NEW THERMAL INFRARED LABORATORY EXPERIMENTS AND INSIGHTS FOR THE INTERPRETATION OF SPECTRAL EXOMARS DATA

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Introduction: New spectral orbital data acquired by the ExoMars2016 Thermal Infrared (TIRVIM) [1] spectrometer have the potential to contain valuable information about the surface and atmospheric composition of the Red Planet. Surface composition derived from TIRVIM measurements is highly complementary to existing datasets from OMEGA [2] and CRISM [3] and due to the higher spectral resolution presents an significant improvement on early TES [4] and PFS [5] studies. As with the earlier datasets a major challenge brought by the TIRVIM data is the extraction of the relevant information about the surface and the separation of atmospheric effects. To achieve this goal, we are performing new laboratory experiments on Martian analogs: a library of new thermal infrared spectra of Martian analog materials and mixtures of them is prepared optimized for the interpretation of spectral TIRVIM data.

The measurements are performed at the Planetary Spectroscopy Laboratory (PSL) of the German Aerospace Center (DLR) in Berlin [6]. Emissivity measurements, recorded at increasing temperatures, are coupled with reflectance measurements on fresh and thermally processed samples. Deconvolution techniques of laboratory emissivity spectra are studied for the investigation and interpretation of atmospherically corrected TIRVIM spectral data.

Data and methods: The methodology applied in this work is based on two main steps: 1) new laboratory emissivity and reflectance measurements on Martian analog materials in the TIR spectral range; 2) use of deconvolution techniques on emissivity laboratory spectra for the analysis of atmospherically corrected TIRVIM surface spectra.

1. Laboratory measurements

The suite of samples selected for this work includes pure end-member minerals that most closely represent class of minerals detected on the Mars' surface using OMEGA and CRISM data [e.g. 2, 7, 8]. Martian analogues including clays, silicates, carbonates, oxides and sulphates are measured in different configurations: emissivity at different temperatures, hemispherical reflectance and bi-directional reflectance.

Measurements are taken using the suite of instruments at PSL:
- emissivity measurements are recorded in vacuum by using an external emissivity chamber designed at DLR to work from 1 to 150 μm, with a high SNR for sample temperatures ranging from ~ 300 to ~ 1000 K. The external chamber is attached to a Bruker Vertex80V FTIR spectrometer;
- hemispherical measurements are recorded by using a gold-coated integration-sphere adapted for vacuum measurements that fits into the internal sample compartment of the same spectrometer;
- bidirectional reflectance measurements are acquired by using two of the Bruker Vertex80V FTIR spectrometers at PSL and a Bruker A513 variable-angle accessory that allows bi-conical reflectance measurements for varying viewing geometry with different phase angles. For this work we choose the following angles configuration: i (incidence) = 0°, e (emission) = 30°.

Emissivity measurements are taken in "Mars-like'' pressure conditions in the emissivity chamber. Samples are heated and measured in emissivity at increasing T, then cooled down to current average Martian temperatures and measured in bidirectional and hemispherical reflectance. A scheme of the measurements protocol is shown in **Figure 1**.
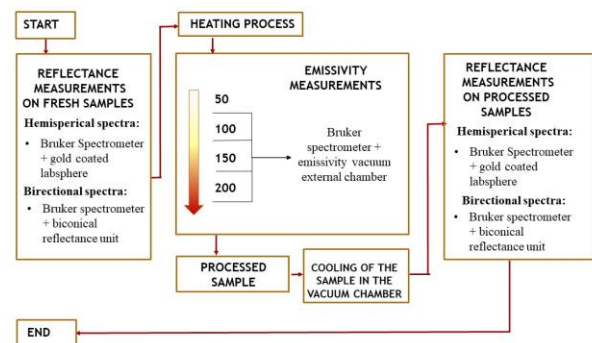

Figure 1. Scheme of the measurements protocol

2. Laboratory data analysis

Emissivity data are calibrated against a blackbody measured at the same temperature and compared with 1-R retrieved spectra. The effect of several parameters (such as grain size, composition, temperature and mixing) on emissivity and reflectance spectra of our samples has been investigated. A study of such parameters is conducted during and after the measurements, to establish detection limits and behavior of mineral mixtures of fine particulates in the thermal infrared portion of the spectrum.

Particular attention has been so far focused on the analysis of carbonates and phyllosilicates pure and

mixed spectra. The spectral behavior of carbonates diagnostic absorption features in mixture with phyllosilicates has been studied (in relation also with T and grain size variations) isolating the band for each sample and measurement collected. Each absorption band has been isolated by fitting and removing the spectral continuum. Spectral parameters as band center, band depth, band area and full width half maximum have been evaluated.

In **Figure 2**, an example of calibrated measurements is shown along with pictures of the samples in the emissivity chamber.
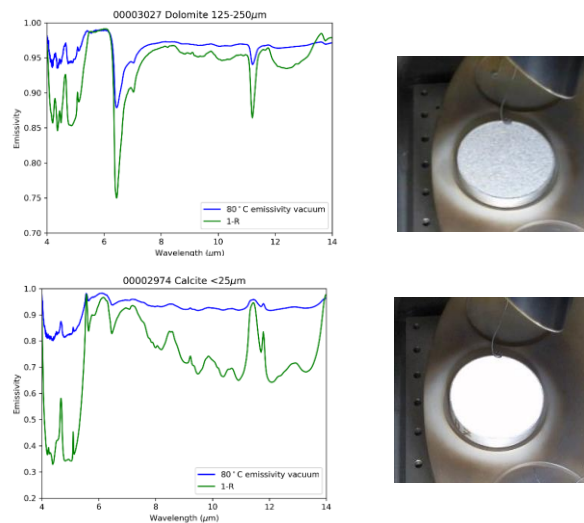

Figure 2. Left: Comparison between emissivity measured in the vacuum chamber at T=80°C and emissivity retrieved from hemispherical reflectance measurements performed at T ambient for dolomite 125-250 µm (up) and calcite < 25 µm (bottom) samples. **Right:** Pictures of two samples in the emissivity chamber taken during the measurements.

3.   Orbital data analysis

The production of laboratory spectra is used for fitting the orbital spectra by means of deconvolution techniques. In particular, two methodologies are here investigated:

1) direct comparison of Martian surface spectra with laboratory thermal emission spectra of terrestrial rock samples. This approach can be used to provide a good estimate of the bulk composition. This technique may be difficult because surfaces may be mixtures of minerals.

2) linear deconvolution of surface emissivity spectra of mineral endmembers to reproduce their behavior in a mixture.

Preliminary results and implication for the analysis of TIRVIM Martian orbital data: The measurements

and data analysis performed in this work are thought in the framework of the Mars Express and ExoMars 2016 missions, and in preparation for the up-coming in-situ measurements of the ExoMars 2020 rover.

The results so far obtained show that:

1. The presence of the phyllosilicate component in our laboratory spectra can strongly decrease the intensity of the main carbonates spectral bands in the TIR;

2. Spectral parameters retrieved for the main carbonates spectral bands (v_1, v_2, v_4) shows that those bands decrease when the phyllosilicate is the fine component, while they dominate the spectrum when the carbonate is the finest one;

3. Grain size of the two components strongly influence and change the appearance of the main carbonates spectral features (especially in emissivity spectra);

4. Deconvolution of end-member spectra are acceptable reproduction of laboratory mixtures spectra (see **Figure 3**)
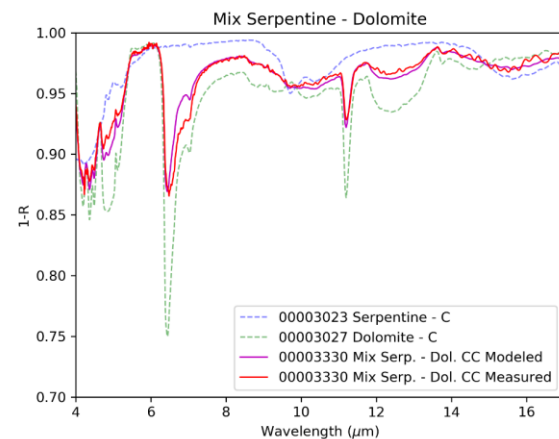

Figure 3. Comparison between pure end-member emissivity spectra of serpentine and dolomite (125-250 µm) and their mixture along with de-convolved spectrum of pure end-members measurements.

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