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Modeling Mercury's Exosphere in the MESSENGER Era

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Mercury has a tenuous exosphere created by the combined effects of solar radiation and micrometeoroid bombardment on the surface and the interaction of the solar wind with Mercury's magnetic field and surface. Observations of this exosphere provide essential data necessary for understanding the composition and evolution of Mercury's surface, as well as the interaction between Mercury's magnetosphere with the solar wind.

The sodium component of the exosphere has been well observed from the ground (see review by Killen et al., 2007). These observations have revealed a highly variable and inhomogeneous exosphere with emission often peaking in the polar regions. Radiation acceleration drives exospheric escape producing a sodium tail pointing away from the sun which has been detected up to 1400 Mercury radii from the planet (Potter et al. 2002; Baumgardner et al. 2008). Calcium has also been observed in Mercury's exosphere showing a distribution distinct from sodium, although also variable (Killen et al. 2005).

During the first two encounters with Mercury by MESSENGER, observations of the exosphere were made by the UltraViolet and Visible Spectrometer (UVVS) channel of the Mercury Atmospheric and Surface Composition Spectrometer (MASCS). Sodium and calcium emission were detected during both flybys, and magnesium was detected for the first time in Mercury's exosphere during the second flyby. The spatial distributions of these species showed significant, unexpected differences which suggest differences in the mechanisms responsible for releasing them from the surface.

We present a Monte-Carlo model of sodium, magnesium, and calcium in Mercury's exosphere. The important source mechanisms for ejecting these species from the surface are sputtering by solar wind ions, photon-stimulated desorption, and micrometeoroid impact vaporization. Thermal desorption on the dayside does not supply enough energy to significantly populate the exosphere, although it does play a role in redistributing volatiles over the surface. In addition, atomic calcium can be produced from the dissociation of Ca-bearing molecules, such as CaO, which can be formed in impact vapors.

The primary loss processes are the escape of neutrals ejected with sufficient energy and photoionization. The former process is supplemented by radiation pressure which accelerates neutrals anti-sunward such that escaping neutrals form a tail pointing away from the sun. Because Mercury's heliocentric distance and radial velocity vary during its orbit, both loss processes are functions of Mercury's true anomaly.

We also consider the spatial distribution of the surface source. Impact vaporization is roughly isotropic over the surface, although there may be a leading/trailing asymmetry in the impact rate due to Mercury's orbital motion. Sputtering is confined to regions where the solar wind can impact the surface, which is shielded somewhat by the internal magnetic field. The surface regions vulnerable depend on the solar wind conditions.

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