AN EMPIRICAL NONUNIFORMITY CORRECTION OF CHANG'E-1 IIM DATA

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Introduction:

As the first Chinese lunar imaging spectrometer aboard Chang'E-1, Imaging Interferometer (IIM) is selected to detect the chemical and mineralogical compositions across the lunar surface [1,2]. Unlike other recently lunar imaging spectrometers, e.g., Moon Mineralogy Mapper and Multiband Imager [3-4], IIM is a Fourier transform Sagnac-based imaging spectrometer. Detailed parameters can be found in the reference [5]. Until now, many achievements have been made with the application of IIM data including elemental mapping as well as data calibrations [5-8]. While as the first interference spectrometer targeted for the Moon, the processing and calibrations of IIM data are somewhat immature. With more experiences and understanding in the applications of IIM data, we find it still needs additional calibrations and corrections, e.g., the different responses of similar geologic units along an image line direction would lead to misleading elemental mapping results. In this abstract, we will present an empirical nonuniformity correction method to solve this problem.

Nonuniformity corrections of IIM data:

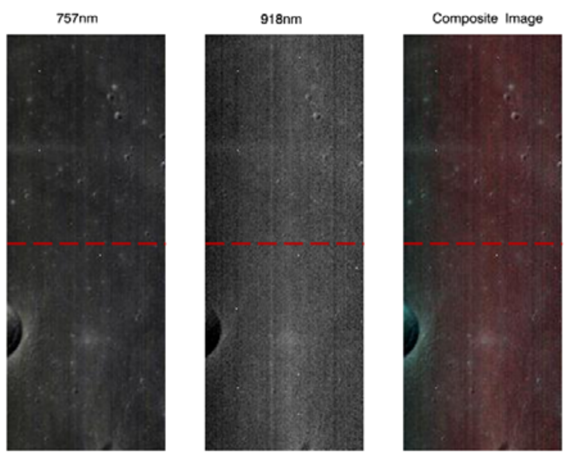

Fig.1. A homogenous region from Orbit 2897. Line 6365 as indicated in red is selected as a standard line for nonuniformity correction.

The findings of the nonuniformity ("flat field") problem can be easily seen in Figure 1, which shows a homogenous mare region ~230km north of Aristarchus crater. The 757nm image exhibits a flat and homogenous region with uniform albedo, while the 918nm image shows an obvious change, i.e., a decrease of intensity can be seen on the left edge pixels relative to the middle's. The color composite image (R: 918 nm, G:757 nm, B:618 nm) shows obvious change in color from left (bluer) to right (redder). As shown in Figure 2, the 757nm data points generally sit on the same level, which is an indication of spectral homogenous region along this line. However, radiance values of 918nm data are greatly degraded by approximately 40% on the left edges in comparison with those of middle pixels.

The need for correction of this inhomogenity has also been suggested by Wu et al.[6], who ascribed this to the inhomogeneity of responses of CCD detector. Considering the lower quantum efficiency and smaller radiance values towards the longer wavelength, these effects stand out especially for the 918nm band (band 31) as seen above. Different from Wu et al.[6], who adopted the reflectance data for this nonuniformity correction, we argue that it should be corrected over the radiance values, considering the physical causes of this degradation is a lowering of the radiance values and that the reflectance values used for reflectance conversion may be updated if the radiance values have been corrected. This correction is may be also affected by the photometric characteristics along specific lines. Therefore, we would suggest the nonuniformity correction to be added as a subsequent supplementary calibration procedure following the photometric correction. Thus we will use the B version of the IIM 2C data (with an updated photometric correction algorithm) for the following correction.

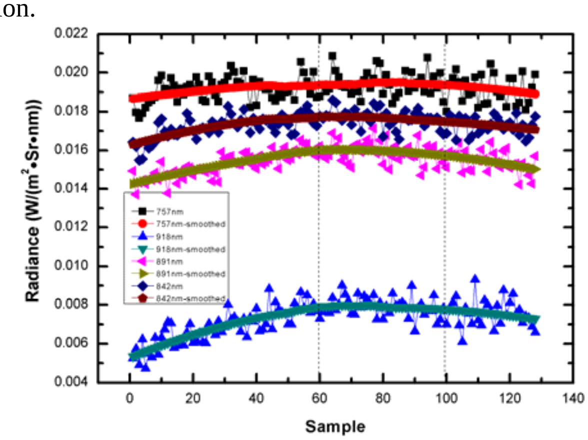

Fig.2. The original and smoothed radiance values along line 6365 of orbit 2897.

Unlike Wu et al.[6], who applied a quadratic polynomial fitting of three standard lines near their calibration site, we will derive an empirical model in a different way with the following concerns. Firstly, the key in our calibration is to find the homogenous region, i.e., spectrally and topographically etc., along the line direction in IIM data. Though the lunar soils have been testified to be sufficiently mixed, the spectral response along the line direction seems to be varies a lot, especially for the highland regions. The second issue is to determine the spectrally homogenous pixels among the 128 samples directions. By collecting more and more standard lines, we get the experience that, for sample 60-100 (region between dashed lines in Figure 2), the radiance values seems to be stable. Thus we take the average value of the middle sample 60-100 as the "true" radiance value for each standard line. Thirdly, based on the performance of every spectral channels, we found 757nm image have relatively uniform spectral responses along the pixels in line direction. However, its zigzag spectral response indicating specific smoothen procedure is of great need with intent to extract the tendency of nonuniformity response and to suppress the effects of pixel noises. The way to derive the nonuniformitiy correction factors includes:

1) Select the standard lines with relatively homogenous radiance values;
2) Smooth the relative noisy radiance values vs sample along certain standard line direction. The routine is based on Savitzky-golay smooth filter;
3) Normalize the smoothed radiance values to the mean of sample 60-100;
4) Assuming 757nm band possesses the least nonuniform effects, the smoothed 757 nm data divided by the normalized data of each bands would finally yield their corresponding correction factors.

Results and Validations:

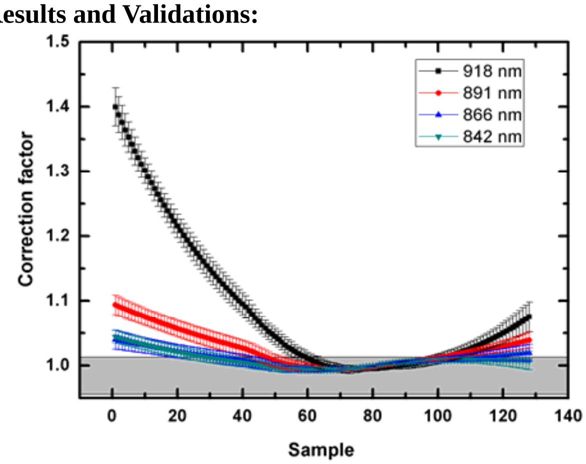

Fig. 3. The empirical correction factors derived for four IIM bands by using 15 standard lines

We selected 15 relatively homogenous standard lines including roughly equal number of highland and mare regions from four orbits (Orbit 2220, 2225, 2897, 2898), in our correction procedures. As can be seen in the Figure 3, band 31(918 nm) has the largest correction factors and those other shorter wavelength bands tend to have smaller correction values. Assuming those with correction factors smaller than 1.01 indicating a negligible need to do correction, thus the cutoffs for shorter wavelength bands also move to the two edges (as indicated by the gray region in Figure 3) , i.e., fewer pixels "truly" need to be corrected.

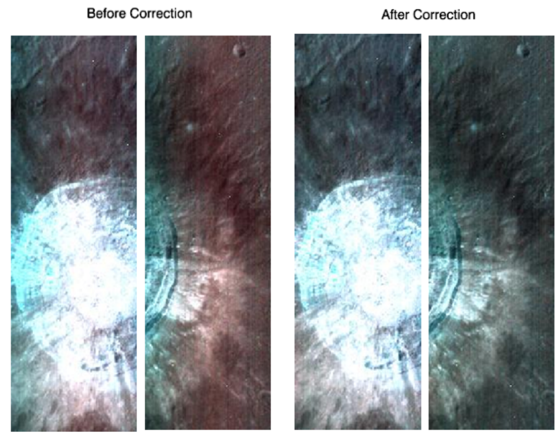

Fig. 4. Composite images of Aristarchus crater before and after corrections

The empirical correction factors are applied onto the IIM data near the Aristarchus crater for validation of our model. As shown in Figure 4, the color composite images exhibit two different color stripes before the corrections. Then the red and blue strips have been totally removed away and the exposed material by Aristarchus crater stands out with good homogeneity after correction. Wu et al.[6] also took this region for validations. In comparisons to their result, our corrected data is shown to be a more 'natural' composite color (Figure 5 in Wu et al.). This discrepancy may be due to the different dataset and correction factors which have been used between the two studies.

Conclusions and future work:

We have obtained an empirical model of nonuniformity correction of the IIM data using 15 standard lines. When the correction is applied on IIM data, it turned out to yield an obvious improvement for the line-direction inhomogeneity of the IIM data. Our modal would be beneficial for the use of the IIM data for elemental and mineralogical mappings. We will try to refine this empirical model and upgrade related data processing pipelines (e.g., reflectance conversion) in the near future.

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