Impact vaporization as a source of calcium in Mercury's exosphere

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Mercury is surrounded by a surface-bounded exosphere with six known components, H, He, Na, K, Ca, and Mg. Both Ca and Mg are of extreme temperature and with a source concentrated on the dawn side. Calcium has been observed in Mercury's exosphere for the past two decades, having been discovered by Bida et al. (2000) using the Keck telescope on Mauna Kea. Observations of the Ca exosphere of Mercury show that the Ca abundance varies in a periodic way with Mercury's orbital longitude (Burger et al., 2014). Note that Mercury's orbit is quite eccentric, $e = 0.2$, so this planet's radial excursions through the interplanetary dust particle (IDP) complex are substantial, ± 20 %, and the observed Ca signal is in fact correlated with the planet's periodic heliocentric distance. It has been suggested that impact vaporization of interplanetary dust striking the planet might be responsible for the periodic variations in Mercury's exospheric Na (Kameda et al., 2009). Note that if IDP impacts are the dominant source of Ca then one might expect the exospheric Ca signal to be maximal when Mercury is at periapse and the heliocentric dust density would be greatest. However the observed Ca signal is instead maximal when Mercury has traveled about 25 degrees past periapse, and two possible explanations come to mind.

(i.) Mercury has a fairly high inclination, 7 degrees, so its vertical motion might be a fair fraction of the dust-complex's vertical thickness. If so then the site of maximum IDP density along Mercury's orbit will be sensitive to the longitude where Mercury's vertical motion carries it across the dust-disk's midplane. (ii.) Alternatively, Mercury's seasonal Ca signal might be influenced by a cometary meteor shower, which would occur if the planet passes through a cometary dust trail; such trails are composed of relatively large dust grains that slowly drift radially due to the Poynting-Robertson drag. This dust is still confined to the comet's orbital plane, so a meteor shower is possible where the two orbital planes intersect. Comet 2P/Encke, which is a prodigious producer of dust, does in fact come quite close to Mercury's orbit, but Encke' s meteor shower should occur later in longitude, about 45 degrees after periapse passage or 20 degrees later than the peak Ca signal, so dust from comet Encke appears to be ruled out as the source of Mercury's Ca. Perhaps other comets are contributing.

Regardless, our main point is that planet Mercury is a collector of IDPs, and that the planet's exospheric Ca may be a proxy for the density of IDPs. Mercury's large orbital eccentricity and inclination allows the planet to sample the IDP complex radially and vertically. Further modeling (which will be reported at conference time) should allow us to infer the tilt and orientation of the dust-disk's mid-plane relative to Mercury's orbital plane, and may also allow us to estimate the dust-disk's vertical scale height.

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References: Bida, T.A., R.M. Killen and T.H. Morgan, Nature 404, 159–161, 2000; Burger, M.H. et al., Icarus, 2014; Kameda, S. et al., Geophys. Res. Lett., 36, L15201, 2009.