DUSTY MAFIC ROCKS ALONG CHANG'E-4 ROVER'S TRAVERSE REVEALED BY THE VISIBLE/NEAR INFRARED IMAGE CUBES. X. Wang[1,2], J. Liu[1,2], D. Liu[1], H. Huang[1,2], L. Guo[1,2], Q. Zhang[1,2], Y. Chen[1,2], B. Liu[1], W. Chen[1], X. Ren[1] and C. Li[1,2], [1]Key Laboratory of Lunar and Deep Space Exploration, National Astronomical Observatories, Chinese Academy of Sciences, Beijing, 100101, China. (wangx01@nao.cas.cn), [2]School of Astronomy and Space Science, University of Chinese Academy of Sciences, Beijing, 100049, China.

Introduction: China's Chang'E-4 (CE-4), which is the first probe to land on the lunar farside, has been working stably for over three years since its touching down on January 3, 2019. The Yutu-2 rover of CE-4 has traveled over one kilometer across the floor of Von Kármán crater at the end of its 38th lunar day. Four rocks (referring to them as R1 to R4) were encountered along the rover's traverse and the onboard Visible and Near-infrared Imaging Spectrometer instrument (VNIS) specifically captured their spectral information. This is the first time close-up spectral images have been collected of rocks exposed at the lunar surface and the undisturbed states of these rocks were recorded.

The VNIS is a special acousto-optic tunable filter (AOTF) spectroscopy with two detection channels. A complementary metal-oxide-semiconductor (CMOS) produces a 256 by 256 pixels image in visible/near infrared range (VIS/NIR, 450-950 nm) and a short wave infrared (SWIR, 900-2395 nm) spectrometer obtains a one-pixel spectrum [1]. This work focuses more on the VIS/NIR image cubes which provide great insight into both spatial and spectral dimensions.

Methods and Results: The VNIS Level 2B radiance data were converted to radiance factor (RADF) using solar irradiance method. Given that the signal at the end of the instrument detection range may be unstable, we only employed the VNIS image cube data in the range of 450-900 nm. To highlight the absorption variations around 1 μm on the rock surfaces, the 750/900 nm spectral ratios were calculated and then classified using K-means clustering algorithm (Fig. 1). Though the viewing geometry would vary greatly due to the irregular rock surface, the effect of viewing geometry on our classification results may not be significant in the case that the phase angle range measured by the VNIS is narrow. The classification results reveal the intriguing spectral variations on these rock surfaces. Class 1 to 3 respectively indicate the portions of the rock surfaces with 1 μm absorption from strong to weak.

In addition, we also obtained the continuous spectra in the range of 450-2395 nm using the same method in [2] (Fig. 2).

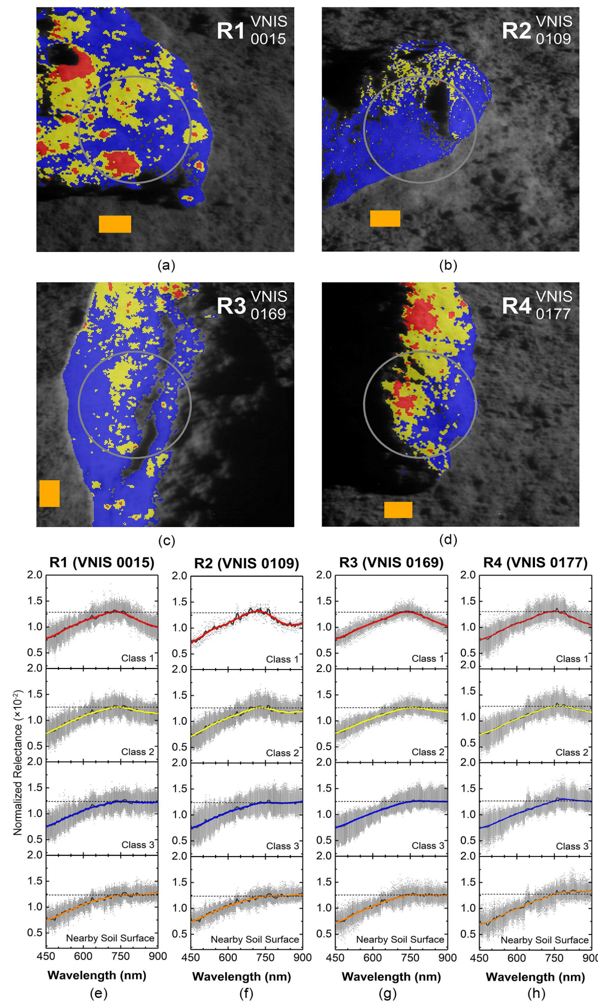

Fig. 1. The classification results of the four rocks and the corresponding average spectra. (a)-(d) shows the classification of each rock surface (Class1: red; Class 2: yellow; Class 3: blue), selected nearby soil surfaces are marked in orange. The field of views (FOVs) of the VNIS are marked in gray circles. (e)-(h) plot the average spectra of the corresponding classes in (a)-(d). All the spectra are normalized by the equation $r_{norm}=r_i/\sum_{i=1}^{i=n} r_i$, where i is the band number. The background gray point sets are the groups of the raw spectra of individual pixels in each class. The gray solid lines are the average spectra and the colored ones are their smoothed spectra.

Surface Dust Coverage: The absorption feature of Class 3 is the weakest. When we compared the average spectrum of Class 3 on each rock with that of the nearby soil surface (orange region marked on each rock's image), we found they are quite similar in spectral shape. Previous spectral investigations confirmed that the spectral characteristics of dust-covered rocks would be somewhat similar to that of soil or regolith [3], which implies Class 3 possibly represent the rock surface completely covered by dust. Further comparison of the classification results with rock images shows that the rock surfaces classified in Class 3 are tend to be distributed in the rock bottoms and the depressed areas of rock, which is consistent with the tendency of these areas to accumulate dust.

Among the four rocks, R3 is special because of its highly inclined facet. The classification results indicate that its inclined facet may also be significantly covered by dust, and the dust coverage tends to decrease with height. Some dust deposition and transport mechanisms may lead to this phenomenon. In addition to deposition of meteoroid bombardment ejecta, near the lunar surface, electrostatically lofted processes also contribute to the evolution and transport of dust [4]. The levitated charged dust could be easily attached to the rock inclined surface. This dust deposition mechanism was also found on the surfaces of CE-3 detected rocks [5].

Mafic Composition: Compared with Class 3, Class 1 and Class 2 have relatively strong absorption features, suggesting that they may contain the spectral information from the rock itself. The 1 μm absorption feature always indicate the mafic minerals that make up the rock [6]. All the four rocks detected by Yutu-2 show prominent absorption features at 1 μm which can be seen from Class 1 and 2, implying these rocks are more likely dominated by mafic materials, instead of plagioclase-rich materials from the lunar upper crust. Besides, we infer the spectral differences between Class 1 and 2 probably indicate the differences in dust coverage or space weathering on the rock surfaces.

Implication for using the VNIS data: Dust coverage will significantly affect the absorption features of the VNIS detected continuous spectra. Based on the image cubes, the proportion of dust-covered rock surfaces (Class 3) and ground soil surfaces distributed in the FOV can be determined by pixel counting. Fig. 3 presents the influence of the dust and soil observed in the FOV on the in-situ measured spectra. Obviously, the 1 μm and 2 μm absorption depths of the continuous spectra decrease with the increasing proportion of dust or soil observed in the FOV. As a result, a direct quantitative investigation on the rock composition without considering the effect of dust coverage could produce unreliable results, perhaps underestimating the contents of mafic materials and overestimating the contents of plagioclase.

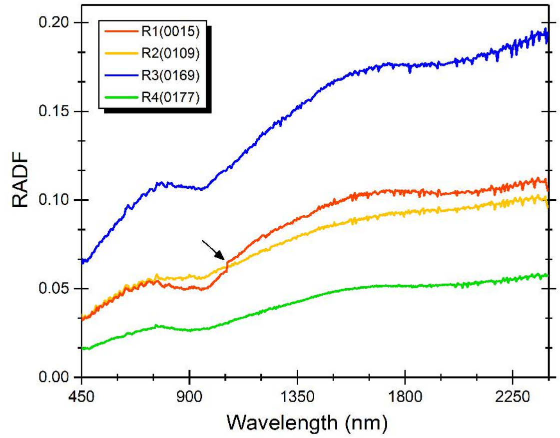

Fig. 2. The continuous spectra of the four rocks measured by the VNIS (450-2395 nm). The arrow indicates a potential anomaly in the R1 spectrum.

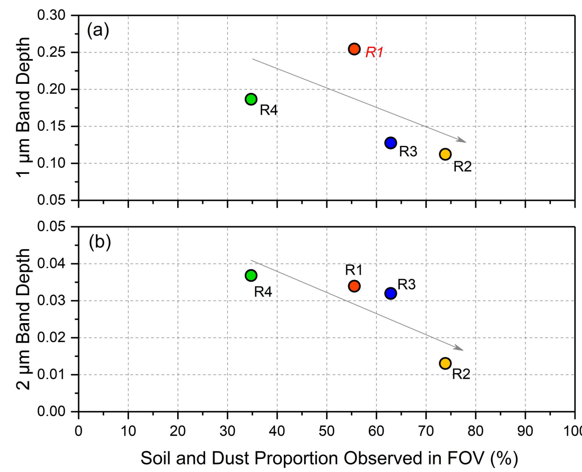

Fig. 3. The influence of the dust and soil observed in the FOV on the continuous spectra of the rocks. The band depth is defined as 1 minus the reflectance value at the band center after continuum removal. Note that point R1 in (a) may be an outlier, because the 1 μm absorption depth of R1 measurement is probably deepened resulting from the anomalous signal.

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