is evidence that sodium is produced with sufficient energy to escape the planet. Smyth and Marconi [1] and Ip [2] found that sodium source velocities of 2 km/sec should be sufficient for sodium to escape from the planet under the influence of the maximum solar radiation acceleration. Extrapolation of the heliocentric velocities in the tail down to the location of Mercury suggests that sodium escaped Mercury with a residual velocity of about 2 km/sec in the antisunward direction. The north-south velocity can be estimated from the cross-sectional profile in Figure 3. If we assume that the heliocentric velocity data from Figure 2 apply to the June 04, 2000 observation, we can estimate the time required for the sodium to reach a downstream distance of 17,500 km, at which point, the cloud has expanded north-south to a diameter of about 40,000 km. From this, we estimate that the initial north-south velocity of the sodium must have been 4-5 km/sec.

Radiation acceleration of sodium atoms on June 04, 2000 was 45% of surface gravity, and on May 25, 2001 was 40% of surface gravity. In both cases, the escape velocity of sodium is reduced from the nominal value of 4.25 km/sec to about 2.5 km/sec. Consequently, the appearance of a sodium tail with sodium velocities in the range 2-5 km sec implies a source velocity in the range 4-7 km/sec, or 2.5-6.0 eV. Particle sputtering is a likely candidate for production of sodium atoms at these energies. The relatively high sodium velocity at right angles to the Mercury-Sun line suggests that much of the sodium is generated at high latitudes, rather than near the equator.

References: [1] Smyth, W. H. and Marconi, M. L., (1995), *Astrophys. J., 441*, 839-864. [2] Ip, W. –H., (1986), Geophys. Res. Lett., 13, 423-426. [3] Potter, A. E. and Morgan, T. H., (1997), *Adv. Space Res., 19*, 1571. [4] Potter, A. E., Killen, R. M., and Morgan, T. H., (1999), *Planet. Space Sci., 47*, 1441-1448.