ANALYSIS OF THERMAL INFRARED SPECTRAL ORBITAL AND LABORATORY DATA FOR PLANETARY SURFACES COMPONENTS RETRIEVAL

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Introduction: Retrieving the mineralogy of a planetary surface from orbital spectral data is a key for investigating its history and evolution. Each orbital spectrum is a mixing of several components: an accurate study of it can lead to the detection of substances that could not otherwise be distinguished at the spatial resolution of the measurements [1]. In addition, as planetary observations and instrumentation become more diverse and sophisticated, many laboratory studies are needed to support the interpretation of these ever-expanding data sets. The analysis of the Thermal InfraRed spectral region (TIR) has a huge potential: it provides a large amount and wide variety of information on the composition, temperature and state of the surface and the atmosphere as well as their interaction. In addition, the study of thermally altered minerals is essential for the analysis of spectral orbital data. Altered materials are found, in fact, on many planetary bodies, because of high surface temperature (Mercury), orbit closer to the sun (asteroids), thermal evolution, impacts, volcanism. For these reasons, we are developing an extreme flexible methodology for the surface component retrievals of planetary bodies from the TIR spectra that will take into account very different conditions: presence/absence of an atmosphere, cold/hot environments.

Data and methods: The proposed methodology is based on two steps: 1) a good atmospheric removal, for the study of planetary objects with an important atmosphere; 2) use of deconvolution techniques of emissivity laboratory spectra, applicable also to atmosphereless bodies. This method is applied to two extreme cases: the cold and atmospheric Mars and the very hot and atmosphereless Mercury.

1. Atmospheric removal

An algorithm for separating the spectral signatures of the surface and atmosphere from spectral orbital data is developed and applied to Mars and Mercury orbital spectral data. In the case of Mars, surface mineralogy derived from TIR measurements is highly complementary to existing datasets from OMEGA and CRISM [2, 3] and due to the higher spectral resolution will significantly improve on early TES and PFS studies [4, 5]. For this purpose, we use newly calibrated data from the Thermal-Infrared channel (TIRVIM) of the Atmospheric Chemistry Suite (ACS) onboard of the Trace Gas Obiter (TGO), ExoMars 2016 mission [6]. Improved recalculated geometries for the observations are applied to the data.

In order to recalibrate the orbital data a new SAS (Surface-Atmosphere-Separation) algorithm is implemented based on a combination of R-mode factor analysis and target transformation. By means of target transformation and factor analysis techniques spectral orbital data can be modelled as a combination of atmospheric endmembers and a residual superficial component. A first application of multivariate techniques to PFS data showed that each spectrum can be well reconstructed by a linear model using only a limited set of endmember spectra identified by means of a target transformation technique [7].

2. Deconvolution of emissivity laboratory spectra

Once all the atmospheric endmembers are identified and characterized, for each orbital spectrum, the residual of this fitting algorithm identify the surface spectral shape. This curve is again fitted by using a linear deconvolution of emissivity spectra for planetary analogue minerals measured at DLR-PSL (Deutsches Zentrum für Luft- und Raumfahrt - Planetary Spectroscopy Laboratory) to assess the surface mineralogical composition of the area under examination [8] (**Figure 1**).

Figure 1. Picture of the laboratory set-up at PSL https://www.dlr.de/pf/desktopdefault.aspx/tabid-10866/19013_read-44359/

The use of the PSL allows the access to a wide collection of samples and measurements that are used to build an improved spectral library, which is then applied to the orbital data.

The PSL laboratory is the only spectroscopic infrastructure worldwide that offers the opportunity to measure emissivity of fine-grained powders, bulk materials and coatings at temperatures from ~ 30°C up to more than 700°C across the whole infrared wavelength range [9].

A study of parameters influencing the spectral behavior of laboratory particulate pure samples and mixtures 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.

This second step based on the production of laboratory spectra for the fitting of orbital spectra by means of deconvolution techniques is applied to the study of Mars and Mercury surfaces and it involves the study of thermally altered materials.

Importance of the two extreme cases of study: In the case of Mars, is helpful to study thermally altered phyllosilicates. Previous studies seem to suggest that thermal alteration of phyllosilicates induced by impact shock or other heat sources might be a widespread process throughout the Martian history [10]. The possible presence of thermally altered phyllosilicates can be related to the post-depositional thermal alteration of Martian sediments as a key component of understanding past Martian aqueous alteration history. Our study is a key for the geological and spectral characterization of the Martian surface and will be useful to determine whether the Red Planet ever had long-term environmental conditions able to support life.

In the case of Mercury, the PSL facility allow measurements of materials in simulated Mercury conditions that will be used for the interpretation of MESSENGER (Mercury Surface, Space Environment, Geochemistry, and Ranging) orbital data [11] and in preparation for the data of the MERTIS (MErcury Radiometer and Thermal infrared Imaging Spectrometer) instrument (BepiColombo mission) [12].

The main objectives of this work are:

- Development of an extreme flexible methodology for surface retrieval from orbital spectral data;
- Use of the information about the surface mineralogy to map the potential habitability of Mars;
- Retrieving the surface mineralogy of Mercury;
- Carrying out a unique laboratory work on planetary analogues materials.

The measurements and the methodology described are thought in the framework of the Mars Express and ExoMars 2016 missions, and in preparation for the upcoming in-situ measurements of the ExoMars 2020 rover; and of the MESSENGER and BepiColombo missions.

Summary: In this work, a new methodology is applied for the surface components retrieval of planetary bodies. The applied methodology is based on a good atmospheric removal, for planetary bodies with an important atmospheric contribution and on the study of thermally altered materials for very hot and/or thermally altered planetary surfaces.

This work have a scientific impact in three main fields:

1) it is a key for the geological and spectral characterization of the Mercury and the Martian surface and will be useful to determine whether Mars ever had long-term environmental conditions able to support life.

2) it allow the development of a methodology that could be adapted for the application to other planetary objects. The algorithm for atmospheric removal from orbital spectra can be used to study objects with an important atmosphere. Linear deconvolution of emissivity laboratory spectra may be used to retrieve the modal mineralogies of a variety of rock samples and can be applied to the analysis of several planetary surfaces, from cold Mars to very hot Mercury.

3) the access to the PSL, with its unique capability of measuring spectra over a wide temperature and wavelength range, allows building a spectral library for the interpretation of planetary surfaces from orbital data.

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