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First results of a spectral clustering analysis applied to OSIRIS-REx color imaging of asteroid (101955) Bennu

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Abstract

The OSIRIS-REx asteroid sample-return mission is currently orbiting primitive near-Earth asteroid (101955) Bennu. Thousands of images are being acquired by the MapCam instrument onboard the spacecraft. In this work we present preliminary results of a spectral clustering analysis applied to these color images.

1. Introduction

MapCam is a medium-field imager, a 125-mm focal length f/3.3 optical system that provides a ~70 mrad (4°) field of view [1]. This camera obtains the images needed for the development of color maps with high spatial resolution. To this purpose, the instrument contains four filters based on the Eight-Color Asteroid Survey (ECAS), with passbands b', v, w, and x, centered at 473, 550, 698, and 847 nm respectively [2]. Among other properties, these filters permit the measurement of spectral slopes, which can be used to constrain the composition and identify the effects of space weathering. Finally, global and site-specific color ratio maps will help the team to identify areas of interest (with a pixel scales of ~< 1 cm) and select a sampling site. Recently, we validated a spectral clustering analysis methodology for the color maps [3] based on an unsupervised machine learning tool. In the next section we summarize our data preparation approach and we present the preliminary results in Section 3.

2. Data Preparation

Before analyzing the RADF calibrated images we need to correct them photometrically. For this purpose, we use the images taken during the Approach, Preliminary Survey, Orbital A, and Detailed Survey phases of the mission in the four color filters. To obtain the photometric angles for each pixel, we use the ISIS software and the shape model developed by the OSIRIS-REx Altimetry Working Group [4]. We implement the most commonly used empirical photometric models (Akimov, Minnaert, Lommel-Seeliger, and Lambert) with several empirical phase functions [5]. We found that the following combination of disk and phase function produced the best results for all four color filters:

$$RADF = A_{eq}\,(\alpha) D(\alpha,\beta,\gamma) \quad (1)$$

$$A_{eq} = A_L e^{(a\alpha + b\alpha^2 + c\alpha^3)} \quad (2)$$

$$D(\alpha,\beta,\gamma) = \cos\left(\frac{\alpha}{2}\right)\cos\left[\frac{\pi}{\pi-\alpha}\left(\gamma-\frac{\alpha}{2}\right)\right] \left[\frac{\cos(\beta)^{c(\alpha)\alpha/\pi-\alpha}}{\cos(\gamma)}\right] \quad (3)$$

Once images were photometrically corrected we applied an equirectangular projection to create mosaics and ran our spectral clustering method in both normalized (at 550 nm) and unnormalized color images of the surface. We removed from our analysis pixels outside of the following limits: reflectance values lower than 0.001 (shadows) and higher than the linearity limit of the CCD, and emission and incidence angles larger than 80°, values for which the photometric model does not work properly.

3. Results

As an illustration of our method, we have applied the clustering technique to a specific region on the surface of Bennu that contains a large rock outcrop (–25º lat, 30º lon) [6]. The results are shown in Fig. 1.

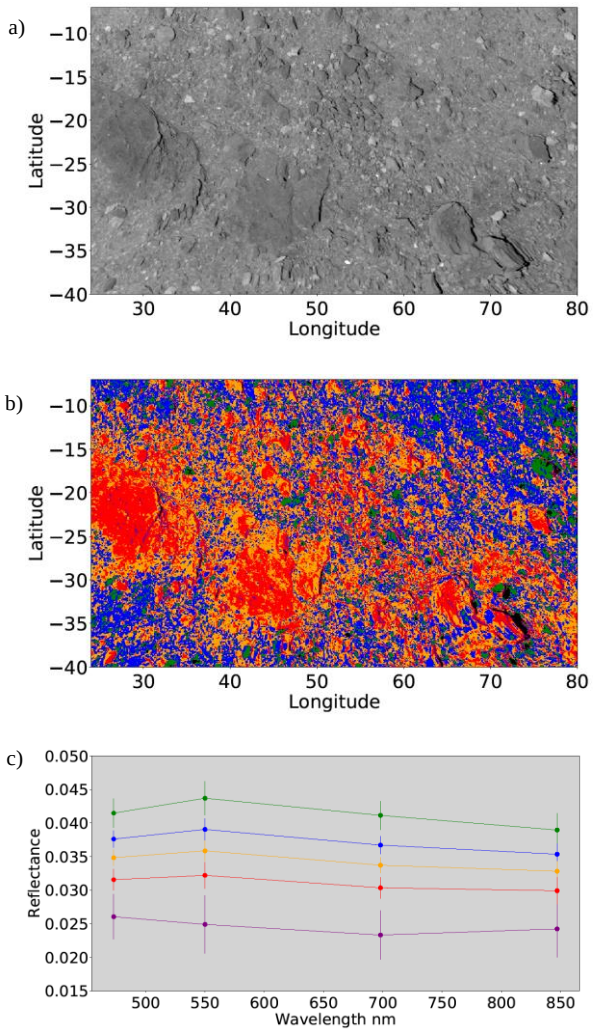

Figure 1: An example of the clustering analysis carried out using Detailed Survey images. a) Studied region in the v-filter. b) Location of the identified clusters over the analyzed area (black pixels are out of the defined limits). c) The five representative spectral clusters with their corresponding error bars (standard deviation), using the same color code as in (b).

We find five distinct clusters that are consistent with the albedo variations and the morphology of the terrain. The four highest-albedo clusters (green, blue, orange and red) are similar in spectral shape, but are differentiated by albedo and spatial distribution. The fifth cluster (purple) has a different spectral shape; however, it is near the shadows and represents areas of poor lighting. Therefore, caution should be taken when interpreting this fifth spectral cluster.

Another approach is to remove albedo differences and enhance variations in spectral shape by normalizing the images. We do not show the results of this second approach in this abstract because of space limitations, but we discuss its application to the color images of asteroid (1) Ceres in a recent publication [3].

Our spectral clustering technique will be applied to images that cover almost the entire surface of Bennu. This is a fast and efficient tool to identify morphological features with distinctive spectral behavior. These regions that can be studied in greater detail to identify differences in composition and particle size.

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