OBSERVATIONS AND MODELING OF HYDROGEN IN MERCURY'S EXOSPHERE. D. M. Hurley[1], R. J. Vervack[1], W. Pryor[2], and R. M. Killen[3], [1]Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Rd., Laurel MD 20723, USA (dana.hurley@jhuapl.edu), [2]Central Arizona College, Coolidge AZ 85128, USA, [3]NASA Goddard Space Flight Center, Greenbelt MD 20771, USA.

Introduction: Observations of Mercury's exosphere by Mariner 10 discovered emission from atomic hydrogen [1-2]. The altitude profiles revealed a two-component distribution for H, including a 420 K component at high altitudes and a 110 K component dominating below 300 km [2]. With limited data from Mariner 10, it was not clear whether the two-component distribution was a persistent feature, and the mechanism of release for these two different distributions remains unknown. Therefore, investigation of the H exosphere of Mercury by the MESSENGER mission is of great interest.

Observations: MESSENGER orbited Mercury for nearly 17 Mercury years. The Ultraviolet and Visible Spectrometer (UVVS) channel of the Mercury Atmospheric and Surface Composition Spectrometer (MASCS) instrument acquired measurements of Mercury's exosphere [3]. To assess the hydrogen content of the exosphere, UVVS observed the Lyman alpha (Ly α) line at 121.6 nm. To zeroeth order, H atoms in the exosphere scatter sunlight via a resonant transition, thus the brightness in Ly α provides the column density of H along the instrument's line of sight through the illuminated exosphere. However, important contributions also exist from scattered solar Ly α from the dayside surface of Mercury and from the background illumination by scattereing of Ly α by H atoms in the interplanetary medium (IPM) [4]. To limit the effects of the background from IPM, this analysis focuses on the inertially fixed pointing mode of observations. During these observations, the interplanetary Ly α component is relatively constant and can be measured far from the planet where planetary emission is negligible, thus the IPM can be subtracted from all of the measurments.

Fig. 1 provides the Ly α emission as a function of local solar time (LST) for all of the inertially-fixed observations. Each point shown represents the average emission at that LST over the entire mission. Sample observations exceed 100 measurements for each point. Figure 1 demonstrates that Ly α is brightest in the dayside morning quadrant with slightly lower densities in the evening dayside quadrant., and much lower densities on the nightside.

Fig. 2 shows the altitude profile derived from a set of observations. The observations are the integrated brightness along each line of sight, with the altitude representing the closest approach of the line of sight to the planet. In this profile, the instrument pointing is fixed in inertial space, therefore the background is expected to be constant. Superimposed on the data points are Chamberlain model profiles using a temperature of 400 K (red) and 100 K (blue), chosen to roughly approximate the temperatures from Mariner 10. The low altitude observations are consistent with a scale height for T=100 K. The high altitude observations match the T=400 K scale height. A model two-component exosphere with a hot and cold component is shown in green. This altitude profile is representative of the observed altitude profiles, indicating that the two temperature populations are a persistent feature in Mercury's H exosphere.

Model: We model the H exosphere of Mercury using a Monte Carlo model [5-7]. The model follows H atoms on ballistic trajectories using the equation of motion under gravity given an initial velocity and position. Radiation pressure has not been included for the simulations of H and collisions are neglected. Because the exosphere is collisionless, models for different species and sources can be run separately and can be combined afterwards to fit the data.

The initial spatial distribution of the atoms assumes that the solar wind is the source of the hydrogen. Owing to Mercury's magnetic field, the solar wind does not have access to the entire dayside of the planet. Instead, a map of the precipitation of solar wind protons [8] is used as an initial location. We ran the model for two different precipitation maps representing a northward interplanetary magnetic field (IMF) and a southward IMF. Both have greater fluxes to the morning quadrant than the evening quadrant, although the difference is more pronounced for southward IMF than northward. This anisotropic initial distribution drives the need for a Monte Carlo model rather than the Chamberlain model. The lateral motion of particles will carry them to regions where there may not be a source term. Thus a non-monotonic altitude distribution may occur.

The initial velocity of the a test particle is randomly assigned from a Maxwell-Boltzmann distribution at a selected temperature [9]. We have performed runs at 100 K, 400 K, and 1000 K. We also performed a run using a velocity distribution assuming a physical sputtering release mechanism, which is a non-thermal energetic distribution [10].

Fig. 3 provides the model output for the 100 K model assuming the northward IMF precipitation map. The map presents the zenith column density as a function of Mercury latitude and longitude, where 0° longitude is the subsolar longitude. Note that the concentrations of exospheric H is highest at mid-latitudes and on the dayside. With the northward IMF, there is a greater flux of solar wind protons to the northern hemisphere from [8] and an asymmetry between the dawn and dusk fluxes. These zenith column densities are the integrated amount of H in a radial sector. Even the cold component of the exosphere does not diverge great distances from the source region. This indicates that the H exosphere observations can be used to probe the source regions of H exosphere, presumably the precipitation of solar wind ions onto the surface of Mercury.

Analysis: We compare model output with MESSENGER observations to determine which model parameters best fit the observations and how much variation is needed between separate altitude profiles. The primary focus of the analysis is to link the source rate and spatial distribution to the data.

Conclusion: MESSENGER/UVVS detected H in the exosphere of Mercury. We assembled altitude profiles using the inertial stare data to reduce the effect of the interplanetary Ly α background. Comparing with a Monte Carlo model, we examine the temperature, spatial distribution, and source rate of the source and compare that to the expected influx of protons to Mercury from the solar wind. Initial indications are that the two-temperature profile discovered by Mariner 10 is a persistent feature of the exosphere. Further analysis will investigate the origins of the two components.

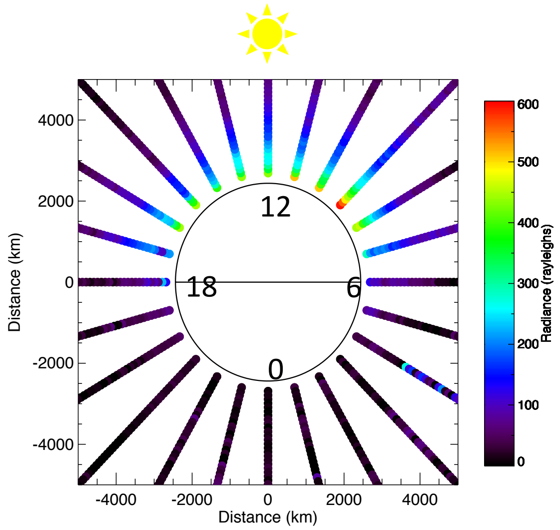

Figure 1. Average Lyman αbrightness as a function of local time at Mercury. The bright points at 4 am local time are likely the result of a star in the UVVS slit.

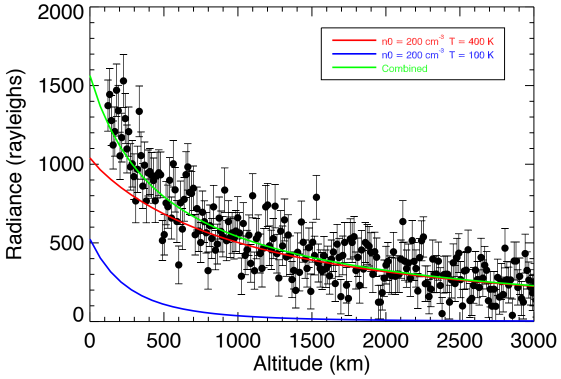

Figure 2. Altitude profile of Ly a brightness. Chamberlain model profiles are superimposed on the data for comparison.

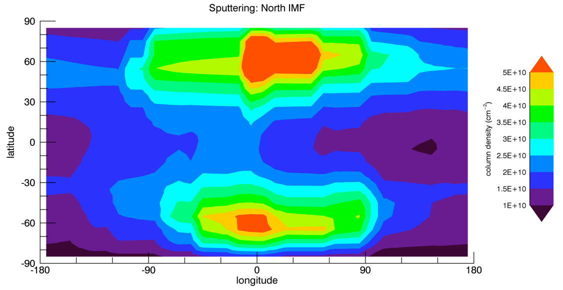

Figure 3. Model zenith column density of H for the North IMF source and 100 K release temperature.

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