PROGRESS ON STUDYING THE SURFACE COMPOSITION OF VENUS IN THE NEAR INFRARED.

J. Helbert[1], A. Maturilli[1], S. Ferrari[2,1], M. D. Dyar[3], N. Müller[4], S. Smrekar[4], [1]Institute for Planetary Research, DLR, Rutherfordstrasse 2, 12489 Berlin, Germany (joern.helbert@dlr.de), [2] Department of Earth and Environmental Sciences, University of Pavia, Via Ferrata 1, 27100 Pavia, Italy, [3]Dept. of Astronomy, Mount Holyoke College, South Hadley, MA 01075, [4]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena CA, 91109

Building on the results presented previously [1] and considering the expected emissivity variation between felsic and mafic minerals with Venera and VEGA geochemical data [2], we have continued our analyses of a set of Venus analog samples. PEL successfully acquired funding from the European Union as part of the EuroPlanet consortium to extend spectral coverage for high temperature measurements down to 0.7 micron. We give here a progress report on the ongoing upgrade and present results of our first test measurements.

The permanent cloud cover of Venus prohibits observation of the surface with traditional imaging techniques over most of the visible spectral range. Fortunately, Venus' CO_2 atmosphere is transparent in small spectral windows near 1 μm. Ground observers have successfully used these windows during the flyby of the Galileo mission at Jupiter and with the VMC and VIRTIS instruments on the ESA VenusExpress spacecraft. Observations have suggested compositional variations correlated with geological features [3-7].

Studying surface composition based on only a small number of spectral channels in a narrow spectral range is very challenging. The task is further complicated by the fact that Venus has an average surface temperature of 460°C. Spectral signatures of minerals are affected by temperature, so comparisons with mineral spectra obtained at room temperature can be misleading.

The Planetary Emissivity Laboratory (PEL): In 2015, PEL installed a new Bruker VERTEX80V spectrometer. Currently two Bruker Fourier transform infrared (FTIR) spectrometers of this type are operated, both located on an optical table and equipped with external chambers for emissivity measurements (**Figure 1**). For this study, a Bruker Vertex 80V optimized for the near to far-infrared spectral range was used. The laboratory is located in a temperature-controlled room at the Institute for Planetary Research in Berlin.

The main feature of the PEL is a high-temperature chamber attached to the Vertex 80V that allows heating of samples to temperatures up to 1000K under vacuum conditions (medium vacuum ≈10-100Pa) [8]. Samples are placed in steel cups equipped with type K thermopiles as temperature sensors. A copper induction coil installed in the chamber and connected to a Linntherm 1.5kW induction system allows contactless heating of ferromagnetic sample cups by induction. Spectral coverage is achieved using a liquid nitrogen-cooled MCT detector and KBr beamsplitter for the spectral range up to 16 μm and a DTGS detector with a multilayer beamsplitter for the remaining spectral range. Main components of the EU-financed upgrades are the InGaAs detector with matching beamsplitter, improved spectrometer electronics, and an optimization of the optical layout in the chamber. Upgrades began in October 2015 and will be completed by the end of 2016.

Laboratory experiments: Building on the results present previously [1] and considering the expected emissivity variation between felsic and mafic minerals with Venera and VEGA geochemical data [5,6] we have continued our analyses of Venus analogs.

Figure 1. New setup at the Planetary Emissivity Laboratory (PEL).

Measuring emissivity at 1 μm at Venus analog temperatures is already very challenging for many reasons. For example, the emissivity of stainless steel increases strongly towards shorter wavelength at high temperatures. This results in a non-negligible contribution to total radiance from our sample cups. At the same time, many natural materials have a high transparency at 1 μm. To solve both issues at the same time, we are currently limiting ourselves to slabbed samples of materials with low transparency that are heated by placing them on a stainless steel disk completely obscured by the sample.

Extending the measurements below 1 μm adds significant new challenges. The main challenge is the very low thermal emission due to the fact that we are on the steep flank of the Planck curve (**Figure 2**). Between 1.18 μm and 0.8 μm the signal drops by more than two orders of magnitude.

Therefore even the use of a steel disk under the slab for heating seems not to be enough. The glow of the steel scattered in the chamber becomes a non-negligible noise term that results in an apparent in-

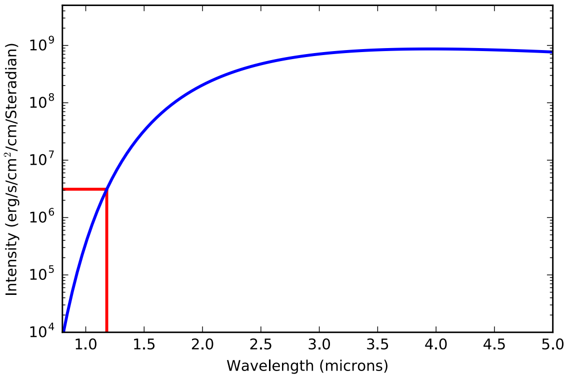

Figure 2: Blackbody curve at Venus surface temperature – within the range covered in our measurements the signal decreases by more than two orders of magnitude

crease of the emissivity around 0.9 µm. We are currently testing a baffling system (**Figure 3**), which improves the situation but cannot solve it completely. Work on this challenge is ongoing.

Figure 3. Current test configuration in the chamber – TOP: Sample at 450°C illuminated by a LED panel in the chamber, BOTTOM: Same scene without additional light.

Still the preliminary results (**Figure** 4) confirm our early measurements for basalt and extend them for the first time below 1 µm. There remains a continuum contribution from the scattered light, which has to be removed by improvements in the setup.

Conclusions: Observing the surface of Venus in the near-infrared requires a dedicated laboratory effort. The atmosphere of Venus dictates which spectral bands on the surface can be observed. This places severe constraints on the ability to identify rock-forming minerals. To complicate matters further, we cannot observe reflectance, as would be the standard at 1 µm. Observations are obtained on the nightside where the thermal emission of the surface is measured directly. Finally, high surface temperature can severely affect the spectral characteristics of the minerals as observed in the mid-infrared [8] and expected from crystal field theory [9,10].

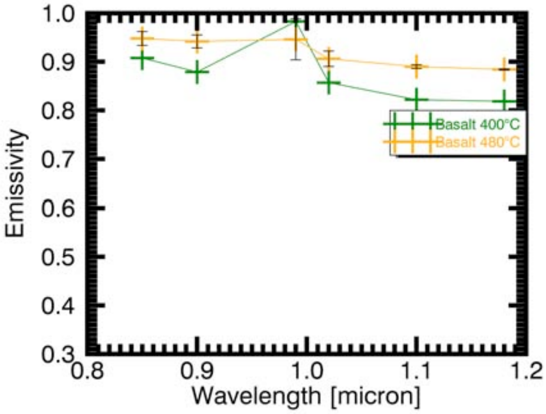

Figure 4: Emissivity of basalt sample in the spectral windows accessible through the atmosphere of Venus**.**

Work in progress at the Planetary Emissivity Laboratory is laying the groundwork for collection of a spectral library for rocks and minerals under Venus conditions. Once acquired, these data will be key in understanding and modeling differences in emissivity between ambient and Venus conditions, potentially enabling calibration transfer between datasets.

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