MAPPING PARAMETERS OF THE LUNAR 1-MICRON SPECTRAL BAND WITH IMPROVED CHANDRAYAAN-1 M^3 DATA. V. Kaydash[1], Ye. Surkov[1], Yu. Shkuratov[1], G. Videen[2]; [1]V.N. Karazin National University, 35 Sumska St, Kharkiv, 61022, Ukraine, [2]Space Science Institute, 4750 Walnut St. Suite 205, Boulder CO 80301, USA.

Introduction: At a surface resolution of about 100 m/pix, hyperspectral-imaging with the scanning spectrometer M^3 onboard Chandrayaan-1 provides a huge amount of data that are very useful for developing new visions of the lunar surface [1]. The M^3 operated from 0.42 to 3.0 μm, where highly diagnostic mineral absorption bands occur. The M^3 data were obtained for >95% of the lunar surface at 85 wavelengths. In the mentioned spectral range, lunar minerals reveal crystal field bands formed, in particular, by electron transitions of the d–d type between split levels of Fe^{2+} ions [2]. Being a transition element, iron has the unfilled external d-shell; hence, electrons placed on the five orbitals d_{xy}, d_{yz}, d_{xz}, $d_{x^2+y^2}$, and d_{z^2} are weakly bound with the nucleus. The wave functions of the electrons in the d-orbitals have different shapes, but are of the same energy if the atom is in a free space. When the atom (cation) is placed in a crystal lattice, the orbitals due to their different shapes are disturbed differently by neighboring anions. The disturbance removes the degeneracy and the energy levels split, which allows quantum transitions with photon absorption. For orthopyroxene, e.g., the splitting produces two bands centered near 0.95 and 1.85 μm. For olivine the splitting produces 3 overlapping bands near 1 μm. The pyroxene and olivine bands are strongly overlapped near 1 μm, producing a common asymmetric absorption structure. The shortwave slope of the band characterized with the color-ratio R(0.95 μm)/R(0.75 μm), where R(λ) is the reflectance, is widely used for assessment of the FeO content and maturity degree (OMAT) of the lunar surface [3-5].

Studied region, source data, and processing: We here focus on studies of the 1 μm absorption structure. We used a portion of the source image M3G20090612T183813_V03 from [6], which comprises a NW portion of Aristarchus Plateau (Fig. 1) that is mantled by pyroclastic material [e.g., 7]. The Aristarchus Plateau is a block of ancient highland that rises 2 km above the surrounding mare basaltic plains.

Unfortunately, M^3 images at all 85 wavelengths reveal noticeable noise, including vertical streaks that can be seen in Fig. 2a that hampers resulting images. We weaken this pattern significantly, producing a 2D Fourier transformation and filtering in the Fourier plane corresponding high frequencies. Then we made the inverse Fourier transformation, obtaining an image with the suppressed streaks.

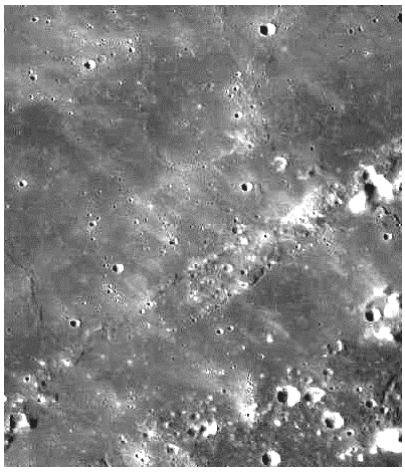


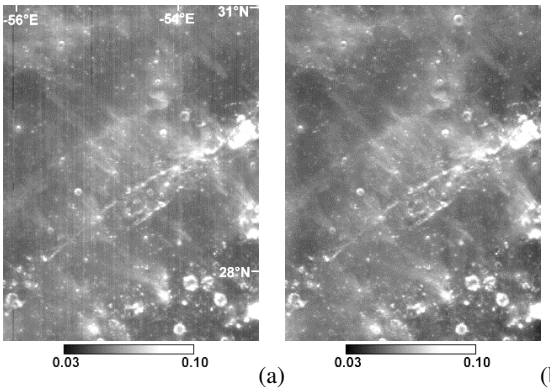
Figure 1. A NW portion of Aristarchus Plateau (coordinates are shown in Fig. 2a). The image is adopted from http://target.lroc.asu.edu/q3

Figure 2b shows a filtered image that can be compared to the initial image shown Fig. 2a. For analysis of spectra R(λ) in each pixel of the image, we exploit Gaussian smoothing with σ equal to about 3 spectral quantizes. Then we approximately scale the spectra by spectral continuum, dividing R(λ) by the function of linear continuum $R_L(\lambda)$ in the range 0.7-1.5 μm. For the function $R(\lambda)/R_L(\lambda)$, we use as an approximation the following fitting equation

$$f(\lambda) = a_1 \exp\left(-\left(\frac{\lambda - b_1}{\sigma_1}\right)^2\right) + a_2 \exp\left(-\left(\frac{\lambda - b_2}{\sigma_2}\right)^2\right). \quad (1)$$

The parameters a_1, a_2, b_1, b_2, σ_1, and σ_2 are free and found using the least-squares technique. Note that this is distinct from an ordinary approach [e.g., 8], when Gaussians peaks are oriented to the bottom; we here describe the 1 μm band by Gaussian wings when Gaussian peaks are directed to the top. In some cases this formal approximation may provide better accuracy. An example of a measured spectrum and its approximation is shown in Fig. 3, revealing good coincidence.

Results and discussion: Figure 4a shows a map of the spectral slope R(1.30 μm)/R(0.75 μm). For comparison we here present also the color ratio R(0.75 μm)/R(0.54 μm). We may note good correlation of these two different ratios. The boundary between red (bright tones) and blue mare regions is almost the same for both the images. Differences are observed only for young craters.



(a) (b)

Figure 2. A part of image M3G20090612T183813_V03 before (a) and after (b) filtering vertical streaks. The image was obtained at λ=0.75 μm; the frame width equals 80 km

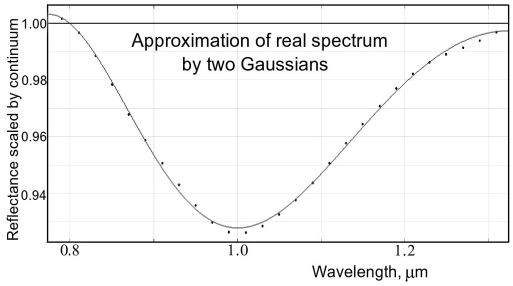
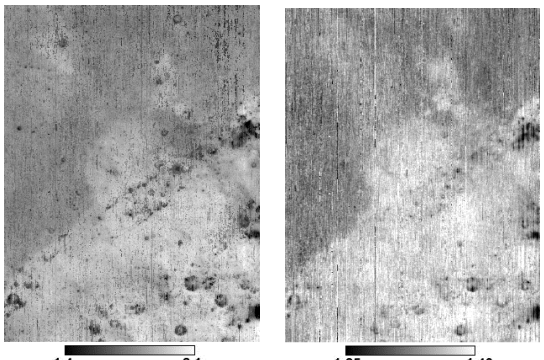
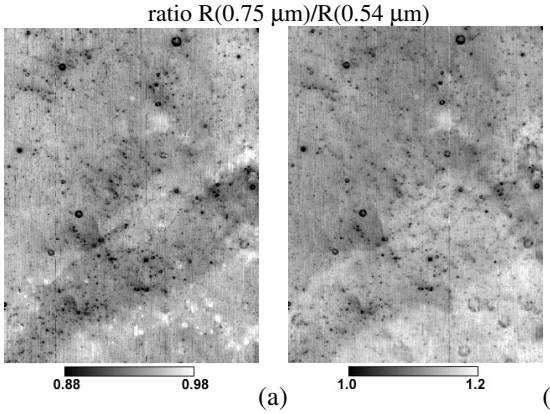


Figure 3. A sample spectrum acquired with M^3, which is approximated with Eq. (1)



(a) (b)

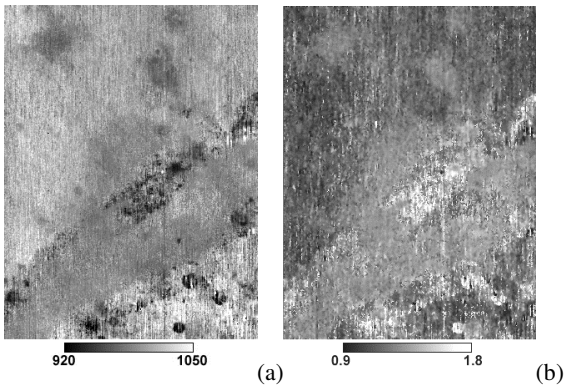
Figure 4. (a): Color ratio R(1.30 μm)/R(0.75 μm). (b): Color ratio R(0.75 μm)/R(0.54 μm)



(a) (b)

Figure 5. (a): The 1 μm band depth. (b): Color ratio R(0.95 μm)/R(0.75 μm)

Figure 5a depicts a distribution of the parameter $R_L(\lambda_{min})/R(\lambda_{min})$ characterizing the depth of the band at the minimum (see Fig. 3). It is interesting that the depth correlates with the color ratio R(0.95 μm)/R(0.75 μm), i.e. this ratio is an adequate parameter to describe the band. On the other hand, important differences between $R_L(\lambda_{min})/R(\lambda_{min})$ and R(0.95 μm)/R(0.75 μm) are seen as well.



(a) (b)

Figure 6. (a): Position of λ_{min}, scale is given in nm; (b): Parameter of band asymmetry

The position λ_{min} of the band minimum and the band asymmetry were computed using the function (1) that was calculated with a 1 nm step. Figure 6a presents variations of the wavelength λ_{min}. As can be seen, the variations are detected reliably with rather low noise. Small values of λ_{min} are characteristic of young craters; whereas, large λ_{min} can be found for pyroclastic material (orange glasses), as is anticipated [9]. The most difficult for mapping is the parameter of asymmetry that is defined as a ratio of the band areas on left and right from λ_{min}. The image of such a ratio is noisy (Fig. 6b), nevertheless, even this parameter is related to surface morphology and, hence, is potentially interesting.

Conclusion: We here present preliminary results of mapping the parameters of 1 μm band using the Chandrayaan-1 M^3 data. This approach seems to be prospective for further investigations, e.g., the same technique can be applied to 2 μm pyroxene band and even to the band related to OH/H_2O compounds.

References: [1] Pieters C. et al (2009) *Curr. Sci. 96*, 500–505. [2] Burns R. (1993) *Mineralogical Applications of Crystal Field Theory.* Cambridge Univ. Press, Cambridge 459 p. [3] Lucey P. et al (1995) *Science 268*, 1150-1153. [4] Lucey P. et al. (2000) *JGR 105(E8)*, 20,297–20,305. [5] Lucey P. et al. (2000) *JGR 105*, 20,377–20,386. [6] https://pds-imaging.jpl.nasa.gov/data/m3 [7] Lucey P. et al (1986) *JGR 91*, D344-D354. [8] Sunshine J. et al. (1990) *JGR 95*, 6955–6966. [9] Adams J. et al. (1974) *Proc. Lunar Sci. Conf. 5th*, 171–186.