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Mercury's Seasonal Sodium Exosphere

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1. Introduction

Mercury's tenuous Na exosphere was discovered in 1985, and has since been observed by a variety of Earth-based telescopes (see summary in [1]). The Mercury Atmospheric and Surface Composition Spectrometer (MASCS) UVVS (UltraViolet and Visible Spectrometer) on the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft orbiting Mercury provides the first up-close look at the Na exosphere [2]. We describe and interpret data from a subset of UVVS observations: dayside limb scans. These observations are altitude profiles of Na emission within above Mercury's dayside equatorial surface. This analysis focuses on the near-surface portion of the limb scans (within 1500km), where we were able to fit the data with a simple model.

2. Data Description and Modeling

Limb scans provide line-of-sight column density versus tangent altitude, the altitude of the line-of-sight above Mercury's limb. Fig. 1 shows an example. The line-of-sight column density is derived from Na D1 and D2 emission lines caused by resonant scattering of sunlight near 589 nm. The column density is found by dividing the radiance (in kiloRayleighs) by the "g value," the rate at which Na atoms scatter photons and then multiplying by 10^3. The g value varies throughout the Mercury year [3], depending on distance from the Sun and radial velocity between the Sun and Na atom. For the purposes of calculating g value we assume that the Na atoms are at rest relative to Mercury.

Chamberlain's expressions provide line-of-sight column density vs. altitude given two parameters: surface density and exospheric temperature.

'Temperature' refers to the kinetic energy distribution of particles launched from Mercury's surface. The model assumes that atoms are launched from Mercury's surface with a Maxwellian distribution, and that there are no collisions between atoms. The only force affecting trajectories is Mercury's gravity.

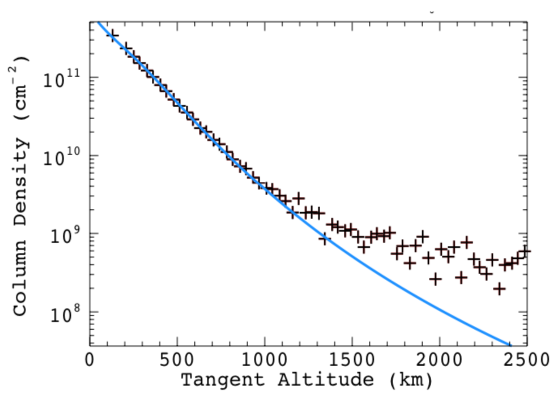

Figure 1: Dayside limb scan (altitude profile) data with Chamberlain model fit (blue) to a "cold" exosphere component. Data points above the blue line indicate a higher temperature population.

The Na exosphere is complicated by solar photon acceleration, which at its peak is about half of Mercury's surface gravitational acceleration. We account for this effect by including an additional term in the Chamberlain equations, as in [4]. The fit only considers the "cold," near-surface portion of the exosphere, which extends from the surface to 500-1500 km altitude. An example fit is shown in

Fig. 1. The fit is quite good below 1100km. Above this altitude there is a second population of more energetic atoms [2].

4. Results

Fig. 2 shows the resultant surface density as determined by the Chamberlain model fits vs. Mercury's true anomaly angle (TAA, the angular distance of Mercury from perihelion) at a local time of 10:00±1hour. The results come from four Mercury years of data (different years are indicated by different colors). There is a striking year-to-year repeatability.

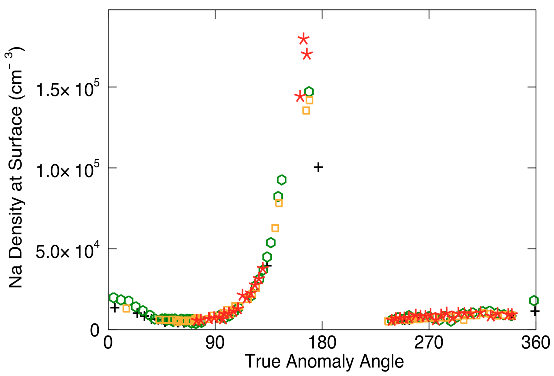

Figure 2: Estimated surface density vs true anomaly near 10:00 local time. Different colors indicate different Mercury years.

The Na density peaks near aphelion (at TAA 180°). There is a smaller peak near perihelion (0°). These maxima correspond to minima in the Na g value and solar photon acceleration. Spacecraft observational constraints are responsible for the lack of data between 180° and 230°. Other local times show similar seasonal behavior, but with small differences that indicate a non-uniform exosphere.

Temperatures from the Chamberlain model fits are shown in Fig. 3. The temperature of this "cold" portion of the dayside exosphere averages about 1150 K, with a standard deviation of about 100 K. As shown in Fig. 3, the temperature is also repeatable year-to-year.

6. Summary and Conclusions

We characterized the dayside, equatorial Na exosphere by analyzing the near-surface portion of the limb profiles (within 1500km altitude). We found that the inferred density varies seasonally, whereas the temperature remains near 1150 K.

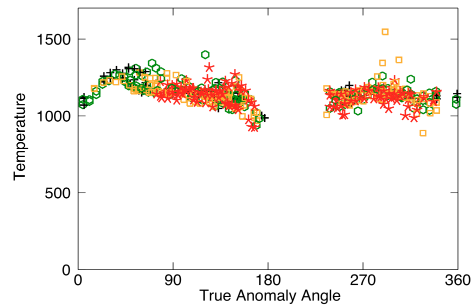

Figure 3: Exosphere temperature. Different colors indicate different Mercury years.

This temperature is consistent with laboratory measurements of photon-stimulated desorption. Ground-based observations (e.g., [1]) and UVVS data obtained while the spacecraft was looking into the exosphere from the night side of Mercury [5] suggest similar temperatures. The presence of a high-altitude hot distribution (Fig. 1) suggests that energetic processes like sputtering are also active [2]. We cannot rule out an even colder contribution from thermal desorption (<~700 K) very near Mercury's surface (<50 km altitude), where the UVVS instrument has not yet observed. The peaks in density at TAA 0° and 180° (Fig. 2) were predicted by some models [6]. These models did not, however, predict as strong a peak near 180° as observed nor the nearly uniform temperature.

References

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