INVESTIGATING THE ORIGIN AND EVOLUTION OF VENUS WITH *IN SITU* MASS SPECTROMETRY. M. G. Trainer[1], P. R. Mahaffy[1], W. B. Brinckerhoff[1], N. M. Johnson[1], and L.S Glaze[1]., [1]NASA Goddard Space Flight Center, Solar System Exploration Division, Greenbelt, MD 20771 (melissa.trainer@nasa.gov).

Introduction: The exploration of Venus continues to be a top priority of planetary science. The Planetary Decadal Survey goals for inner-planet exploration seek to discern the origin and diversity of terrestrial planets, understand how the evolution of terrestrial planets relates to the evolution of life, and explore the processes that control climate on Earth-like planets [1]. These goals can only be realized through continued and extensive exploration of Venus, the most mysterious of the terrestrial planets, remarkably different from the Earth 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.

Priority Measurements: 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. A key issue that remains after more than 50 years of planetary exploration is the formation and evolution of the atmosphere, particularly in the context of the other terrestrial planets [2]. 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 (Figure 1). 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 [3]. These studies are only possible through *in situ* measurement, and can be accomplished by a modern neutral mass spectrometer (NMS) such as that developed at NASA Goddard, based on flight-proven technology.

Instrumental Approach: Comprehensive analysis of mixing ratios and isotopic abundances of noble gases Ne, Ar, Kr, and Xe can be accomplished by the NMS by ingesting and processing atmospheric gas during a brief residence time consistent with the Pioneer Venus and Venera Probes (~1 hr.). Noble gases are typicallly present at low abundances in planetary atmospheres, and thus the accurate measurement of elemental and isotopic abundances presents an analytical challenge for any *in situ* instrument. Argon and neon were determined by the Venera 11/12 MS and Pioneer Venus MS to be present at approximately 70 and 7 ppm, respectively [5]. Inconsistent measurements of Kr between these missions suggest an upper limit of ≤ 100 ppb for this species, and non-detections of Xe support a similar upper limit at the ppb-level. Yet, measurements of these noble gases are necessary to constrain atmospheric evolution models. Thus, proper execution of atmospheric enrichment is needed to enhance the signal from trace noble gases and secure the required measurements with adequate precision to advance our understanding of Venus' atmospheric history.

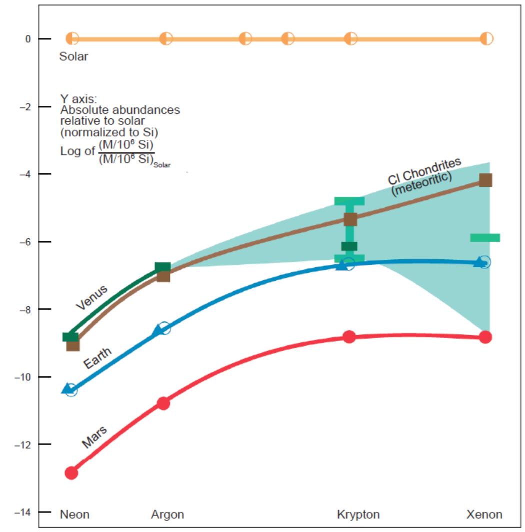

Figure 1. Noble gas abundances for Earth, Mars, Venus, chondrites, and the Sun. Missing Xe and poorly constrained Kr data for Venus are critical for understanding the history of its early atmosphere. From Baines et al. [4].

Noble Gas Enrichment. The measurement of noble gas abundances during probe descent has been demonstrated previously by the Galileo Probe Mass Spectrometer mission into Jupiter [6,7]. GPMS used two enrichment cells to scrub the ingested atmosphere of H_2 and other active gases in order to enhance noble gases and their isotopes. These groundbreaking measurements were acquired with < 10 minutes of MS time, following ~10 minutes of gas processing during which direct MS measurements of the atmosphere were made.

For a future Venus mission, improvements to the enrichment process, pumping throughput, and instrument sensitivity over GPMS and Pioneer Venus MS would result in successful measurement of noble gas targets. Such advancements have been implemented on the Mars Science Laboratory Sample Analysis at Mars (SAM) investigation [8]. SAM's wide dynamic range quadrupole MS, and the incorporation of both scrubbers and getters into the gas manifold, effectively remove chemically active gases such as CO_2, trace noble gases from sub-picomole to nanomole abundances to be measured.

In particular, following enrichment of noble gases relative to the atmosphere, static mass spectrometry is utilized to maximize the signal from these low abundance, inert species. During static mass spectrometry, the quadrupole is isolated from the wide range pump, and only reactive species are pumped using a chemical getter. The resulting enrichment in heavy noble gas atoms within the analyzer enables the detection and quantitative determination of isotopic ratios with excellent precision in a short amount of time (Figure 2).

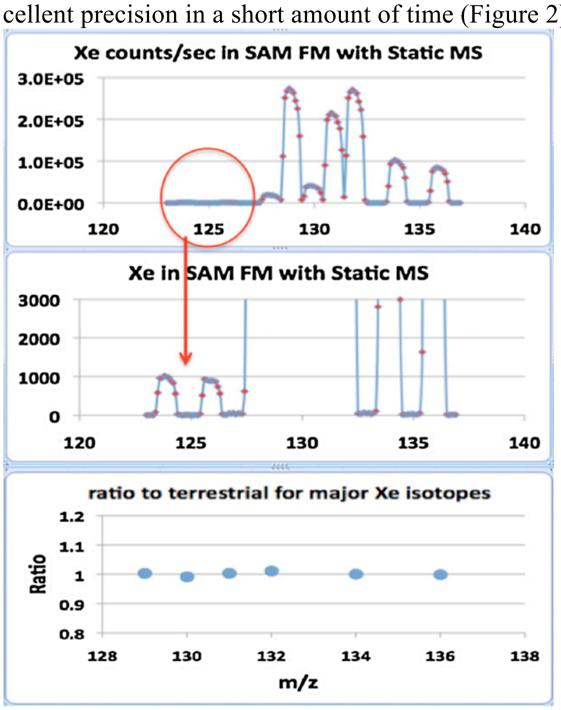

Figure 2. Static mode performance of the SAM QMS demonstrates the 1-2% precision in isotopic measurements achieved in short integration times. The entire set of measurements that generated the ratio plot in the bottom frame was acquired in 30 seconds [8].

Summary: Measurement of noble gas abundances on Venus remain a high priority for planetary science [1,2]. This can be accomplished as part of an atmospheric investigation using flight-proven technology and demonstrated enrichment techniques. Additional insights are gained by combining measurements of noble gases with accurate profiles of trace gases such as SO_2, H_2S, and H_2O in the lower atmosphere to elucidate the sulfur cycle and to gain insight into crustal oxidation and volcanism, which can speak to the probability of past surface water.

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