EPSC Abstracts
Vol. 13, EPSC-DPS2019-1599-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Mapping the photometric and spectral diversity of Enceladus using CASSINI/VIMS data

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Introduction

Between 2005 and 2015, spectral observations have been gathered by the Visual and Infrared Mapping Spectrometer (VIMS) on-board Cassini during 22 Enceladus close encounters, in addition to more distant surveys. Our objective is to produce a global hyperspectral mosaic of the complete VIMS data set of Enceladus between E-1 (Feb. 17, 2005) and E-22 flyby (Dec. 19, 2015) in order to study spectral variations among the different geological units. This requires accurate photometric corrections and selection of the best observations in term of spatial resolution and illumination conditions.

Photometric correction

The application of a photometric correction is necessary to remove the illumination and viewing effects from radiance factor spectra. This way, spectral variations can correctly be attributed to changes in composition or physical properties of the surface. A photometric function describes the variation in surface brightness as a function of illumination/lighting and viewing angles. It therefore corrects the image according to incidence, emergence etc. It is commonly composed of two parts: a geometric correction (D) and a phase correction (F).

$$\frac{I}{F}(\lambda, i, e, \alpha) = D(i, e, \alpha) \times F(\lambda, \alpha) \quad (1)$$

Many models have proposed in the literature to describe the photometric behavior [e.g. 1, 2]. In our case, the disk function D is computed following the Akimov model [2]:

$$D(i, e, \alpha) = D(\beta, \gamma, \alpha) = \cos\left(\frac{\alpha}{2}\right) \times \cos\left[\frac{\pi}{\pi - \alpha}\left(\gamma - \frac{\alpha}{2}\right)\right] \times \frac{(\cos\beta)^{\frac{\alpha}{\pi-\alpha}}}{\cos\gamma} \quad (2),$$

where γ and β are the photometric longitude and latitude, respectively, defined as

$$\gamma = \tan^{-1}\left(\frac{\cos i - \cos e \times \cos\alpha}{\cos e \times \sin\alpha}\right) \quad (3)$$

$$\beta = \cos^{-1}\left(\frac{\cos e}{\cos\gamma}\right) \quad (4)$$

The phase function F can be derived as a function of phase, for various wavelengths, by fitting the observation data after correction with the disk function D. In our case, we have used a second-degree polynomial fit to describe the phase function F (except for 3.10 µm where a first-degree polynomial fit was sufficient).

Data set is filtered to remove saturated data and extreme observation conditions not suitable to produce global mapping. To exploit only pixels of good quality, some criteria are applied: (1) values of the incidence and emergence angles on the pixel's center ≤ 80°, (2) values of the solar phase angle on the pixel's center ≤ 100°, (3) spatial resolution better than 50 km/px as a first step. Multiple wavelengths are studied (1.36, 1.78, 2.00, 2.25, 3.10 and 3.60 µm).

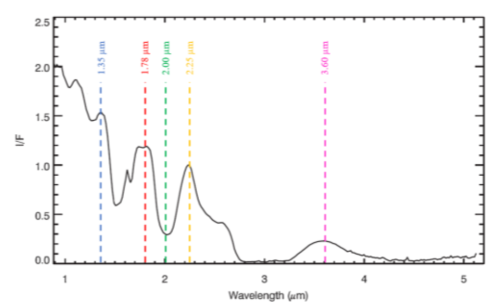

Figure 1: Typical spectrum of Enceladus with corresponding wavelengths

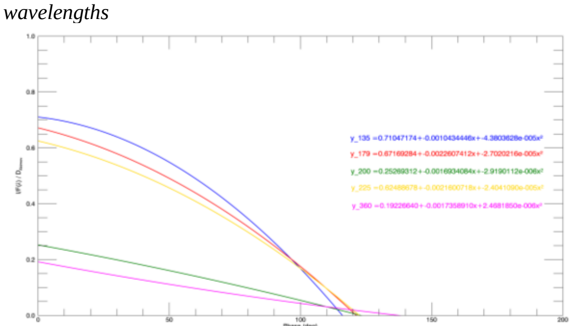

Figure 2: Phase curves derived from global data set at different wavelengths (colors correspond to the Fig.1)

The idea is then to use this global photometric function at different wavelength to optimize it at regional scales. Regions of interest have been selected based on structural units [3]. One of these regions is the South Polar terrain.

The example of south polar terrain

Figure 2 displays a VIMS RGB composite of the South Pole of Enceladus before and after the photometric correction. This correction allows us to put emphasis on the Tiger Stripes and the southern curvilinear terrain, revealing reddish terrains correlated with the main faults and the terrain surrounding the SPT.

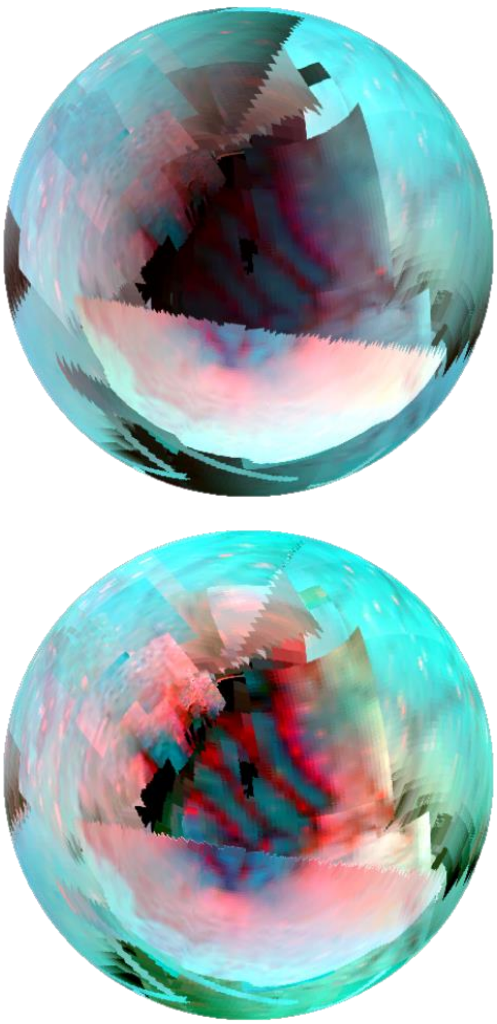

Figure 3: VIMS RGB composite of the South Pole of Enceladus, with the Red, Green and Blue controlled by the 3.09 µm, 2.0 µm and 1.78 µm channels respectively before and after the photometric correction.

Conclusion and perspectives

As mentioned before, once the data set has been corrected from the photometry, spectral variations can be more deeply studied in order to search for correlation between spectral units and features highlighted by the photometric correction. A complete mapping of the surface and detailed comparison with ISS high spatial resolution images are currently ongoing and will be presented at the conference.

Acknowledgements

The present work received financial supports from CNES (VIMS/Cassini, JUICE) and from the GeoPlanet programme for the Région Pays de la Loire (France).

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