The Venus Emissivity Mapper (VEM) – Obtaining Global Mineralogy of Venus from Orbit. J. Helbert[1], D. Dyar[2], I. Walter[1], D. Wendler[1], T. Widemann[3], E. Marcq[4], G. Guignan[4], A. Maturilli[1], S. Ferrari[5], N. Mueller[1], D. Kappel[1], M. D'Amore[1], A. Boerner[1], C. Tsang[6], G. E. Arnold[1], S. Smrekar[7], R. Ghail[8]; [1]DLR (Germany); [2]Mount Holyoke College (USA); [3]LESIA (France); [4]LATMOS (France); [5]Univ. degli Studi di Pavia (Italy); [6]Southwest Research Institute (USA); [7]Jet Propulsion Laboratory (USA); [8]Imperial College (UK)

Introduction: The Venus Emissivity Mapper is the first flight instrument designed to focus on mapping the surface of Venus using atmospheric windows around 1 µm. After several years of development, VEM has a mature design with an existing laboratory prototype verifying an achievable instrument SNR of well above 1000, as well as predicted error in retrieval of relative emissivity of better than 1%, assuming the availability of an improved Venus topography.

It will provide a global map of rock type, iron contents and redox state of the surface by observing the surface with six narrow band filters, ranging from 0.86 to 1.18 µm. Three additional windows allow corrections for cloud composition and variability, two measure water abundance, and three compensate for stray light. Continuous observation of Venus' thermal emission will also place tighter constraints on current day volcanic activity. Eight of the channels provide measurements of atmospheric water vapor abundance as well as cloud microphysics and dynamics and permit accurate correction of atmospheric interference on the surface data. Combining VEM with a high-resolution radar mapper, such as on the ESA EnVision or NASA VERITAS mission proposals, will provide key insights into the divergent evolution of Venus and Earth.

VEM Design: The VEM system design, discussed in detailed in [1, 2], is a pushbroom multispectral imaging system. It leverages a proven measurement technique pioneered by VIRTIS on Venus Express (VEX) [3-10], but it incorporates lessons learned from VIRTIS to achieve greatly improved sensitivity and spectral and spatial coverage:

- a filter array (rather than a grating) provides wavelength stability (band-center and width-scatter) ~5× more stable and maximizes signal to the focal-plane array (FPA), and
- first coverage of the spectral windows below 1µm,
- a two-stage baffle decreases scattered light and improves sensitivity,
- use of an InGaAs detector with an integrated thermal electric cooler (TEC) eliminates the need for cryogenic cooling.

VEM's design draws strongly on DLR's BepiColombo MERTIS instrument (launching in 2018). This design maturity, combined with a standard camera optical design, leads to low development risk.

A first performance evaluation of the VEM prototype used two Venus analog samples heated to Venus surface temperatures [2]. The retrieved emissivities match the laboratory values, and the uncertainty for a single unbinned exposure is <0.35%. VEM uses onboard software developed for MERTIS to bin, co-add, and losslessly compress data upon uplink command. During the science orbits, VEM oversamples at 10 km spatial resolution (33×33 pixel binning). To further enhance SNR, VEM uses digitial TDI to provide 189× gain over single-pixel SNR. Using current performance of the laboratory prototype for a single unbinned exposure and SNR enhancement due to onboard processing, we expect a system SNR of well beyond 1000.

VEM atmospheric correction: Methodology for retrieving surface emissivity is complex but well understood and demonstrated. To distinguish between surface and atmospheric contributions, VEM uses an updated version of the extensively tested pipeline developed to process VIRTIS data [5], combined with a radiative transfer model (RTM) [11-14]. Surface emissivity retrieval techniques were developed based on Galileo NIMS observations at 1700, 1800 and 2300 nm [15]. VEM cloud bands occur at 1195, 1310, and 1510 nm [16], the first on the flank of the 1180-nm surface windows [17]. VEM's cloud bands are close to surface bands, providing near-optimal correction.

Conclusion: VEM builds on recent advances in the laboratory analog spectroscopy at PSL at DLR [1, 18]. It is the first flight instrument specially designed to focus on mapping the surface of Venus using the atmospheric windows around 1 µm. VEM has a mature design with an existing laboratory prototype verifying an achievable instrument SNR of well above 1000 as well as a predicted error in the retrieval of relative emissivity of better than 1%.

References: [1] J. Helbert, *et al.*, Proceedings of SPIE. 9973, 99730R-99730R-13 (2016). [2] J. Helbert *et al.*, DOI: 10.1117/12.2275666 (2017). [3] P. D'Incecco *et al.* PSS, (2016). [4] J. Helbert *et al.*, GRL, 35(11), (2008). [5] N. Mueller *et al.*, JGR, 113, (2008). [6] N. T. Mueller *et al.*, Icarus, 217(2), 474-483 (2012). [7] N. Mueller, *et al.*, JGR: Planets, (2017). [8] S. E. Smrekar *et al.*, Science, 328(5978), 605-8 (2010). [9] M. S. Gilmore et al., Icarus, 254, 350-361 (2015). [10] E. R. Stofan *et al.*, Icarus, 271, 375-386 (2016). [11] R. Haus et al., Icarus, 284, 216-232 (2017). [12] D. Kappel, Journal of Quantitative Spectroscopy and Radiative Transfer, 133, 153-176 (2014). [13] D. Kappel et al., Icarus, 265, 42-62 (2016). [14] D. Kappel, *et al.*, Advances in Space Research, 50(2), 228-255 (2012). [15] G. L. Hashimoto *et al.*, JGR, 113, (2008). [16] S. Erard et al., JGR-Planets, 114, (2009). [17] B. Bézard *et al.*, JGR, 114, (2009). [18] M. Gilmore *et al.*, Space Science Reviews, (2017).