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Insights into physical processes promoting atomic species into Mercury's exosphere

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Abstract

Recent observations of Mercury's exosphere both from the MESSENGER spacecraft and from ground-based telescopes have shed light onto physical processes occurring at Mercury and have raised additional questions.

1. Introduction

Two atomic species (H and He) were detected in Mercury's exosphere with the ultraviolet spectrometer on Mariner 10, and there was a marginal detection of O. Five additional elements were discovered or have strict upper limits set by ground-based telescopic searches: Na, K, Ca, Fe, and Al. More recently, Mg has been observed in the exosphere by the Mercury Atmospheric and Surface Composition Spectrometer (MASCS) on the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft. Each of these species has its own distinct spatial and temporal variability, arguing that the physics of the gas-surface interaction, the plasma interaction with the magnetosphere and surface, the solar radiation force, and gravitational forces are all important in promoting the atoms into the exosphere and in redistributing them about the exosphere and surface. We discuss two of the least understood species, Mg and Ca, in this report.

2. Magnesium

Magnesium was discovered in observations by the Ultraviolet and Visible Spectrometer (UVVS) channel on MASCS during the second MESSENGER flyby [1]. Although the abundance of Mg is similar to that of Na, the radiance values are much less, providing lower signal-to-noise ratios and a less definitive measurements of spatial distribution. However, during the third MESSENGER flyby, remarkable limb scans were obtained over the polar regions that showed that the Mg tangent-column abundance over the north pole is almost constant to an altitude of about 800 km, above which it rapidly decreases [2]. This behavior indicates that the process that is important in promoting Mg at the north pole is a resonance process, and that the velocity distribution of the ejecta is highly peaked at velocity of 2 km/s as shown in Figure 1. The altitude distribution of Mg seen at the south pole is, however, similar to that of Ca and appears to be a hot coronal distribution [3].

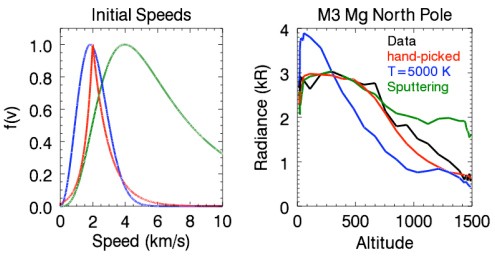

Figure 1: With the three assumed speed distributions in the left panel, we modelled the resulting altitude distribution for Mg above the pole. The data (black curve on right panel) are fit with a velocity distribution that is highly peaked at 2 km/s (red curve). The red speed distribution was chosen as a best fit to the data and does not represent a specific physical process but probably indicates a resonance such as dissociative excitation.

3. Calcium

The calcium abundance observed by MASCS [1,2] in Mercury's exosphere is consistent with that observed with ground-based telescopes [4,5]. A new and unexpected result is a persistent dawn enhancement in calcium, which could not have been seen from Earth. This persistent dawnside enhancement is particularly surprising for a refractory element. Explanations may be related to nightside sequestration, which would imply a dawnside enhancement in surface concentration, preferential dawnside sputtering due to the convection of ions in Mercury's magnetosphere, or dawnside impact vaporization. However, these same processes would presumably affect the other species, requiring a difference in loss processes to preclude the same dawnside pileup. Additional observations are needed to determine whether Mg also exhibits a dawnside enhancement.

4. Summary and Conclusions

MESSENGER MASCS spectral observations have yielded the discovery to date of one new neutral species, Mg [1], and one ion, Ca^+ [2], in Mercury's exosphere. Important clues to the physical processes at work are given by the altitude distributions and spatial distributions of these elements about the planet. The distributions of Mg and Ca differ from those expected, particularly in the baffling dawnside concentration of calcium and the polar altitude distribution of Mg.

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