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Mass Spectrometry in Jupiter's Atmosphere: Vertical Variation of Volatile Vapors

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The Galileo Probe made the first and only in situ measurements of composition in Jupiter's atmosphere, led by the Galileo Probe Mass Spectrometer, or GPMS [1]. The major contribution from this instrument was the measurement of abundances and isotope ratios of the noble gases, as well as the volatile gases CH_4, NH_3, H_2O, and H_2S [2,3]. These initial results were further refined by detailed laboratory calibrations for the noble gases [4] and the volatiles [5]. The probe measurements resulted in the first determination of the heavy element abundances (except carbon that was known previously) and He/H ratio, which provide critical constraints to models of the formation of Jupiter and the origin of its atmosphere [6,7].

The condensable volatiles, or CVs (ammonia, H_2S, and water), increased with depth in the probe entry site. This vertical variation was observed at levels much deeper than the modeled cloud bases, as predicted by one-dimensional chemical equilibrium models. The discrepancy is due to the probe's entry into a dry region known as a 5-μm hot spot. The 5-μm hot spots are part of an atmospheric wave system that encircles Jupiter just north of the equator. Despite the anomalous meteorology, the bulk abundances of NH_3 and H_2S were measured by the probe, and found to be enriched with respect to solar composition (similarly to the non-condensable volatile CH_4). The deepest water mixing ratio, however, was observed to be depleted relative to solar composition.

We review an updated context for the CV vertical profiles measured by the GPMS, based on the latest results from remote sensing, simulation, and reinterpretation of Galileo Probe measurements. In particular, we find that (1) the bulk abundance of water in Jupiter's atmosphere must be greater than the subsolar abundance derived from the deepest GPMS measurements [8], and that (2) CV mixing ratios are controlled by a range of processes in addition to condensation of the ices NH_3, NH_4SH, and H_2O [5–9]. Both bulk abundances and spatial variation of these species will be further constrained by the Juno mission, scheduled to arrive at Jupiter in 2016.

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