EPSC Abstracts
Vol. 12, EPSC2018-242, 2018
European Planetary Science Congress 2018

Analysis of spectral orbital and laboratory data to further constrain Martian habitable environments

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Abstract

A large amount and a wide variety of information can be retrieved from the study of the thermal emission and reflectance spectra of a planetary object. An analysis of spectral orbital and laboratory data is used to create a map of the Martian surface showing the global distribution of potential habitable regions. This will be of highest interest to future Mars missions and it will be a key to further investigate the history and evolution of the planet. To achieve this goal, the surface mineralogy of the planet is retrieved implementing an advanced method for separating the spectral signatures of the Martian surface and atmosphere. The global distribution of potential habitable regions of the Martian surface will be mapped based on the analysis of the presence, type and abundance of aqueous alteration minerals observed in orbital spectral data.

1. Introduction

Understanding the history of water on Mars is of fundamental importance to disclose the evolution of its surface and atmosphere and its potential habitability. In particular, the mineralogical record provides significant clues on the geochemical environment and aqueous history of the planet. Evaporites, clays and other sedimentary rocks can prove the presence of liquid water environments during the Martian history on or near the surface. The mineralogical information, placed in its geological context, will allow to reconstruct the processes of formation of several structures observed on the Martian surface (i.e. fluvial structures such as valley networks, paleolakes and sedimentary deposits), which involve the chemical action of liquid water. Such kinds of processes have been sometimes responsible for the conditions of habitability on Earth, and this may be the same on Mars.

Much knowledge of Mars mineralogy relies on data collected remotely, using infrared spectroscopic tools [1,2,3]. Molecular lattice vibrations lead to distinctive minima, diagnostic of composition, in electromagnetic radiation thermally emitted from the surface [4]. Similarly, in the visible and near infrared wavelengths sunlight reflected from the surface of Mars has also characteristic features at certain wavelengths that are diagnostic of the surface composition [1]. Therefore, thermal and reflectance spectra contain a lot of information about the surface composition of a planet and its mineralogy, allowing building a picture of a planet's surface.

Nearly every mission to Mars has onboard an instrument devoted to spectroscopy. This includes instruments like Thermal Emission Spectrometer (TES) onboard Mars Global Surveyor [5], the imaging spectrometer Observatoire pour la Mineralogie, l'Eau, le Glace e l'Activite (OMEGA) [6] and the Planetary Fourier Spectrometer (PFS) [7] onboard Mars Express, and the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) onboard Mars Reconnaissance Orbiter [8] that provide remote measurements of mineralogy and thermophysical properties of the Martian surface.

But the interpretation of these data is often difficult and requires a big effort from the scientific community. This variety of information presents the complicated problem of isolating each of the atmospheric and surface components and determining their relative contribution to the measured radiance. The aim of this work is the use of a new surface-atmosphere algorithm to allow both surface and atmospheric contribution retrievals with the main goal to investigate the potential habitability in the history of Mars mainly through the identification of hydrated minerals (such as phyllosilicates, hydrated silica) and evaporites (such as carbonates, sulfates and chlorides).

Some works suggest, in fact, that aqueous alternation minerals, such as phyllosilicates, could have played a key role not only the origin of life on Earth [9] but also in the preservation of biosignatures [10]. For this reason, phyllosilicate regions on Mars may represent very interesting environments that can provide conditions favorable to preserving evidence of biomarkers [9, 10, 11].

However, the orbital spectra can only be interpreted by means of comparisons with those of planetary analogue samples, prepared and analyzed in laboratory. For this reason, an ongoing and detailed laboratory work on Martian analogues materials is planned for the best interpretation of spectral orbital data. Therefore, the main objectives of this work are:

- Mapping of the potential habitability of the Red Planet;
- Development of a good methodology for surface and atmospheric retrieval from orbital spectral data;
- Carrying out a unique laboratory work on planetary analogues materials.

2. Data and methods

To achieve the objectives discussed in the previous section, new detailed surface mineralogy is derived from the so far largely unexplored Mars Express PFS dataset. Surface mineralogy derived from TIR measurements is highly complementary to existing datasets from OMEGA and CRISM and due to the higher spectral resolution will significantly improve on early TES studies. For this purpose, we use newly calibrated PFS data and improved recalculated geometries for the observations.

In order to recalibrate the PFS data a new SAS (Surface-Atmosphere-Separation) algorithm will be implemented based on a combination of R-mode factor analysis and target transformation. By means of target transformation and factor analysis techniques PFS data can be modelled as a combination of atmospheric endmembers and a residual superficial component. A first application of multivariate techniques to PFS data confirmed that they can be fully represented by a linear model using only a limited set of end-member spectra identified by means of a target transformation technique [12]. R-mode factor analysis and target transformations were also applied to PFS measurements in the same region where OMEGA detected the phyllosilicates on Mars to retrieve and characterize the number and the spectral shape of the varying component present in the spectra [13]. Once all the atmospheric endmembers were identified and characterized, for each PFS measured spectrum, the residual of this fitting algorithm identify the surface spectral shape. This curve was again fitted by using a linear deconvolution of emissivity spectra for Martian analogue minerals measured at DLR-PSL (Deutsches Zentrum für Luft- und Raumfahrt - Planetary Spectroscopy Laboratory) [14]. The use of the PSL allows the access to a unique collection of samples and measurements that are used to build an improved spectral library, which is then applied to the PFS data. The application of this technique will be improved and extended to the entire PFS dataset.

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.

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