Second Review of:

Mercury's Subsolar Sodium Exosphere: An ab initio Calculation to Interpret MASCS/UVVS Observations from MESSENGER

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1. The response to the referee comments are adequate except for the discussion of scale height. Actually what the authors say is correct for the true anomaly angles they calculate. However, the data that they are using, which is from Cassidy et al. (2015), are at TAA angles between 65 and 70 degrees, where the radiation pressure is maximum. In this case the radiation pressure is 50% of gravitational pressure, and the scale height is reduced to 2/3 of the no radiation pressure value. Therefore the scale height for T=594 is 39 km and the scale height for 1200 K (appropriate for PSD) is 78 km. I believe that the fit to the data is actually shallower than what is shown in the Gamborino paper, and fits the 78 km scale height quite well. This was the conclusion of Cassidy et al. (2015) and is why Cassidy et al. conclude that the data are consistent with photon-stimulated desorption.

Also note that the maximum radiation pressure is at 65° not 90° as stated by the author because of the combined influence of heliocentric distance and radial velocity caused by the ellipticity of the orbit. If the simulated scale height is 57 km as they state, then the scale height that would have been attained without radiation pressure would have been 85.5 km, consistent with a temperature of 875 K. This is too hot to be consistent with thermal vaporization.

2. I still have additional questions about the results on thermal desorption.

In order to review the results in the Gamborino paper I asked the question, what is the thermal desorption rate at the subsolar point of Mercury?

These are my calculations:

1. The adsorption time is given by

$$\tau_{ads} = \frac{1}{\nu}\exp(\frac{Q}{kT})$$

where $\nu = 10^{13}$ s^{-1}
Q= 2 eV
T= 594 K

Then $\tau_{ads} = 10^{-13} \exp(3.2 \times 10^{-12}$ erg$/(1.38 \times 10^{-16} * 594)$

$\tau_{ads} = 8.99 \times 10^{3}$ sec

The surface number density is given by

$n_{surf} = (dn/dt)\tau_{ads}$

Assume that 1/3 of the upward impact vaporization flux is lost. Then the downward flux is 2/3 Fup

The surface number density is then 2/3 Fup * 9×10^3

$n_{surf} = 8.4 \times 10^{10}$ Na cm^{-2}

This is the *adsorbed* number density on the surface, not in the exosphere.

What is the thermal desorption rate, K_{des}?

$K_{des} = A_{des} \exp(- E_{des}/kT)$

A = vibration frequency = 10^{13} s^{-1}

E=0.8 - 2.35 eV

If E=2 eV then the desorption rate (per atom) is

$K_{des} = 1.1 \times 10^{-4}$ s^{-1}

The thermal desorption rate is then:

$\phi_{therm} = n_{surf} * K_{des} = 9.3 \times 10^6$ cm^{-2} s^{-1}

 This means that the thermal desorption rate is equal to the impact vaporization rate. It turns out that this is independent of the adsorption time.

The ratio of the scale heights is
$H_{lv}/H_{therm} = 6.7$

the ratio of the number densities is

$n_{0therm}/n_{0lv} = 2.6$

If the fluxes are the same, the surface density in the exosphere at the surface has to be in the ratio of the square root of the temperatures (i.e. outward velocity). That means that there are 2.6 times as many thermal atoms at the surface than IV atoms but the scale height of the thermal atoms is 0.15 that of the IV atoms. The thermal atoms would not be seen.

3. Compare Figure 4 from Gamborino et al. with the above calculation. If the surface number density ratio of thermal to IV is 2.6 what would be the ratio of surface tangent columns?

The tangent column is proportional to the surface number density and the square root of the scale height.
The ratio of the surface number densities is 2.6, and the square root of the ratios of the scale heights is 0.385, so that the product is exactly 1.00.
That means that the surface tangent columns of the thermal sodium and the IV are the same. The thermal component would not be seen in this case. It is curious that the same result is obtained independently of the adsorption energy because the number density at the surface is inversely related to the desorption rate, limiting the thermal component.

The thermal to hot surface tangent columns in Gamborino et al. Figure 4 shows a ratio of about 250. If the adsorbed atoms are derived from the primary source (section 3.3) (e.g. Impact vaporization) then this cannot be the case. Other possibilities are that the PSD source partially thermalizes on impact with the surface (I think that Smyth came to this conclusion a long time ago.) But the other conclusion (from statement 1 above) is that the scale height of the cold component is more consistent with PSD, not thermal desorption.

4. Page 13: The number density (in the exosphere) at the surface given on Gamborino line 29 is the same as I estimated for the adsorbed surface number density (which is not the same thing).

5. It is not possible to understand the ratios of column densities in Table 2. I derived that the ratio of surface exospheric number density of thermal to IV is 2.6. The ratio of thermal to IV scale height is about 0.13, which we both agree. Therefore the ratio of the thermal column to IV column should be 0.34. Given that, the IV column would be 2×10^{10} cm^{-2}, or two orders of magnitude less than that given in table 2, column 3.

6. The other questions I have are that the column abundance given for PSD in Table 2 is greater than the maximum possible for a collisionless exosphere, and that given for SP is larger than the observed abundance. These serious questions that need to be addressed because Mercury has an exosphere, not an atmosphere.

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Referee