THE DAVINCI VENUS MASS SPECTROMETER INVESTIGATION. M. G. Trainer[1] , C. A. Malespin[1], P. R. Mahaffy[1], W. B. Brinckerhoff[1], S. Atreya[2], C. R. Webster[3], A. E. Hofmann[3], J. B. Garvin[1], S. A. Getty[1], G. N. Arney[1], N. M. Johnson[1], E. N. Kohler[1]. [1]NASA Goddard Space Flight Center, Greenbelt MD (melissa.trainer@nasa.gov), [2]University of Michigan, Ann Arbor, MI, [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA.

Introduction: The Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging (DAVINCI) mission, selected as part of the NASA Discovery Program, will incorporate science-driven flybys and an instrumented descent sphere [1]. DAVINCI measurements at Venus will reveal a new understanding of the atmosphere, surface, and evolutionary path of Venus as a possibly once-habitable planet and analog to hot terrestrial exoplanets. The primary mission design for DAVINCI features a launch in 2029, two flybys in 2030, and descent sphere atmospheric entry by the end of 2031. The in situ atmospheric descent phase provides the opportunity to measure the chemical and isotopic composition of the Venus atmosphere during a ~ 1 hr atmospheric transect above Alpha Regio. These in situ investigations will yield new data on the atmospheric profile including the near-surface environment, notably including the first unique characterization of the deep atmosphere environment and chemistry: trace gases, key stable isotopes, oxygen fugacity, constraints on local rock compositions, and topography of a tessera.

The in situ compositional measurements during the descent on Venus are acquired using two of the DAVINCI payload elements: the Venus Mass Spectrometer (VMS) and the Venus Tunable Laser Spectrometer (VTLS). These two analytical instruments strongly leverage heritage from the MSL Sample Analysis at Mars (SAM) instrument suite to provide complementary compositional data on the abundance and precise isotope ratios of atmospheric gases [2]. The VMS investigation will focus on the gas phase composition of major and minor atmospheric species with high resolution during the descent, as well as measurements of Venus' noble gases to provide insight into the origin and evolution of the Venus atmosphere. These measurements will resolve long-standing uncertainties on the abundances and isotopic ratios of species at Venus from prior missions [3].

Venus Mass Spectrometer Design: VMS is a GSFC-developed quadrupole mass spectrometer with a gas-enrichment and pumping system that enables both direct sampling and measurement of trace noble gases. VMS has a broad mass range from 2 to 550 Da at unit resolution, enabling the detection of new trace gas species. VMS is mounted to the DAVINCI Descent Sphere (DS) instrument deck, isolated from the Venus atmosphere save for two dedicated sample inlet ports.

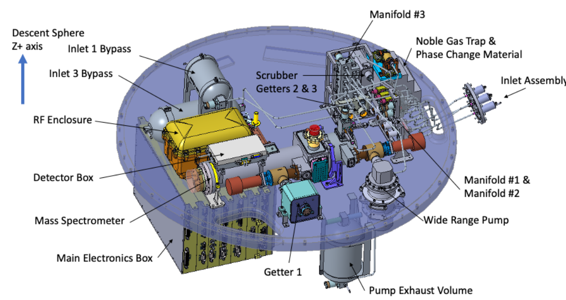

Figure 1. The Venus Mass spectrometer (VMS) as laid out on the DAVINCI Descent Sphere Instrument Deck.

Pressures in the sampling lines are controlled with carefully sized flow restrictors and capillaries. Two independent inlets and sampling lines are used during the descent, providing additional range to accommodate the increasing pressure during the descent. Evacuated bypass volumes draw samples into the lines and past the inlet capillaries for ingestion into the mass spectrometer.

Previously, the Pioneer Venus Large Probe Mass Spectrometer suffered a clog from a sulfuric acid droplet(s) [4]. To avoid this on DAVINCI, the VMS incorporates heated inlet tubes to vaporize trapped droplets, filters of passivated/sintered metal spheres to capture particles large enough to cause clogs in capillary leaks used for pressure reduction, and a second inlet that is reserved for sampling below the sulfuric acid cloud and haze.

Noble Gas Investigation: VMS will make comprehensive measurements of the noble gases at Venus (He, Ne, Ar, Kr, Xe) to address long standing questions about Venus' origin and evolution by filling critical gaps in data [5]. Discrepant measurements of Kr prohibit the discrimination between solar and chondritic sources (Figure 2). Xenon has not been measured at Venus but is needed to 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. The abundance and isotopic distribution of this heavy noble gas in particular provide insight into the mystery of divergent evolution of the terrestrial planets.

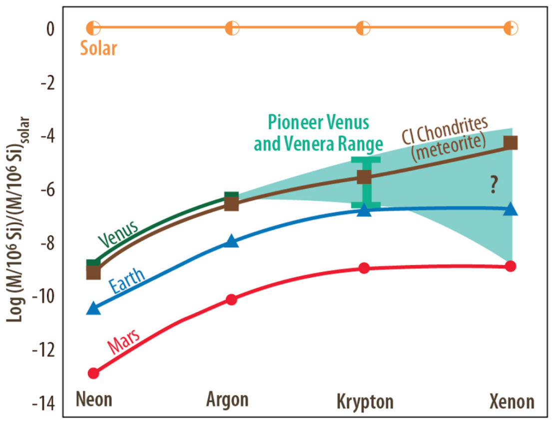

Figure 2. Noble gas abundances for Earth, Mars, Venus, chondrites, and the Sun. Missing Xe and poorly constrained Kr data for Venus are critical for understanding the history of its early atmosphere. From Baines et al. [6].

The DAVINCI VMS carries an enrichment system that removes the chemically active gases from a sample taken in the well-mixed atmosphere, isolating and enriching the trace noble gases. The enrichment combined with static mass spectrometry enables sensitive detection of even the ppbv-level isotopes.

The VMS enrichment system is based on similar elements and processes to those used to measure noble gases on Jupiter [7,8] and Mars [9,10]. As on Galileo Probe, the enrichment and mass spectrometry measurement steps must take place on a rapid timescale during the descent, on the order of 10 minutes for each step. VMS will utilize a carefully choreographed and tested sequence to measure each of the noble gases as well as stable nitrogen isotopes in N_2. Alternate ionization energies will be used to separate interferences between Ne and doubly ionized Ar.

Chemical Composition Investigation: VMS will acquire hundreds of trace atmospheric composition measurements during the descent for understanding present-day chemical processes and cycles in the lower Venusian atmosphere. Measurements will occur every ~200 m or better below 55 km, particularly in the lowest 16 km of the atmosphere (Figure 3).

VMS measurements of chemically active gases will help to understand coupled chemical processes and circulation of the sub-cloud atmosphere. Vertical composition profiles and gradients in the deep atmosphere are needed to constrain abundances of atmospheric volatiles, thermochemical and some photochemical reaction cycles, and the chemical interactions at the atmosphere–surface interface.

Complementary and synergistic with VMS is the Venus Tunable Laser Spectrometer (VTLS), which is a 3-channel infrared spectrometer based largely on heritage from the SAM-TLS on MSL [11]. The VTLS will measure the vertical mixing ratios of H_2O, CO_2, CO, OCS, SO_2, and H_2S during the descent. Among these targeted gases, VTLS will provide high-precision (~ 2‰) isotope ratio measurements of D/H and $^{18}O/^{16}O$ in water, $^{13}C/^{12}C$ in CO_2, and $^{34}S/^{33}S/^{32}S$ in both SO_2 and OCS.

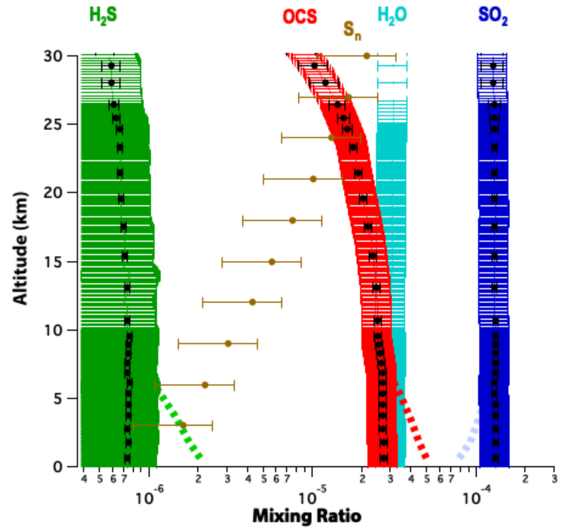

Figure 3. Representative vertical profiles with altitude-sampled measurements of selected key species for VMS in the lower atmosphere. Averaging of individual VMS spectra can achieve smaller uncertainties without significant loss of vertical structure information, as illustrated with the black points with reduced error bars. Possible gradients near the surface that would be detectable are indicated with dashed lines at altitudes <10 km.

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References: [1] Garvin J.B. et al (2022) *PSS* https://doi.org/10.3847/PSJ/ac63c2. [2] Mahaffy P. R. et al (2012) *Space Sci. Rev.* 170. [3] Johnson N.M. and de Oliveira M.R.R. (2019) *Earth & Space Sci*, 6, 1299–1318. [4] Donahue T. M. et al (1982) *Sci*, 216, 630. [5] Avice G. et al (2022) *Space Sci Rev* 218:60. [6] Baines K.H. et al (2013) in *Comparative Climatology of Terrestrial Planets*, ed. S. Mackwell et al. (Tucson, AZ: Univ. Arizona Press). [7] Niemann H.B. et al. (1992) *Space Sci. Rev.* 60, 111-142. [8] Mahaffy P.R. et al (2000) *JGR, 105,* 15061-15071. [9] Atreya S.K. et al (2013), *GeoRL*, 40, 5605. [10] Conrad P. et al (2016) *EPSL* 454 1-9. [11] Webster C.R. et al (2023) *Space Sci. Rev.* 219: 78.