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Merging datasets for photometric study

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Abstract

We have developed tools to study the photometry of Europa using a Bayesian approach. We merged datasets from New Horizons' LORRI and Voyager's ISS cameras to maximize coverage. We encountered issues of absolute calibration and compatibility of the data and we propose here a way to efficiently merge datasets from different cameras. We also propose a way to estimate correction coefficients for the absolute calibration of each individual image at the same time as the photometric behavior. We use here the Hapke model and realize a Bayesian inversion of the Hapke parameters on 20 areas of interest on Jupiter's moon Europa as well as correction coefficients for a collection of 57 images from LORRI and ISS.

Introduction

Studying the photometry of targets of interest is a very useful tool to remotely analyze the physical state of its surface [1,2,3]. In the course of such a study on Europa [4,5], we have developed different tools to process images taken by space probes and derive accurate photometric information. Photometric studies require two pieces of information: reflectance and geometry. The first can be obtained by radiometric calibration, the second necessitates precise information about spacecraft pointing and position to accurately project each pixel and derive the geometry of observation (incidence, emission, phase angles).

A very dense dataset is needed to realize a reliable study i.e. multiply the geometries of observation of a same area with different viewing and illumination angles. To achieve that, it is useful to merge datasets from different cameras in the same study.

1. Dataset

We use 39 images from the Voyager probes dataset taken with the Imaging Science System (ISS) [6] in the clear filter and 18 images from the New Horizons spacecraft taken with the Long Range Reconnaissance Orbiter (LORRI) [7].
However, their filters do not exactly match in their spectral coverage. We make the choice of offsetting the Voyager data so it can be comparable to that of LORRI taken as a reference. To do so, we consider that the effective wavelength is the most representative of the filter and use the ratio of the geometric albedo at the respective effective wavelengths as the offset.

2. Method

2.1 Correction of meta-data

We corrected for spacecraft pointing and mon attitude. Images taken by the Voyager probes underwent distortion and distance correction as well.

2.2 Model

We are using Hapke direct model detailed in Hapke, 1993 [8]. Six parameters are to be estimated: b, c, ω, θ, h and B0. We are conducting a regional study of Europa's photometry on 20 regions of interest [4,5]. As illustrated by fig. 1 some images taken in very similar conditions show a significative difference in reflectance values. To account for these effects in the best way possible we have added image-dependent coefficients to modulate the value of the reflectance – we model $r_{i,k} = (1+\alpha_k) r_{i,Hapke}$ where α_k is associated to image #k and i is the pixel number.

2.3 Bayesian Inversion

We have developed an inversion tool using a Bayesian approach based on previous work done on Mars [3] and recent improvements [9]. No a priori knowledge of the parameters are inferred except for their physical domain of variation. We modified our previous algorithm [10] to estimate a correction factor on the absolute calibration of each image.
This means that we have 6 Hapke parameters for each region of interest added to 57 correction coefficients i.e. 6x20 + 57 = 177 parameters to estimate.

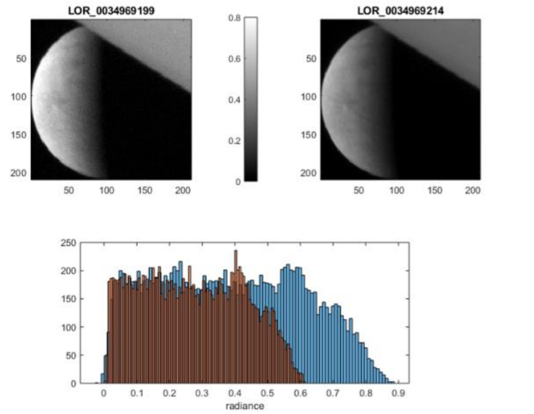

Figure 1: Comparison of two observations taken a few minutes apart. Top: the two LORRI images. Bottom: Histograms of the calibrated radiance of both images, only for Europa crescent

3. Results

The photometric results are discussed in another abstract [4].

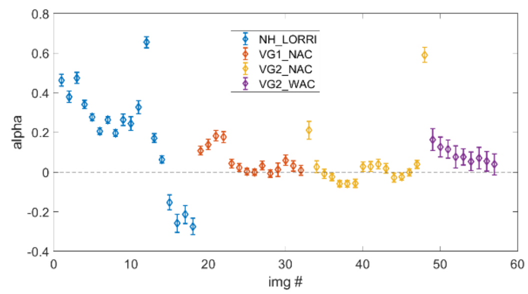

Figure 2: Correction coefficients for all the images

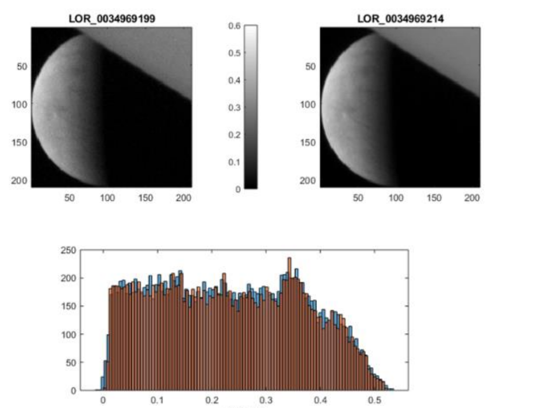

Figure 3: Same as fig. 1 after correction with estimated coefficients

Fig. 2 shows all the values of the alpha coefficients for the collection of images we used. Most values are very close to zero especially for the Voyager images. We can also note a positive bias on most images, notably the ones taken by Voygaer 2 wide angle camera (in purple in fig. 1). New Horizons' LORRI images present the most scattered and greatest correction coefficients. Fig. 3 illustrates the successful correction with the estimated coefficients on the images of fig. 1.

Conclusion

We have presented an algorithm to estimate photometric parameters at the same time as the absolute calibration of images in the dataset. In this particular study, we have successfully corrected discrepancies in our merged dataset of LORRI and ISS images, but we are still working to understand these discrepancies.
The entire pipeline we have developed is adaptable to any additional dataset and photometric model.

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