EPSC Abstracts
Vol. 10, EPSC2015-463, 2015
European Planetary Science Congress 2015

Description of CoTCAT (Complement To CRISM Analysis Toolkit) and data reduction suite for CRISM

B. Bultel, C. Quantin and L. Lozac'h
Laboratoire de Géologie de Lyon: Terre, Planètes, Environnements, Université Lyon 1, ENS Lyon, CNRS UMR 5271, Villeurbanne, 2, rue Raphaël Dubois, 69622 Villeurbanne cedex, France. **Corresponding author:** Benjamin Bultel, +33472446235, benjamin.bultel@univ-lyon1.fr

Abstract

CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) hyperspectral data have a spatial resolution ranging from 12 to 36m/pixel allowing the high resolution mapping of minerals at the surface of Mars. However, the signal-to-noise ratio (SNR) makes challenging the discrimination of minerals spectrally close such as certain phyllosilicates and carbonates. Here, we discuss different processing of data reduction used to improve the signal-to-noise ratio and to highlight the alteration minerals at the surface of Mars and their limit. We show that our tool allows to understand trends in global mineralogy present in hyperspectral data cube.

1. Introduction

CRISM on-board MRO (Mars Reconnaissance Orbiter) is a visible to near-infrared hyperspectral imaging spectrometer between 0.4-4.0 µm with a spectral resolution of 6.10^{-3} µm. We here use the Targeted Data mode that acquires data at spatial resolutions ranging from 12 to 36m/pixel. The S detector samples wavelengths from 0.4 to 1.0 µm (107 channels), and the L detector samples wavelengths from 1.0 to 4.0 µm (438 channels) [1]. The NIR domain is often used to detect the hydrated minerals on the surface as they have characteristic absorptions between 1.9 µm and 2.6 µm [1].

CAT (CRISM Analysis Toolkit) is a pipeline developed by the CRISM Team that allows the correction of the photometric effects, the atmosphere contribution and the first order noise [1, 2, 3 and 4]. Even after those processing, it is still challenging to discriminate different minerals with slight spectral difference like alteration mineral [5, 6 and 7]. We present a processing of data reduction to use as a complement of CAT to remove the noise still present in the data after the use of CAT. We present here this method and its tests on synthetic data cube built with artificially noised spectra from spectral library. We then applied ratioing method to highlight the main absorption present in the spectra. It allows us to use a trend tools to understand the global mineralogy present in the cube.

2. From CAT to CoTCAT

We use CAT to preprocess the CRISM data. It first applies a photometric correction [1]. Then, it corrects contribution of the atmosphere [2 and 3]. CAT also includes a filtering tool (CIRRUS: CRISM Iterative Recognition and Removal of Unwanted Spiking) that first remove the outlying values along the spectral dimension named as spectral spike [4]. The filtering tool also removes the spatial stripes by the median of neighbour values in the spatial dimension. Even after these processing, data are still noisy especially the ones acquired after several years around Mars and there is often a remaining spectral contribution of the Martian atmosphere.

We design a noise removal pipeline to be used after CAT preprocessing to denoised and smooth the data. It consists in the application of three successive filters: the sharpening-median filter, a mobile median and a mobile average filter [8]. The mobile average is used to smooth the signal, but this filter is sensitive to isolated value (spike). We so use a median filter before which is supposed to be less sensitive to isolated values. We start with a sharpening-median filter which function is to detect the isolated value and replace them. This filter is so the less sensitive to isolated values allowing afterwards the use of the mobile median and the mobile average.

3. Ratioing methods

The remnant contribution of atmosphere, the presence of dust and the existence of instrumental artifacts still bother the study of any CRISM cube. Ratioing methods are used to remove their contributions [1 and 6]. The most usual method is to use as denominator a spectrum judged by the user as spectrally neutral when possible in the same column of detector as the target spectrum [6 and 9]. This method has the disadvantage to be manual and to possibly introduce a bias. We investigate different way of automatic ratioing method of a CRISM data cube. First, we analyze the use of the median spectrum of the whole data cube as denominator. Then, for comparison, we process to the automatic ratio of the data cube by the median spectrum of each column that is supposed to remove the detector dependent effects, or the smile effect [1]. In some case, the median spectrum on each column is not spectrally neutral. We so developed an automatic tool to search for the most spectrally neutral spectrum of each column of detector. On each column, the spectrum with the less variation of reflectance channel by channel is selected to be the denominator for the column.

A comparison of the different ratios allows us to conclude that they are all efficient to highlight alteration minerals but that their use for interpretation of the global shape of the spectrum may by strongly affected by the shape of the denominator [1] while it may be more challenging for mafic mineral that have efficient way to highlight the surface.

4. Trend tool

Alteration minerals such as phyllosilicates carbonates, zeolithes, ferric oxydes, mono- and poluyhydrated sulfates have different diagnostic combinations of absorptions. We built a tool that (1) can found the two main absorptions on all the spectra of a CRISM cube; (2) remove the continuum and (3) determine the exact centres of absorptions. The results are plot in a graphic that discriminate different mineral phase.

It allows us to understand trends in global mineralogy present in the cube studied. This tool is not claiming to conclude on the mineralogy present in a data cube but is a powerful guideline for the spectral analysis.

4. Discussion and conclusion

The denoising tools, the ratioing methods and the data reduction tool present have been tested on library spectra artificially noised and on CRISM data, these results will be presented. We suggest here a simple tool of noise removal to be used as a complement to others noise removal techniques. Our tests reveal the relevance of our tools until SNR as low as 20. We have compared the analyze of CRISM data cube with and without our complement tools. We have demonstrated that the use of our tools greatly improves the mineral mapping technique using band depth map computation but that quantitative data processing must be carried out with care due to the decrease of the spectral fidelity. This tool could be a valuable support to Martian local geological investigation such the ones required for the landing sites selection of robotic missions.

Acknowledgements

The research leading to these results has received funding from the European Research Council under the European Union's Seventh Framework Program (FP7/2007-2013)/ERC Grant agreement n° 280168.

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