DIGITAL TUNABLE LASER SPECTROMETER FOR VENUS ATMOSPHERIC ISOTOPE RATIOS.

C. R. Webster[1], J. Blacksberg[1], L. E. Christensen[1], G. J. Flesch[1], S. Forouhar[1], R. Briggs[1], D. Keymeulen[1], and P. R. Mahaffy[2], [1]Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109; Chris.R.Webster@jpl.nasa.gov [2]NASA Goddard Space Flight Center (GSFC), 8800 Greenbelt Rd., Greenbelt, Md., 20771. Paul.R.Mahaffy@nasa.gov .

Introduction: The Tunable Laser Spectrometer (TLS) is a powerful new instrument for NASA's planetary missions that can make precise measurements of gas abundances and their isotope ratios in C, H, N, O, S not only in planetary atmospheres but also in gases evolved from in situ processing of rock or soil samples – as demonstrated on MSL's Curiosity rover [1, 2, 3]. TLS excels in capability for isotope ratio measurements in C, H, O and S (all three isotopes are needed in O, S), while the mass spectrometer (MS) excels at survey exploration of a variety of gases and the unique capability of noble gas measurements.

TLS-SAM-MSL on Curiosity: For Mars, TLS within the SAM instrument suite has made critical measurements (atmospheric methane [3] and isotope ratios of C, O in carbon dioxide and of H, O in water [1], and the D/H and O isotope ratios in ancient clays [2], etc.) that have established its high science return.

Isotope Ratios for a Venus Probe Mission: Triple isotope plots for oxygen [4] and sulfur [5] are powerful tools for identifying meteorite origin in context with planetary formation and evolution determined by interaction between the atmosphere and surface. Even with enriched isotope ratios found on Mars and Venus due to atmospheric escape processes the extent to which triple isotopes follow mass-dependent or mass-independent fractionation [6] is a powerful tool for scientific analysis. For Venus as an example, unravelling the transition from photochemical to surface thermal equilibrium requires triple isotope ($^{32}SO_2$, $^{33}SO_2$, $^{34}SO_2$) measurements at a precision of 1 per mil that must be made repeatedly in a short timescale (minutes) during probe descent, a requirement not met by TLS-SAM-MSL (5 per mil) nor any mass spectrometer.

Digital Venus TLS (VTLS): For a Venus probe, TLS will be upgraded with fast, agile digital electronics that drive several lasers simultaneously to maximize the data quality and return during these short but very important missions. Target gases include CO, OCS, H_2O, CO_2, and SO_2 (Fig. 1).

For a Venus probe descent, VTLS be housed in a room-temperature pressure vessel that would ingest several gas samples at low pressure (10-50 mbar) and analyze them. Venus requirements vs VTLS capability is given in Table 1. At a precision of ~1‰, VTLS will be able to distinguish the Venus fractionation lines in O and S in context with other planets and therefore test formation and evolution scenarios.

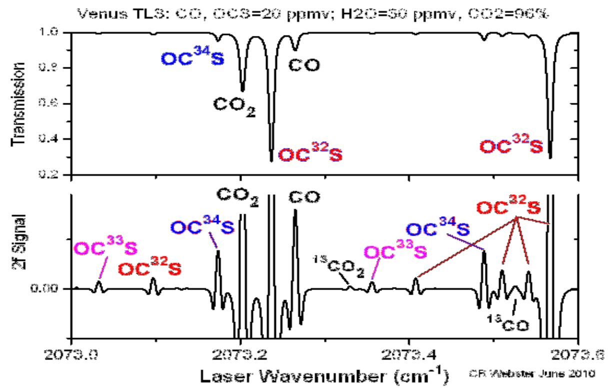

Fig. 1. VTLS is designed to accommodate 3 wavelength channels (2.78 to 7.4 µm). The spectrum is what VTLS would see at its sampling pressure of 20 mbar.

Table 1. Limits of detection and measurement capability for a 3-channel VTLS.

Gas	VTLS Limit of detection	Expected Abundance (ppmv)	Venus Requirement	VTLS capability in 10 mins
H_2O	100 ppbv	~1-200	5%	2-5%
CO	1 ppbv	~15-50	5%	2%
OCS	0.05 ppbv	~1-40	5%	2%
SO_2	0.1 ppmv	~10-150	5%	2%
D/H in H2O			5-10%	1% for 1 ppmv H_2O
delta-value: $^{18}O/^{17}O/^{16}O$ in CO_2			2‰	1‰
delta-value: $^{18}O/^{16}O$ in H_2O			2‰	1‰
delta-value: $^{34}S/^{33}S/^{32}S$ in OCS and SO_2			2‰	1‰
delta-value: $^{13}C/^{12}C$ in CO and CO_2			2‰	1‰

References: [1] Webster C.R. et al., *Science* 341, 260 (2013). [2] Mahaffy P.R. et al. Science Express 16 Dec. 2014. [3] Webster C.R. et al., *Science Express*, 16 Dec. 2014 science.1261713.[4] Dominguez G. (2010) *ApJ 713* L59 doi:10.1088/2041-8205/713/1/L59.[5] Farquhar J. et al. (2000), *Science 289*, 756. [6] Wiechert U et al. (2001), *Science* 294 (12) 345-348.

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