THE SPECTRAL CALIBRATION OF CHANG'E-1 IIM DATASET

Zongcheng Ling[1], Jiang Zhang[1], Zhongchen Wu[1], Bo Li[1], Jianzhong Liu[2] [1]School of Space Science and Physics and Shandong Provincial Key Laboratory of Optical Astronomy & Solar-Terrestrial Environment, Shandong University at Weihai, Weihai, Shandong 264209, P. R. China; [2]National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012, P.R. China, (zcling@sdu.edu.cn)

Introduction

Imaging Interferometer (IIM) is China's first lunar imaging spectrometer aboard Chang'E-1, with science goals to collect the information of chemical and mineralogical compositions across the lunar surface [1,2]. IIM is a Fourier transform Sagnac-based imaging spectrometer covering the visible to near infrared spectral range (0.48-0.96 μm), which has a very different optical design from other recent lunar spectrometers like Moon Mineralogy Mapper (M^3) and Multiband Imager (MI)[3-4], etc. IIM data have already shown its potentials in lunar elemental mappings and geologic studies [e.g., 5-7]. However, as the first interference spectrometer targeted for the Moon, the calibrations of IIM data are somewhat immature. We have shown the empirical correction method of correction for the line-direction nonuniformity based on our experiences and understanding of IIM data [8]. Recently, we found a need to correct the sample-direction nonuniformity caused by intrinsic dark current variation along the push-broom direction, which have not removed completely by former data processing pipelines. In this abstract, we will present a new empirical method to correct the sample-direction nonuniformity to solve this problem of IIM data. Because this correction is mainly based on the spectral curve of IIM data, thus we regard it as "spectral calibration" for additional steps in the data processing pipeline.

Spectral Calibration Procedures

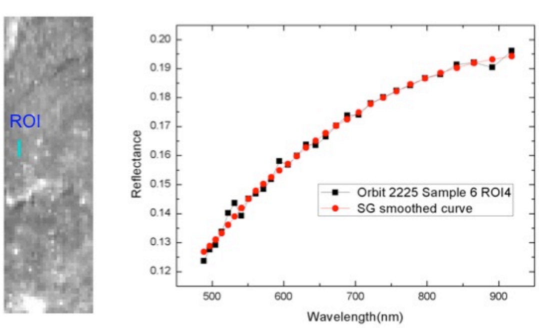

Fig.1. The selection of a homogenous Region of Interest (ROI) in Chang'E-1 IIM 757nm image of Orbit 2225, and the spectra of ROI 4 (6X1 pixels in size) from sample 6. The black curve is the raw data and the red is the calibrated spectra smoothed by Savitzky-golay(SG) method.

IIM data is firstly binned into 4X4 pixels to suppress the random noise and improve the signal-to-noise ratio. The spectra of Region of Interest (ROI, 6X1 pixels) show some obvious peak signals at 550nm, 594 nm, etc., as shown in Figure 1. This will lead to misleading interpretations of IIM data when using the spectral shape for the science interpretations. The spectral calibration of IIM dataset is thus of great need. This phenomenon is not easy to decouple because of the complexity of dark current varying with different lunar geologic units. We try to find homogenous regions for the extraction of such kind of spectra. We collect the data based on the principle of the push-broom of IIM spectrometer, i.e., one line is reduced from an imaging of interferogram which each sample is expected to have similar dark currents during the data acquirement of IIM. The spectral feature near 600nm is determined as "false" signal due to the dark current. We therefore try to find the tendency of our spectra and to remove this artifact. The spectral uniform region should be determined for such analysis.

The necessity for correction of sample-direction inhomogeneity of IIM data has not been addressed before. Its physical mechanism should be better understood in order to get rid of the errors in the data. We ascribed this effect to the dark current variations of the CCD detector. Although dark current subtraction has been applied to the interferogram data, the in-flight dark current signals are not so well treated as shown in Figure 1.

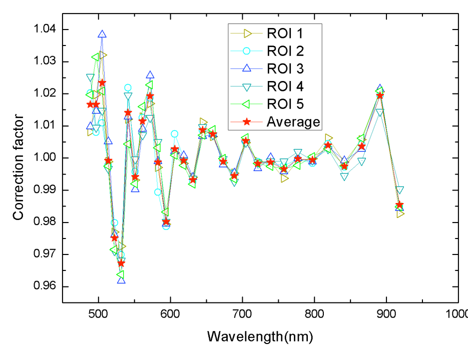

Fig.2. The correction factors derived for sample 6 by using 5 ROIs in the same sample of Orbit 2225.

To smooth the zigzag spectral features as shown above, we use the Savitzky-golay smooth filter to derive the "true" spectra. For each sample of the image, we obtained certain "true" spectra and then they were divided by the raw spectra to derive the correction factors. The spectral band 1(B1, 480nm) and band 32 (B32, 946nm) are excluded in in the smooth procedures due to their poor data quality and very low signal-to-noise ratio. We generally find five ROIs for the extraction of correction factors for each sample, and the average values of these ROIs are used as the correction factor for the spectral calibration. The derived factors of 5 ROIs shown in Figure 2 show very similar values and tendencies, which reinforce the idea that these variations of spectral bands are from intrinsic for IIM dataset and should be corrected before the science applications.

Results and Discussions

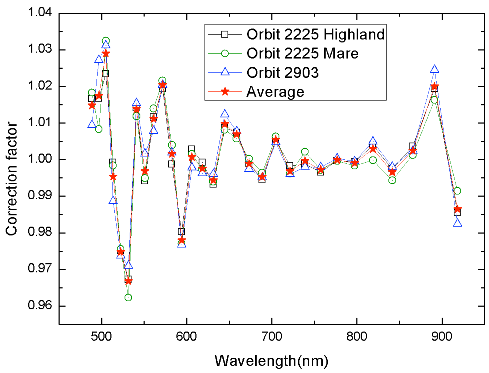

Fig. 3. The correction factors among different orbits (2225 and 2903) and terrains (highland and mare regions)

We manually selected 5 relatively homogenous ROIs (6X1) for each of the 32 samples in the binned data including both highland and mare regions from two orbits (Orbit 2225 and 2903) during our correction procedures. As shown in Figure 3, they all show similarities of band-to-band variations of correction factors, which indicate that the systematic artifacts are caused by the data itself and thus could be removed by latter calibrations. The spectral bands below 600nm and above 900nm (B30-B31) have relatively larger correction factors while in between (B14-B29) have very small corrections factors which agree with their spectral S/N and data quality analysis. All three series of correction factors have similar values implying similar levels of dark current background for the CCD detectors. We regard the average values of the three sets of correction factors as the final correction factors for spectral calibration of IIM data.

The empirical correction factors are applied to the IIM data for validation of our model. Figure 4 show a small fresh crater (15.40°E 19.66°N) and its spectra collected from its rim. The crater rim materials show nice peak absorptions indicating of fresh low-Ca pyroxene minerals exposed from beneath the impact carter. Before the spectral calibration corrections, its spectra show some very noisy and tiny peaks in the optical region near 600nm. While after correction the noisy 3 peaks have been removed away. Noted that our correction is aimed to correct the intrinsic causes, which not only works for the reflectance data but also should work for the radiance data, which can be regarded as an compensate for the dark current corrections of IIM dataset. Our calibration method could improve the relative accuracy of 4% for specific bands.

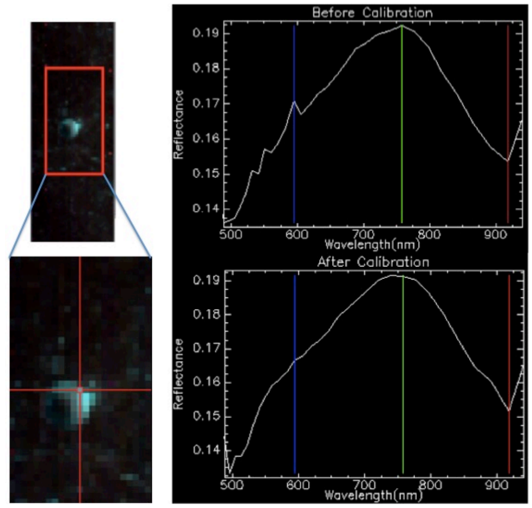

Fig. 4. The application of spectral calibration on IIM data at the rim of a small crater. The IIM data is from Orbit 2225 in false color (R:918nm, G:757nm, B:594nm).

Conclusions and future work

We have obtained an empirical model of sample-direction nonuniformity correction of the IIM data. When the correction is applied on IIM data, it turned out to yield an obvious improvement for the spectral profile of the IIM data. Our calibration would be beneficial for the science applications of the IIM data for elemental (e.g. FeO and TiO_2) and mineralogical mappings. We also believe our method for the dark current refinement could also be of significance for other lunar imaging spectrometers in the subtraction of dark current. Furthermore, China's Chang'E-3 mission with a lander and rover ("Yutu") has successfully softly landed on lunar surface to the east of Sinus Iridum in Mare Imbrium (19.51°W, 44.12°N) on Dec. 14, 2013. One of the eight payloads is VIS/NIR imaging spectrometer (VNIS), which will take in-situ measurements of lunar regolith reflectance spectra [9]. We hope the calibration methods of IIM data could provide helpful guidance for future data processing of VNIS.

Acknowledgements: This work was supported by the National Natural Science Foundation of China (11003012, 41373068, U1231103), the Natural Science Foundation of Shandong Province (ZR2011AQ001), and Independent Innovation Foundation of Shandong University (2013ZRQP004).

References: [1]. Li et al.(2010) Sci. China Earth Sci., 53, 1091–1102. [2] Ouyang et al.(2010) Chin. J. Space Sci., 2010, 30(5): 392-403. [3] Pieters et al.(2009), Current Science. 96, 500-505. [4].Ohtake et al., (2010) Space Sci. Rev. 154: 57–77 [5].Ling et al.,(2011) Chin. Sci Bull, 56(4-5), 376-379. [6] Wu et al.(2010), Planet Space Sci, 58, 1922-1931. [7] Liu et al., (2010), Sci. China Phys. Mech Astron. 53(12), 2136-2144.[8]. Ling et al.,(2011) LPSC #2213.[9]. Liu et al., (2013), RAA, 13(7): 862-874.