Ann. Geophys. Discuss.,
https://doi.org/10.5194/angeo-2018-109-AC1, 2018

Annales Geophysicae Discussions Open Access EGU

Interactive comment on "Mercury's Sodium Exosphere: An *ab initio* Calculation to Interpret MASCS/UVVS Observations from MESSENGER" *by* Diana Gamborino et al.

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Received and published: 16 November 2018

R. K. Comment:This paper concludes that thermal desorption dominates all other processes in the production of sodium in Mercury's exosphere.

Reply: Just as a remark, the former statement is only true for the specific day of observation, TAA, and observation geometry. Something we mention and discuss throughout the paper.

R. K. Comment: There are several mistakes made in coming to this conclusion. First, on page 14 the scale height of thermally desorbed atoms at the subsolar point was

listed as 57 km. However, it was already shown by Cassidy et al. (2015), and previously by Bishop, that the scale height at the subsolar point is reduced by radiation pressure by a factor of 1/ (g + mbcos(q)) which in this case is 40%. Thus the actual scale height is 40 km. The implication of this is that MASCS would never have seen these particles even if they were there because MASCS did not scan below 50 km.

Reply: Following is a table showing the different Scale Height values, H, for T=594K, m=22.99amu, TAA=158°(Rorb=0.458AU), subsolar point, g=3.703 m/s2, gr=mbcos(sza)=0.453 m/s2 (Smyth, 1986):

– Theoretical (from barometric formula, no radiation pressure): H = kBT / mg = 58 km – Theoretical + radiation pressure: H = kBT / m(g+gr) = 51.6 km – Our numerical model: simulating TD + radiation pressure, and g=g(h) Altitude, h, at which: TD_density_data(h=0) / e = 57 km

In our numerical calculation, the scale height is calculated from the density profile and we consider the variation of g with altitude (something not considered in the barometric formula). We look at when density is reduced by 1/e and this agrees with the Chamberlain theory. Both, Monte Carlo and Chamberlain theory have full implementation of the photon pressure at the given TAA of the observation. Both MC and Chamberlain match the observations. We are confident that these results are right. We agree that at a couple of scale heights the signal is much lower than at the surface but this thermal signal is observed by MASCS.

R. K. Comment: More importantly however is the use of the full number density of Na in the crystalline lattice in this calculation. It is known that thermal desorption only acts on adsorbed atoms.

Reply: Indeed, thermal desorption acts only on adsorbed atoms, an assumption that we make from the beginning (see section 3.3). The full number density of Na is only used to simulate the "source" population (produced by SP and MIV), whereas for the "ambient" population (produced by TD and PSD) the number density is calculated from the resulting returning flux from SP and MIV. We revised the text to make sure this is clear (see second paragraph in section 4).

R. K. Comment: As discussed by Farrrell et al. (2015) an atom on the surface of a space weathered planet will only execute a few oscillations before finding and becoming trapped in a deep potential well. They conclude that: "We point out that diffusion times of H migrating outward also apply to H migrating inward, deeper into the regolith. We have not investigated this possibility, but presume that the H trapped in a vacancy (high U) cannot easily migrate outward to space or inward to deeper locations. It is effectively trapped." This conclusion must apply to all species, not just H. "It is more likely that the loitering H retention is very mild (1% per lunation), and when it gets too large is offset by other loss processes like impact vaporization and sputtering." W. M. Farrell, D.M. Hurley, M.I. Zimmerman, Solar wind implantation into lunar regolith: Hydrogen retention in a surface with defects. Icarus 255 (2015) 116–126

Reply: We agree that the processes of interactions of atoms on realistic regolith surface are complicated and the energetics of adsorptions of the atoms on the regolith grains are varied. Hydrogen atoms are chemically very reactive species, actually are radicals, and thus will behave differently compared to metallic atoms, thus generalization from H to Na cannot be made straight forward. The observations presented in Cassidy et al. (2015) of the near surface Na exosphere are nicely reproduced by the MC and the Chamberlain model using thermal desorption in a quantitative way.

R. K. Comment: Thermal desorption: page 4 line 20:"The flux of thermally released Na atoms is given by n 0 vt h , where v th is the mean speed." In fact the release must be integrated over the Boltzmann distribution.

Reply: We agree and have revised the text and corrected the mistake. The theoretical thermal flux is indeed proportional to the integral of the Maxwell-Boltzmann distribution. However, as explained in Sections 3.3 and 5.1, we actually calculate this flux as the sum of the returning flux from MIV, SP, and the diffusion-limited exospheric flux (see

expression 8 in Section 5.1).

R. K. Comment: Micro-meteorite vaporization: The reference to Borin et al, 2009 should be updated. I believe that this paper was revised and the flux was revised downward.

Reply: Thanks for your comment. Indeed, in Borin et al. (2010) the flux was reduced by a factor of $\sim$2.6, still high. The reference Borin et al. (2009) is only used by us to give and idea of the range of uncertainty, but we actually use the values given by Müller et al. (2002).

R. K. Comment: Sputtering; The reference to Collier et al. (2001) is mis-quoted. What they actually said was "Neutral particles in this energy range, which encompass most of the plasma in the heliosphere, can result when energetic particles charge exchange with the Earth's hydrogen geocorona." Since Mercury does not have an extensive hydrogen corona with the density of the Earth's geocorona, this charge exchange is not going to happen at Mercury. The solar wind does not have a neutral component. The neutral's were measured inside the earth's geocorona due to charge exchange.

Reply: Thanks for pointing that out. We put the wrong reference there. In the Collier et al. (2003) paper it is shown that there is a neutral solar wind component that originates from the solar wind – dust interaction near the Sun. We have added the right reference.

R. K. Comment: Other comments: Page 1: The existence of oxygen: the Mariner 10 observations were generous upper limits. MESSENGER actually has a new limit of 2 R. R. J. Vervack Jr., R. M. Killen, W. E. McClintock, A. W. Merkel, M. H. Burger, T. A. Cassidy, and M. Sarantos. New discoveries from MESSENGER and insights into Mercury's exosphere. Geophys. Res. Lett., 10.1002/2016GL071284

Reply: Thanks for your comment. This reference was added to the text (see Introduction).

R. K. Comment: Page 2 line 4: MESSENGER also measured the sodium tail: Mc-

Clintock, W. E. et al., Mercury's Exosphere: Observations During MESSENGER's First Mercury Flyby. Science 321, 92 - 94, 2008. More recent observations were by Carl Schmidt et al.

Reply: Thanks for your comment. Reference was added to the text in that same line.

R. K. Comment: Figure 2: The normalization of all sources to a column density of 10 11 cm -2 at the surface is not realistic and is misleading.

Reply: Thanks for your remark. We agree that the normalization does not make sense and the main purpose of this figure is to show the different shapes and slopes of the tangent altitude profiles when varying the release mechanisms and characteristic temperatures. To avoid confusion, we have normalized the tangent column density at the surface to one and re-did Figure 2.

Please also note the supplement to this comment:
https://www.ann-geophys-discuss.net/angeo-2018-109/angeo-2018-109-AC1-supplement.pdf

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