A LABORATORY STUDY ON END-MEMBER MIXING FOR THE DECONVOLUTION OF SPECTRA MEASURED FROM VEM ON NASA VERITAS MISSION. A. Maturilli[1] , A. Van den Neucker[1], G. Alemanno[1], J. Helbert[1] and M. D. Dyar[3], [1]German Aerospace Center (DLR) - Institute of Planetary Research, Rutherfordstrasse 2, 12489 Berlin, Germany (alessandro.maturilli@dlr.de), [2]Planetary Science Institute, 1700 East Fort Lowell, Suite 106, Tucson, AZ 85719.

Introduction: In June 2021, NASA selected the VERITAS and DAVINCI missions under the Discovery program) and ESA selected the mission EnVision (under the Cosmic Vision plan) to study the planet Venus. All three missions will collect data to help scientists understanding how Venus geology has evolved over time, what geologic processes are still active on its surface, and if water was ever present.

VERITAS is designed to gather global, high-resolution topography and imaging of Venus' surface and produce the first maps of global surface composition, thermal emissivity, and gravity fields. Onboard the spacecraft will be two scientific instruments, the Venus Emissivity Mapper (VEM) and Venus Interferometric Synthetic Aperture Radar (VISAR).

VEM will map the Venus surface emissivity using six spectral bands in five atmospheric windows that see through the CO_2-rich clouds. VEM also carries eight additional bands for calibration and detection of near-surface water vapor.

The Planetary Spectroscopy Laboratory (PSL) is operated by the VEM PI-team. It is the only facility in the world capable of acquiring emissivity spectra of Venus analogs in vacuum at Venus surface temperatures (routinely 400°, 440°, and 480°C), and hemispherical reflectance (in vacuum at 25°C) in the VEM spectral range. We present here results on spectra of binary mixtures of end-members to improve our understanding of mixing properties at this wavelength and assist with interpretation of VEM data.

VEM on VERITAS: Venus experiences a mean surface temperature of over 400 °C, and a carbon dioxide-rich atmosphere with a surface pressure of about 92 times that of Earth at sea-level. The dense atmosphere and its cloud layers are quite impermeable to visible and infrared radiation, making remote sensing a challenge. Observations of Venus have shown, however, that the surface can be observed through a number of narrow spectral windows in the spectrum of CO_2. Using those windows, the Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) instrument on Venus Express made observations of fresh basalt and recent volcanic activity on the surface. Despite its low sensitivity and thermal drifting, VIRTIS produced a foundational proof-of-concept dataset that eventually led to VEM's design. VEM will be the first instrument in orbit around Venus that will be focused solely on these semi-transparent spectral windows, allowing for a complete mapping of the surface composition and surface redox states.

The Planetary Spectroscopy Laboratory PSL: The Planetary Spectroscopy Laboratory (PSL) at DLR in Berlin is a well-established facility providing spectral measurements of planetary analogs from the visible to the far-infrared range for comparison with remote sensing spacecraft/telescopic measurements of extraterrestrial surfaces. Three identical FTIR instruments are operating at PSL in a climate-controlled room. They include a Bruker Vertex 80V (high-end model) that can be evacuated to ~0.1 mbar. An external simulation chamber is attached to one FTIR spectrometer to measure the emissivity of solid samples. It features high efficiency induction system to heat the samples under vacuum to temperatures from 320K up to above 900K, while keeping the chamber at almost ambient temperature. A shutter allows the spectrometer to be separated from the external chamber. Sample cups for emissivity measurements in the VNIR spectral range are made of Hi-T resistant ceramic with embedded a stainless steel disk acting as an heater, and are manufactured under DLR custom design to prevent metal glowing to disturb the sample emitted signal measurement (more details in [1]).

Samples selected for this study: For this study of areal and intimate mixtures of analogues in the VEM spectral range, we chose two end-member samples with

Figure 1. The two end-members and the two 50%+50% mixtures (spatial and intimate, both in volume) in the ceramic sample holders used for emissivity measurements.

very different spectra. One sample is a coarsely

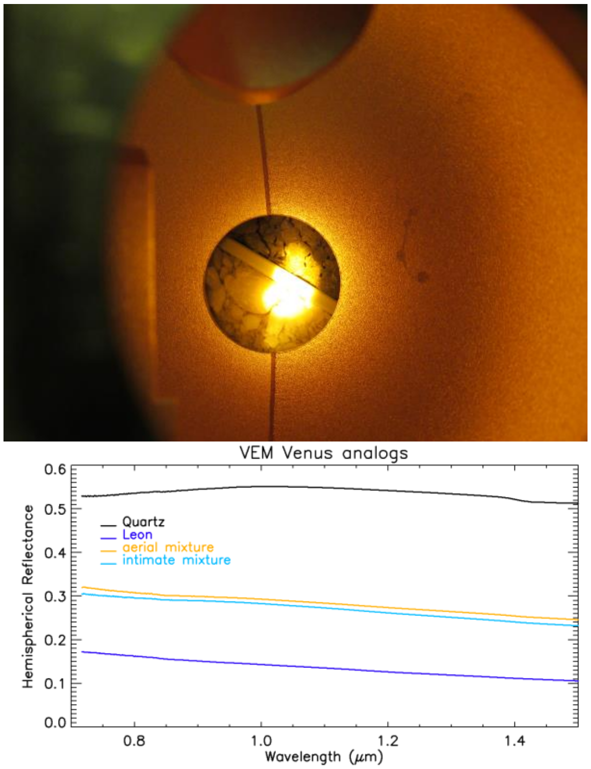

Figure 2. (top) Picture of the aerial mixture taken from the upper aperture of the hemispherical optical device. (bottom) Spectra of the two end-members and two mixtures in the VEM spectral range.

crushed quartz from Mongolia, sieved to a grain size > 250 µm; the other is a basaltic andesite from Chile (Leon Muerto volcano), also with grain size > 250 µm too. For this study, we used a custom-designed ceramic sample holder that allows one half of the cup to be filled with one material and the second half with the other end-member, keeping the two samples spatially separated (see Figure 1).

For this experiment, we used two sample cups containing the end-members, a third with an intimate mixture 50%+50% (in volume) of the two end-members, and a fourth cup containing the two end-members separated by a thin ridge in the middle of the cup.

Hemispherical reflectance measurements at 25°C: Hemispherical measurements of end-members and mixtures under vacuum used a gold-coated integration half-sphere. Figure 2 (top) shows the aerial mixture inside the hemispherical unit just before the measurement is taken. Note that the incoming light is almost precisely centered on the cup separation border, so that the incoming light is half reflected from end-member 1, and half from end-member 2.

Figure 2 (bottom) shows the hemispherical reflectance spectra acquired. The spectrum of the areal mixture lies almost exactly between spectra of the Leon (quite dark material, spectral reflectance is low and pretty flat) and the much brighter and feature-rich spectra of the quartz endmember. The same spectral features as pure quartz here have reduced intensity due to the effect of the darker end-member. The difference between spectra of the intimate and aerial mixtures is very small, and can be explained by the presence of the thin cup separator present in the spatial mixture, This ceramic wall is brighter than the Leon sample and thus increases the reflected light. For this particular example, the areal/intimate mixture spectrum is a quasi-perfect linear combination of the spectra from the two end-members is composed.

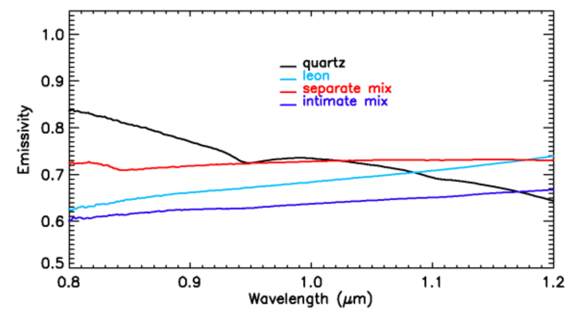

Figure 3. Emissivity spectra for the 2 endmembers and the 2 mixtures, all taken at 400°C in vacuum.

Emissivity measurements at 400°C: Samples were measured in vacuum at 400°C (Figure 3). The quartz emissivity spectrum (black curve) is strongly influenced by its transparency, hence we mostly see the spectrum of the underlying, very hot ceramic cup. This explains its tilted shape and very high signal. The separate mix spectrum (red) is also influenced by the half of the cup containing almost transparent sample, leading to its spectral behavior, especially <0.9 microns. The Leon sample (light-blue) has visual emissivity of a grey body, then it increases slowly when approaching the IR region. The intimate mixture (blue) spectrum is lower than all the others, likely because the quartz grains, embedded in the darker Leon structure, lower the overall emissivity (the sample is brighter than the pure Leon). In this case, we do not see any signal coming from the ceramic cup because the dark Leon material is preventing the quartz component from being transparent in the mixture.

Conclusions: This work is just our first step in the process of understanding emissivity spectra of mixtures in the VNIR spectral range: a massive laboratory activity is already planned. Nevertheless, it highlights the difficulties of calibrating emissivity data acquired under Venus conditions, and serves as a reminder of the importance of careful interpretation of individual spectra.

References: [1] Helbert J. et al. (2023) *This conference*.