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Reflectance conversion and data quality evaluation for Chang'E-3 VIS/NIR Imaging Spectrometer (VNIS)

Bin. Liu, Chunlai Li, Guangliang Zhang, Jianjun Liu, Xin Ren, Xu Tan, Xiaoxia Zhang, Yongliao Zou
National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012, P R China; (liub@nao.cas.cn / Fax: +86-010-64888703)

Abstract

Based on the released VNIS level 2B radiance data, we got VNIS reflectance data by the in-situ detect reflectance conversion method. Then, VNIS radiance data accuracy was evaluated and reflectance data quality was compared with the reflectance of M3 and APOLLO returned lunar mare samples.

1. Introduction

The second phase of Chang'E Program is landing and performing in-situ detection on the lunar surface. The Visible and Near-Infrared Imaging Spectrometer (VNIS), mounted on the front of Chang'E-3 Yutu rover [1], is designed to develop in-situ detection of lunar minerals and resources distribution [2], and the mineralogy of lunar basalts helps in understanding the geologic evolution of the Moon. The spectral range of VNIS is from 0.45μm to 2.4μm, lunar minerals can be recognized effectively in this spectral coverage [3-4], for example, pyroxene and olivine.

Until now, four detection mode data and three calibration mode data of VNIS have been released to Chinese scientists, it's urgent to evaluate the data quality, which will greatly help scientists to better understand and apply VNIS' data, it will also be helpful to improve the data processing methods.

2. VNIS data description

VNIS is an AOTF type imaging spectrometer, this type of spectrometers have been widely used in deep-space exploration [5-6]. It includes two channels, a V-NIR hyper-spectral imager and a SWIR spectrograph. There are two modes when VNIS worked on lunar surface since it carried a calibration target, when VNIS aimed at lunar surface, it worked at detection mode, and when VNIS aimed at the calibration target, it worked at calibration mode.

The route of Yutu rover and the distribution of detection nodes is shown in figure 1. After the first two lunar days exploration, VNIS has got four different areas (nodes E, S3, N203 and N205 in figure 1) detection mode and three calibration mode data, the sum of data size is 350MB.

The VNIS data processing pipeline include dark current subtraction, temperature calibration, radiance calibration, geometric calibration etc. [7-8]. VNIS data used in this paper is level 2B based on the above calibrations.

3. Reflectance conversion

Reflectance data is basic for minerals identification and quantification, the precision of which is directly affect the precision of minerals detection. Since the Chang'E-3 lander and Yutu rover landed on the northwest Imbrium, the detection area didn't include the Cayley Plains area, which is the standard area for reflectance conversion and calibration [9]. We adopted the reflectance conversion method described by Liu et al. [10], the formula is as follow:

$$R_j = \frac{\pi I_j}{F(\lambda)\cos(i)}$$

Rj is the jth band reflectance of VNIS, Ij is radiance data after radiance calibration, F(λ) is the solar irradiance [11] resampled by VNIS bandpass, and cos(i) is the cosine of solar incident angle.

The four detection node's reflectance data were found discontinuous at the band boundary of the two channels (near 900nm). To remove this phenomenon, the SWIR channel reflectance data was selected as standard since it is more stable and has smaller spectral jitter, and then translation factor (reflectance ratio between band 900nm and band 895nm) was calculated to translate V-NIR channel reflectance to be continuous with SWIR channel reflectance.

4. Spectral data quality evaluation

VNIS level 2B radiance data was firstly evaluated by comparing calibration target's data after radiance calibration with its theoretical radiance values after solar irradiation, since calibration target is almost lambertian and its reflectance has been calibrated in laboratory. The comparison result is shown in figure 2, the two kinds of radiance values fit very well, the relative error of the SWIR channel is only 1.05%, and the relative error of the V-NIR channel is 4.13%. This result demonstrates that VNIS has a good precision on radiance calibration.

Reflectance data was also evaluated by comparing VNIS data with M3 and lunar mare samples' data. M3 reflectance spectrum of the Chang'E-3 landing site was selected (pixel located at (283, 15633), file name is M3G20090207T061610_V01_RFL.IMG), Nine APOLLO returned lunar mare sample's reflectance data were also selected to compare, the comparison results are shown in figure 3. We could see that all the reflectance data have similar absorption features near 1000nm except lunar sample 71061. VNIS reflectance also has a weak absorption feature between 1750～2400nm, but the slope of VNIS reflectance data at longer wavelength is lower than lunar sample.

5. Conclusion and discussion

We present the preliminary results on VNIS reflectance conversion and spectral data quality evaluation. As suggested by the radiance and reflectance data comparison, VNIS data has a good precision on radiance calibration, and the relative error of the SWIR channel is only 1.05%. The difference between VNIS reflectance data with M3 and Lunar mare samples are probably as follow: (1) the spatial coverage between VNIS, M3and lunar mare sample data is not the same; (2) the viewing geometry between VNIS and M3, lunar mare sample is different; (3) the state of lunar mare sample in the laboratory is not the same as lunar surface.

References

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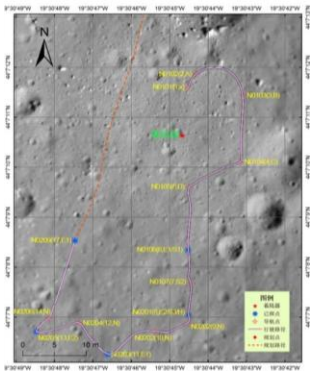

Figure 1. The route of Yutu rover and detection node distribution.

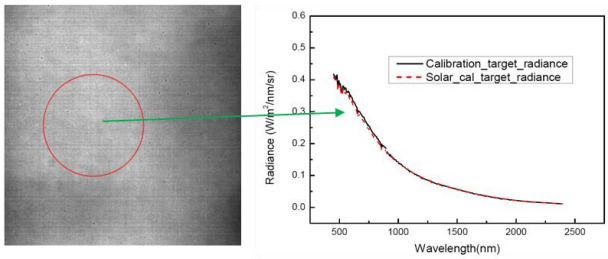

Figure 2. Calibration target radiance data of Detection node E (The red circle is the location of SWIR detecor's field of view in the V-NIR image, the center point of the circle located at (96, 128) of the image, and the radius is 54 pixels). The dark line is the radiance data after radiance calibration, and the red line is the theoretical radiance values after solar irradiation.

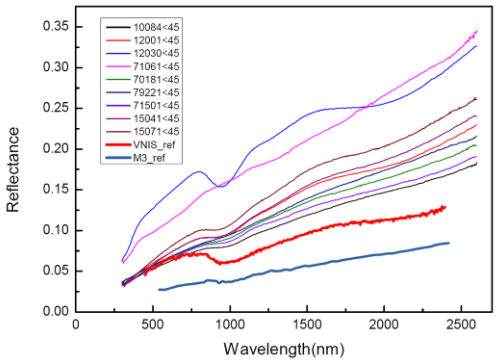

Figure 3. VNIS reflectance data of detection node E compared with M3 and luanr mare sample data.