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

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Abstract. We report the first detections of Al and Fe, and strict upper limits for Ca\(^{+}\) in the exosphere of Mercury, using the HIRES spectrometer at the Keck I telescope. We report observed 4-\(\sigma\) tangent columns of 1.5\(\times\)10\(^7\) Al atoms cm\(^{-2}\) at an altitude of 1220 km (1.5 Mercury radii (R\(_{\text{M}}\)) from planet center), and that for Fe of 1.6\(\times\)10\(^8\) cm\(^{-2}\) at an altitude of 950 km (1.4 R\(_{\text{M}}\)). The observed 3-\(\sigma\) Ca\(^{+}\) column was 3.9\(\times\)10\(^6\) ions cm\(^{-2}\) at an altitude of 1630 km (1.67 R\(_{\text{M}}\)). A simple model for zenith column abundances of the neutral species were 9.5\(\times\)10\(^7\) Al cm\(^{-2}\), and 3.0\(\times\)10\(^8\) Fe cm\(^{-2}\). The observations appear to be consistent with production of these species by impact vaporization with a large fraction of the ejecta in molecular form. The scale height of the Al gas is consistent with a kinetic temperature of 3000 - 9000 K while that of Fe is 10500 K. The apparent high temperature of the Fe gas would suggest that it may be produced by dissociation of molecules. A large fraction of both Al and Fe appear to condense in a vapor cloud at low altitudes.

Introduction

A 4-\(\sigma\) detection of Al and Fe, and strict upper limits for Ca\(^{+}\) in the exosphere of Mercury were measured at the Keck I telescope with the High Resolution Echelle Spectrograph in May of 2008 and 2009. A 4-\(\sigma\) tangent column of Al atoms of 1.5\(\times\)10\(^7\) cm\(^{-2}\) was measured at an altitude of 1220 km (3660 km from planet center, or 1.5 Mercury radii (R\(_{\text{M}}\)) on 14 May 2008; and a 4-\(\sigma\) tangent column of Fe of 1.6\(\times\)10\(^8\) cm\(^{-2}\) was found at an altitude of 950 km (1.4 R\(_{\text{M}}\)) on 3 May 2009. The observed 3-\(\sigma\) upper limit Ca\(^{+}\) column was 3.9\(\times\)10\(^6\) ions cm\(^{-2}\) at an altitude of 1630 km (1.67 R\(_{\text{M}}\)) on 080515, and 6.4\(\times\)10\(^6\) ions cm\(^{-2}\) at an altitude of 510 km on 090503. A simple model for zenith column abundances of the neutral species are 9.5\(\times\)10\(^7\) Al cm\(^{-2}\), and 3.0\(\times\)10\(^8\) Fe cm\(^{-2}\). The observations appear to be consistent with impact vaporization of surface material with a large fraction of the ejecta in molecular form. The derived temperature of the Al gas is about 3000 - 9000 K while that of Fe is 10500 K, although the temperatures are not well constrained because of limited spatial coverage.