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Limits to Mercury's magnesium exosphere from MESSENGER second flyby observations

Menelaos Sarantos (1,2), Rosemary Killen (3), William McClintock (4), E. Todd Bradley (5), Mehdi Benna (2,6), James Slavin (1), and Sean Solomon (7)

(1) NASA Goddard Space Flight Center, Heliophysics Science Division, Greenbelt, MD 20771, USA (menelaos.sarantos-1@nasa.gov), (2) Goddard Earth Sciences and Technology Center, University of Maryland, Baltimore County, Baltimore, MD 21228, USA, (3) NASA Goddard Space Flight Center, Planetary Magnetospheres Branch, Greenbelt, MD 20771, USA, (4) Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO 80303, USA, (5) Department of Physics, University of Central Florida, Orlando, FL 32816, USA , (6) NASA Goddard Space Flight Center, Solar System Exploration Division, Greenbelt, MD 20771, USA, (7) Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015, USA

The discovery measurements of Mercury's exospheric magnesium, obtained by the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) probe during its second Mercury flyby, are modeled to constrain the source and loss processes for this neutral species. Fits to a Chamberlain exosphere reveal that at least two processes are required to reconcile the distribution of magnesium measured far from and near the planet: a hot ejection process at the equivalent temperature of several tens of thousands of degrees K, and a competing source at lower temperatures, 3000–5000 K. The cooler process is consistent with an impact vaporization source at an inferred rate of (3–7)x105 atoms cm^{-2} s^{-1}. Models of ion sputtering indicate that this process may provide $\sim$20% of the column abundance measured over the polar areas if a mean influx to the surface of 2x10^{8} solar-wind protons cm^{-2} s^{-1} poleward of $\pm$50° latitude and an effective sputter yield of 0.1 per ion are assumed. This result leads to the conclusion that another energetic process, such as the rapid photodissociation of exospheric MgO, assumed to be produced by meteoroid and micrometeoroid impacts at an inferred rate of (5–12)x10^{5} molecules cm^{-2} s^{-1}, is required in order to explain the residual distant neutral component. The total amount of impact-produced magnesium is found to be less than that predicted by impact vaporization models for any reasonable combination of magnesium abundance in the regolith, a result that, subject to uncertainties in the meteoroid influx, suggests that condensation during hypervelocity impacts might constitute a major loss process for gas-phase refractories.