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Modelling the Phobos MRO/CRISM dataset in the 0.5-2.5 μm range with multiple optical constants

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Abstract

The Phobos origin remains the subject of scientific discussion. There is no definitive evidence if it is a captured asteroid or if it formed in situ around Mars. Recently, the JAXA Mars Moon eXploration (MMX) mission has been approved as the next Japanese flagship mission, with the main aim of solving this puzzle by sampling the surface of Phobos and returning the samples back to Earth for analyses by 2029. Nevertheless, before waiting for such important future analysis, the Mars Reconnaissance Orbiter (MRO) CRISM dataset still remains a fundamental means to study Phobos surface mineralogical composition.

We use the CRISM 0.5 – 2.5 μm dataset obtained on 10/23/2007 when Phobos was on the dark side of Mars. The data were obtained with a phase angle of 40° and a scale of 356 m/pixel. The photometric incidence (i) and emission (e) were calculated from the 3D shape model of [1] by using the SPICE kernels MRO-Phobos geometric information [2]. We then computed the Lommel-Seeliger disk function for each CRISM Phobos pixel:

$$D(i,e) = 2\cos(i)/\cos(i)+\cos(e).$$

The CRISM corrected dataset is then obtained by dividing the I/F images by D. In our analyses, the photometrically corrected regions with angles larger than 80° are excluded.

After eliminating the bad pixels and lines we applied a statistical clustering over the entire dataset (0.5-2.5 μm) using a K-means partitioning algorithm previously developed [3] and applied to various data [4, 5]. The algorithm uses the Calinski and Harabasz criterion [6] to find the intrinsically natural number of clusters, making the process unsupervised. A natural number of seven clusters was identified within the CRISM Phobos dataset, as shown in Fig. 1. Each resulting cluster is characterized by an average spectrum (Fig. 2), and its standard deviation.

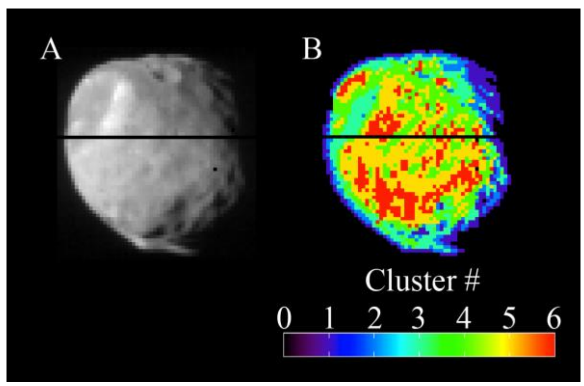

Fig. 1: A) The CRISM original I/F Phobos dataset. B) The seven clustering classes identified by statistical clustering.

This approach has been previously applied for compositional interpretation of different Solar System objects, e.g. asteroids, Mars, Mercury and Iapetus [7, 8, 9, 10]. The algorithm is agnostic of the physical meaning of the resulting clusters, and scientific interpretation is required for their subsequent compositional evaluation.

Shkuratov's model [11] was used for compositional interpretation of Phobos spectra. The model calculates the albedo of a powdered surface from the optical constants of candidate materials. We started the modeling using the materials suggested by Pajola et al. [12] that include Tagish Lake meteorite [TL, 13] and Mg-rich pyroxene glass [PM80, 14].

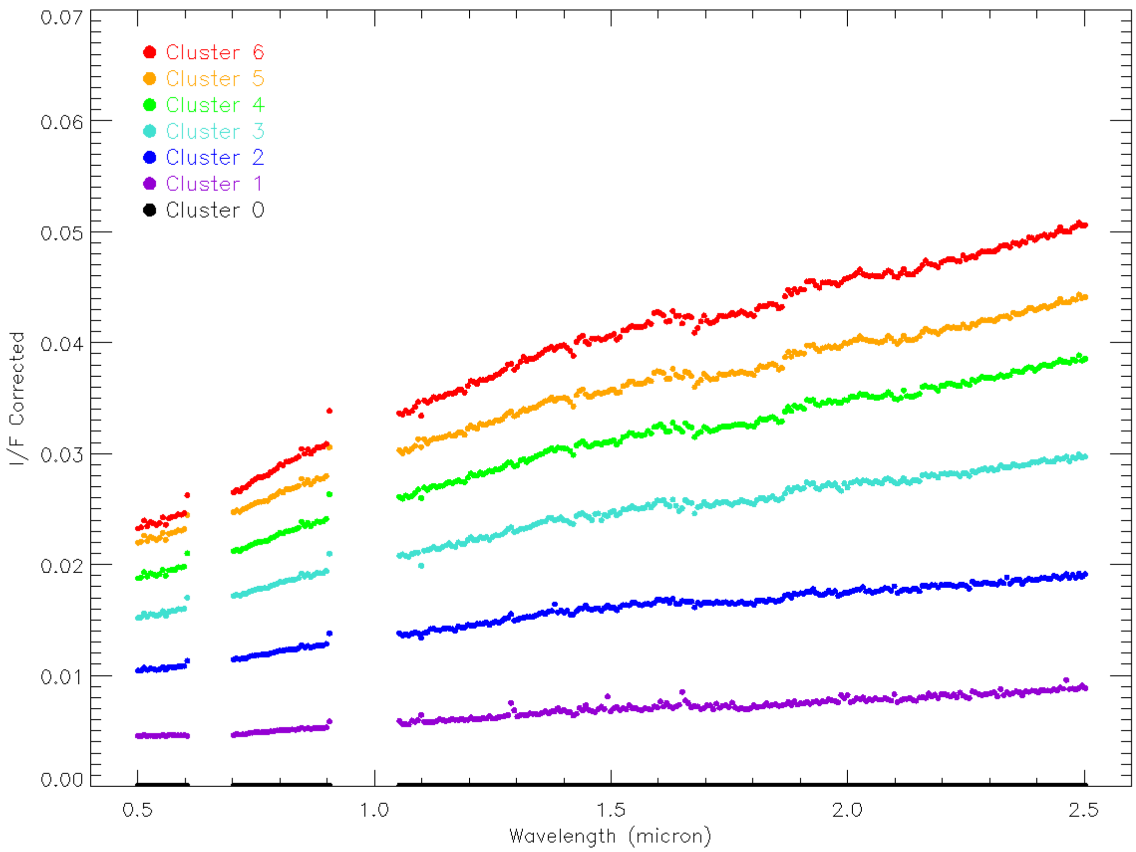

Fig. 2: The mean spectra for each class presented in Fig. 1.

The Shkuratov model is used in a downhill simplex algorithm [15] that iteratively, and simultaneously changes the relative abundance and grain sizes of these two components to minimize the differences between the model and observations using a χ^2 criterion. The best-fitting models were achieved with a simple intimate mixture.

The results obtained for the clusters identified from the statistical analyses will be presented, together with different best-fitting compositions characterized by multiple optical constants.

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