SPECTRAL ATMOSPHERIC END-MEMBERS RETRIEVAL FROM EXOMARS THERMAL INFRARED (TIRVIM) DATA.

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Introduction: Thermal infrared spectral data from planetary bodies provide a powerful tool for studying their atmospheric and surface composition. The thermal infrared spectra contain a large amount and wide variety of information on composition, temperature and state of the atmosphere. In addition, surface properties and the surface-atmospheric interaction can be studied. Accurate interpretation of these spectra requires a careful identification and separation between atmospheric and surface components. A methodology based on factor analysis and target transformation techniques was applied to the thermal infrared data of the ExoMars2016 Trace Gas Orbiter (TGO) to retrieve the different contributions present in the spectra. TGO has a suite of spectroscopic instruments for the investigation of the Red Planet in the infrared spectral range known as Atmospheric Chemistry Suite (ACS) [1] consisting of three spectrometers observing Mars in solar occultation, nadir and limb geometry in the Near-InfraRed (NIR), Mid-InfraRed (MIR) and Thermal InfraRed (TIR) spectral channels. Among them, the ACS thermal-infrared channel (TIRVIM) covers the spectral range between 1.7-17 μm with apodized resolution varying from 0.2 to 1.3 cm^{-1} [1]. TIRVIM has similar capabilities to IRIS (Mariner 9), TES, and PFS in several aspects, but has some advantages: - higher spectral resolution; - better noise equivalent radiance (from 0.08 mW/m2/sr-1/cm-1); - dense spatial coverage (TGO has a circular orbit of 400 km) [1]. The main goal of this study is to process and interpret this dataset to extract the relevant information about the Martian surface and atmosphere.

Methodology: The first step of our work focuses on characterizing the atmospheric contributions that can be extracted from the TIRVIM data. To analyze the ExoMars TIRVIM data and retrieve and characterize the number of varying atmospheric components present in these data and their spectral shape, a methodology was applied based on a combination of R-mode factor analysis and Target Transformation (TT) techniques [2, 3]. These techniques are demonstrated to be able to extract the composition of laboratory samples [4, 5]; to extract the principal varying components from a big spectral dataset in the thermal infrared [3], and then to identify them as components of the atmosphere and separate their contribution from surface emission [6]. This methodology, previously successfully adopted for the analysis of TES and PFS data [2, 7, 8], was, here, applied for the first time to the analysis of the new and at higher spectral resolution TIRVIM dataset.

Application to TIRVIM data: Martian TIRVIM spectra acquired along the orbits that cross Elysium Planitia, landing site of the NASA's Insight (Interior exploration using Seismic Investigations, Geodesy and Heat Transport) lander, were here analyzed, for possible future comparison with Insight data. Considering that the PCA works best when the different components have significant variation in the data, we selected data where these variations are more likely to occur. In fact, the analyzed data covers a diurnal as well as seasonal variation. The selected data orbits span from Ls=150°C to Ls=210°C, covering part of the Martian summer and of the Martian autumn going through the autumn equinox in the northern hemisphere of the planet. Corresponding Local Times (LOCT) covers Martian days and Martian nights (see Fig. 1).

Applying the PCA and a smoothing function to the data[1], it was possible to successfully extract the independent eigenvectors of the dataset and to verify that the TIRVIM data can be effectively described as a linear combination of the recovered general TIRVIM atmospheric end-members. Each TIRVIM spectrum was compressed from 695 component or wavelength to 20 principal components coefficients, preserving 93% of the original data variance. Analyzing the principal eigenvectors, we could select some capturing the variations in the data associated with the presence of water ice and dust in the Martian atmosphere.

After applying the PCA, a list of PFS and TES atmospheric end-members extracted from [3] and [2] were used as initial guesses for the TT, to interpret the abstract eigenvectors retrieved from the PCA and attribute them a physically coherent meaning.

The PFS and TES retrieved atmospheric end members used are:

- DUST_HIGH_CO2_TES: endmember retrieved from PFS [3] PCA+TT based on TES [2]. Atmospheric dust emissivity with high pressure [2] (on Mars mainly CO2).

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- DUST_LOW_CO2_TES: atmospheric dust emissivity with low pressure [2] (on Mars mainly CO2).
- WATER_ICE_CLOUD_HI_LAT_TES: atmospheric water ice emissivity at high latitudes [2].
- WATER_ICE_CLOUD_LO_LAT_TES: atmospheric water ice emissivity at low (equatorial) latitudes [2].
- PUREGAS_SYN: calculate pure Mars atmospheric gases (mainly CO2, H2O).

Results and discussion: In this paper, we present the first application of PCA and TT techniques to a sample of TIRVIM data. Comparisons between the results obtained here from TIRVIM data and those previously obtained on PFS and TES data are showed in **Figure 1**. These results validate the method used and show that it is capable of determining the number of independently variable components and recovering the spectral endmembers present in the TIRVIM data. The spectral shapes of atmospheric dust and water ice aerosols were recovered. Moreover, the analyzed data appear to contain a small surface contribution. We plan to investigate this point in our upcoming work to show that this method has the potential to extract valuable information from TIRVIM data not only about the atmosphere, but also about the surface of the Red Planet. Derived surface emissivity products will be analyzed by linear deconvolution analysis with the laboratory spectral database of Martian analogues measured at the Planetary Spectroscopy Laboratory (PSL) of DLR, in Berlin [5].

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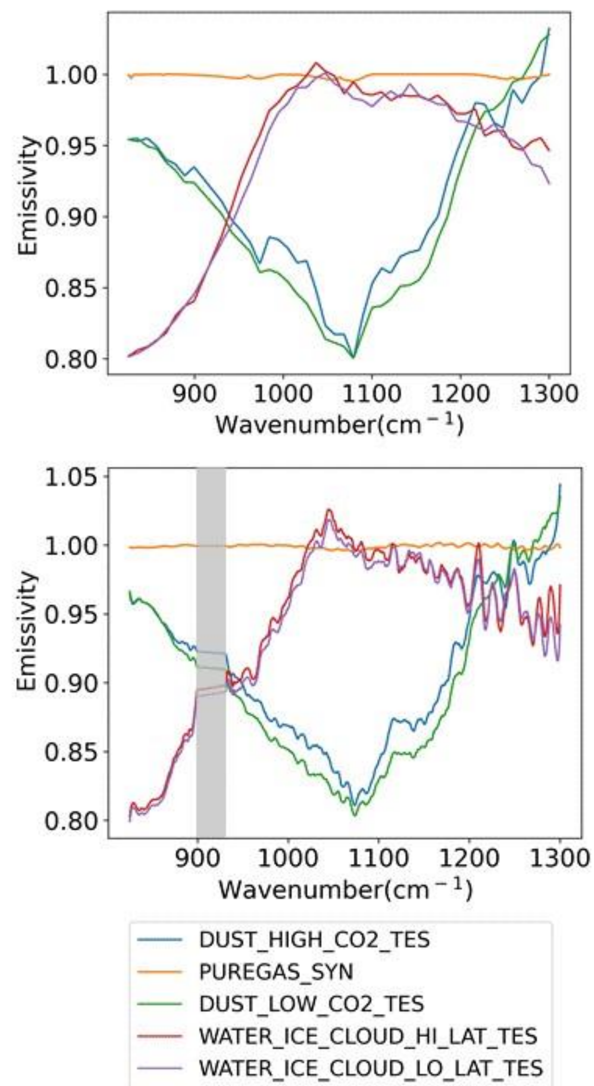

Figure 1. Comparison between the general TES/PFS extracted endmembers [2, 3] (upper panel) and the endmembers extracted from the TIRVIM data in this work (bottom panel). Grey area: wavelength cut due to high instrumental noise.