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Investigation of a small set of hyperspectral images through non-negative source separation

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Abstract

1. Introduction

In typical hyperspectral images encountered in Earth and Planetary Sciences, the spatial extent of a pixel is usually large enough to contain a mixture of various surface/atmospheric constituents which contribute to a single pixel spectrum. Unsupervised spectral unmixing [1] aims at reconstructing the spectral signatures of materials present in an image and at estimating their abundances in each pixel (Fig. 1). Bayesian Prior Source Separation (BPSS) [2] is an interesting way to deal with this unmixing challenge under linearity constraints.

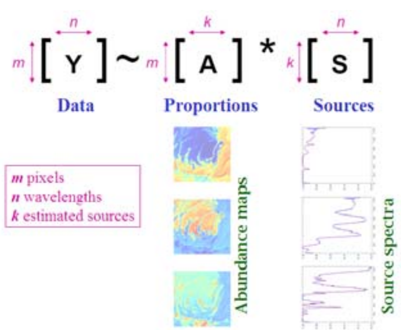

Figure 1: The non-negative source separation issue in the case of hyperspectral data.

2. Method

The BPSS algorithm notably ensures the non-negativity of both the unmixed component spectra and their abundances. This constraint is crucial to the physical interpretability of the results. A sum-to-one constraint can also be imposed on the estimated abundances [3] (its relevance depends on the nature of the dataset under consideration). Thanks to adequate implementation strategies [4], computational issues (due to the large size of the data and to the nature of the algorithm) have been overcome, and a pixel selection method, performed as a pre-processing step, also allowed to reach significantly lower computation times without inducing a strong loss of quality as regards the estimation of the sources. As this selection aims at extracting a few especially relevant pixels among all the image pixels (selection method used here: convex hull [5]), it also contributes to the identification of the most pure sources present in the analyzed image.

After performing tests on synthetic datasets (generated by linear mixing of known mineral endmembers) in order to better understand the limitations of this approach [4], the method has been applied on real planetary datasets. Pertinent results have been obtained for data coming from instruments onboard planetary spacecrafts such as OMEGA (Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité, onboard Mars Express) [4], VIRTIS (Visible and Infrared Thermal Imaging Spectrometer, onboard Venus Express) [6] and CRISM (Compact Reconnaissance Imaging Spectrometer for Mars, onboard Mars Reconnaissance Orbiter) [7]. Overall, results gathered in those different cases proved the ability of the BPSS approaches to provide an insight in the analysis of different planetary hyperspectral datasets.

3. Results for a small collection of VIRTIS images

A possible next step is the processing of a collection of images coming from the same dataset, acquired in sufficiently similar conditions and covering similar or contiguous areas of the planetary body under consideration. We will investigate if and how the sources estimated by analyzing these hyperspectral images can be related to each other and if this could contribute to a better interpretation of the results and help to obtain a synthetic view of the spectral diversity within the collection of images.

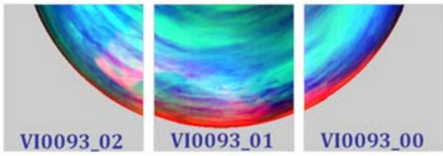

Figure 2: Example of set of consecutive VIRTIS images (256*256 pixels) analyzed with BPSS. Here they are displayed in false colours (R:1.27µm, G:1.75µm, B:3.93µm). Latitudes range from about 0° (limb) to 60°S (upper part of the middle picture). Sky background has been removed (only pixels with an elevation above surface layer < 200 km were kept).

We analyzed small sets of successive VIRTIS images (see example with 3 images on Fig. 2). The VIRTIS instrument [8] (onboard Venus Express) provides spectral signatures relative to the dense Venusian atmosphere. Sources estimated when analyzing a single image appear to correspond to distinct atmospheric layers [6]. For each image several runs of BPSS were performed, attempting at estimating a certain number of sources. Then, the sources estimated on the different images were collected, and a classification of these sources was performed through hierarchical clustering (Fig. 3) in order to see which sources could be related to each other, from one image to another.

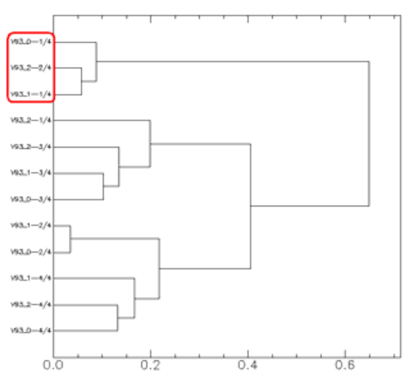

Figure 3: Dendrogram showing the hierarchical clustering performed on the set of sources obtained for the different runs, for the 3 images under consideration (Fig.2), attempting at estimating 4 sources with BPSS. Sources plotted on Fig. 4 are highlighted in red.
Spectrum-spectrum distances = correlative distances
Cluster-cluster distances = average linkage distances

A good source-to-source matching between the different analyzed hyperspectral images was not systematically obtained, but was possible for some of them, such as the source unambiguously corresponding to the O_2 glow in the high atmosphere (Fig. 4).

A more detailed analysis of the results will include a comparison with results obtained for VIRTIS data through another statistical approach: ICA (Independent Component Analysis) [9].

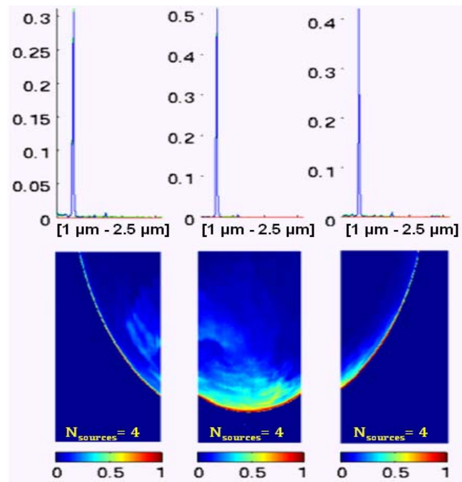

Figure 4: Similar sources obtained on different images (cf. Fig. 2) for runs attempting at estimating a same number or sources (here: 4). These sources are highlighted in red on Fig. 3.

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