INVESTIGATING THE ORIGIN AND EVOLUTION OF VENUS WITH DESCENT PROBE MASS SPECTROMETRY

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ABSTRACT

The exploration of Venus continues to be a top priority of planetary science. Venus is the most mysterious of the terrestrial planets, with a complex surface enshrouded in a thick atmosphere, remarkably different from the Earth's despite the gross similarities between these "twin planets". It is unknown if this apparent divergence was intrinsic, programmed during accretion from distinct nebular reservoirs, or a consequence of either measured or catastrophic processes during planetary evolution. Even if the atmosphere of Venus is a more "recent" development, its relationship to the resurfacing of the planet's enigmatic surface is not well understood. Resolving such uncertainties directly addresses the hypothesis of a more clement, possibly water-rich era in Venus' past as well as whether Earth could become more Venus-like in the future.

Future missions will require a focused investigation of the atmospheric composition, to complete the picture sketched by the probes of the 1970s and 1980s and developed further by recent missions such as Venus Express. Comparing noble gas mixing ratios and isotopes of Venus, Earth, Mars, Jupiter, and the sun will help determine the timing and extent of atmospheric escape on Venus, a central process in planetary evolution. Precise isotope systematics of Xe, an element not yet measured at Venus, can resolve uncertainties among models of the original atmospheric composition and potentially lead to a more refined understanding of the relative importance of planetary degassing on Venus, Earth, and Mars [1]. Similarly, accurate profiles of trace gases such as SO_2, H_2S, and H_2O in the lower atmosphere are needed to trace the S-O-H cycle through crustal oxidation and volcanism, which can speak to the probability of past surface water. These studies are enabled by a modern neutral mass spectrometer (NMS) such as that developed at NASA Goddard, based on flight-proven technology.

A Goddard NMS is included in the payload of the Surface and Atmosphere Geochemical Explorer (SAGE) mission, recently selected for a concept study in NASA's New Frontiers program. NMS operates by ingesting and processing atmospheric gas during the ~1 hr. descent of the SAGE lander to the surface of Venus. This instrument offers a comprehensive analysis of (i) noble gases: all mixing ratios and isotopes; (ii) light isotopes: $^{15}N/^{14}N$ in N_2, $^{13}C/^{12}C$ and $^{18}O/^{16}O$ in CO_2, and $^{34}S/^{32}S$ in S-species; and (iii) trace gases: SO_2, OCS/COS, H_2S, H_2O, H_2SO_4, and S_n (n=1-8). The science return of NMS is amplified by data from other included instruments such as a tunable laser spectrometer, which provides highly precise abundances and isotope ratios for selected species such as H_2O, CO, CO_2, SO_2, OCS, and N_2O. Additional insights are gained by combining atmospheric analysis with surface chemistry and mineralogy. NMS is also applicable to other Venus mission concepts under consideration such as dedicated atmospheric descent probes, long-duration balloons, and even landed platforms supporting analytical laboratory analysis of solid samples.

1. Pepin, R. O. (2006) Atmospheres on the terrestrial planets: Clues to origin and evolution, *Earth Planet. Sci. Lett. 252*, 1-14.