

Observations of Al, Fe and Ca⁺ in Mercury's exosphere

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Abstract

We report 5- σ tangent column detections of Al and Fe, and strict 3- σ tangent column upper limits for Ca⁺ in Mercury's exosphere obtained using the HIRES spectrometer on the Keck I telescope. These are the first direct detections of Al and Fe in Mercury's exosphere. Our Ca⁺ observation is consistent with that reported by the The Mercury Atmospheric and Surface Composition Spectrometer (MASCS) on the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft [1].

1. Introduction

Two atomic species were detected in Mercury's exosphere with the UV spectrometer onboard Mariner 10 (H, and He) with a marginal detection of O. Three additional elements were discovered previously by ground-based telescopic searches: Na, K, and Ca [2, 3]. More recently Mg has been observed in the exosphere by the MASCS UV spectrometer onboard MESSENGER [4]. Each of these species has its own unique 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 as well as gravitational forces, are important in promoting the atoms into the exosphere and in redistributing them about the exosphere and surface. We report the detection of two new species, Al and Fe, in Mercury's exosphere, and the confirmation of Ca⁺.

2. Aluminum

Aluminum has been observed at the Keck I telescope using the HIRES high-resolution spectrometer. A zenith column of $(1.4 - 2) \times 10^7 \text{ cm}^{-2}$ was inferred by Bida and Killen [5], assuming a temperature of 8200

and 4800 K, respectively. This small observed column abundance of atomic Al is only 5% of that predicted from impact vaporization of a regolith containing 5% Al. We conclude that impact vaporization ejects Al primarily in molecular form, similar to Ca [6] and that very little of this oxide dissociates in the exosphere.

3. Iron

Iron has also been observed in Mercury's exosphere using the HIRES spectrometer on the Keck I telescope. Column abundances of iron are more than an order of magnitude larger than those of Al, in spite of predictions of small iron abundance in the regolith. This would imply that iron, unlike Al, is not promoted into the exosphere primarily in the molecular form, or that it easily dissociates. However, the zenith column abundance inferred from observations, $(2.9 - 8.2) \times 10^8 \text{ cm}^{-2}$ was calculated on the assumption of a Chamberlain exosphere. The observed altitude distribution of Fe, if correct, would lead us to infer that Fe is partially the product of molecular breakup in the exosphere, and the surface abundance of Fe in the atomic form is less than inferred on the basis of a Chamberlain exosphere.

4. Summary and Conclusions

We report new, first-time detections of two new neutral species in Mercury's exosphere by ground-based observations: Al, with an observed tangent column density of $2.4 \times 10^7 \text{ cm}^{-2}$, and Fe, measured at $6.2 \times 10^8 \text{ cm}^{-2}$. In addition, important clues to the physical processes at work are given by the altitude distributions of these elements: the very low, decreasing density of Al argues for a molecular source, while the high, increasing density of Fe implies a reduced surface density compared to models and significant secondary production from molecular dissociation.

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