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Study of the photometric properties of the comet 67P/Churyumov-Gerasimenko with the OSIRIS instrument of the Rosetta spacecraft

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Abstract

The ROSETTA mission is the cornerstone mission of the European Space Agency devoted to the study of the minor bodies of the Solar System. Its primary objective is to perform an extensive study of the comet 67P/Churyumov-Gerasimenko (hereafter 67P/CG). Launched on the 2^{nd} of March 2004, the spacecraft overflew the asteroids 2837 Steins in 2008 and 21 Lutetia in 2010. Since its encounter with 67P/CG in July 2014, the spacecraft has been escorting the nucleus thus allowing to study it with cameras, spectrometers, dust analysers and radio science experiments. The spacecraft will continue its escort at least until December 2015.
We present the results on the photometric properties of the nucleus derived from disk-averaged and disk-resolved images of the OSIRIS instrument acquired in 2014-2015 including the close fly-by data acquired on the 14^{th} of February 2015.

1. Introduction

After 10 years of flight and a cumulative travelled distance of 6.4 billions kilometers, the Rosetta spacecraft reached the comet 67P/CG in July 2014 and has been escorting it ever since. The scientific camera system (OSIRIS), one of the 11 instruments onboard the orbiter, has been presented in [1].
OSIRIS is constituted by the Narrow Angle Camera (NAC) and the Wide Angle Camera (WAC). The NAC has a 2°x2° field-of-view and an angular resolution 18.6 μrad/px. Its filters are optimised for the study of the mineralogical properties of the nucleus. The WAC has a 12°x12° field-of-view and an angular resolution of 101 μrad/px, its filters are optimised for the study of the gaseous species of the coma.

2. Observations and data reduction

The OSIRIS instrument has mapped the 67P/CG nucleus in the 250-1000 nm wavelength domain at different phase angles (ranging between 1° and 90°) with a resolution that went below 1 m/px for the NAC. We analysed sequences of images taken over the period of July-August 2014, as well as high-resolution images acquired during the close fly-by of February 2015. From the 2014's images, we produced the disk-integrated photometry in eight different filters covering the 325-990nm together with the disk-resolved photometry with the orange filter (centred at 649 nm), covering the 1.3° to 54° phase angle range. Those sequences were taken specifically for the hyperspectral mapping of the nucleus with a resolution up to 2.1 m/px. The details of this dataset was presented in [2]. The images were treated with the OSIRIS standard pipeline, converted into I/F radiance and then corrected for illumination conditions using the Lommel-Seeliger disk law. We registered images according to their respective sequences and performed disk-averaged and disk-resolved photometric analysis using Hapke modelling [3,4,5].
On the 14^{th} of February 2015, the Rosetta probe performed a close fly-by of a part of the Ash region [6]. The probe dived straight down from an altitude of 50 km just after midnight, reached the point of closest-encounter at a altitude of approximately 6 km around 12:40, and climbed up towards an altitude of 254 km three days later before adopting a new attitude. This imply that in between the beginning of the close fly-by and the point of closest encounter, the resolution of the NAC varies between 1.5 and 0.11 m/px and the WAC's varies between 7.9 and 0.59 m/px. Furthermore, we considered a set of 158 images

that were taken with the NAC and 67 with the WAC between 02:30 and 20:05 of the 14^{th} of February and covering a phase angle domain ranging between 80.2 $^\circ$ and less than 1 $^\circ$. At the time of writing, we concentrated this analysis mainly on a subset of 70 NAC images that were taken between 12:00 and 13:10 with different filters. The most repeated sequence of filters used during the flyby includes the 480 nm, 649 nm and 743 nm filters.

Those images will permit to study some of the surface properties of the comet to a degree of precision never achieved before.

3. Results and perspectives

The Hapke modelling obtained from the disk-averaged reflectance in 8 filters yields a low single-scattering value ranging from 0.028 to 0.066 in the 325-1000 nm wavelength domain and an asymmetry factor (g_λ) around -0.40, indicating light backscattering. The data shows a strong opposition effect. Hapke modelling of disk-resolved images confirm the strong opposition effect and the dark surface with a single scattering albedo of 0.042. We find a porosity value reaching 87% for the upper surface layer of 67P/CG's nucleus. As reported in [2], this value is higher than those found by laboratory experiments, though recent works evoke fractal aggregates as the best analogues of cometary dust. Surfaces composed of such material have porosity ranging from 80% to 90%, which would be in agreement with our fit of the Hapke 2012 model. Furthermore, we do not see clear wavelength dependence of g_λ, B_0 and h_s parameters, implying that the shadow-hiding effect must be the main cause of the opposition surge. The geometric albedo at different wavelengths derived from Hapke modelling perfectly matches the comet spectrophotometry behaviour.

The Hapke modelling gave parameters for 67P/CG that are compatible with previously studied comets such as Hartley 2, Tempel 1 and Wild 2 [7,8,9].

The derived geometric albedo at 649nm is 0.065 ± 0.02, which implies that the surface of 67P/CG is dark in absolute terms. It is however one of the brightest among the other cometary nuclei investigated by space missions [7,8,9]. The nucleus shows colour and albedo variations across the surface: Hapi is about 16% brighter than the mean albedo over the surface, while the Apis and Seth regions are about 8-10% darker. The analysis revealed also a strong phase reddening for the nucleus for both disk-averaged and disk-resolved data, with the disk-averaged spectral slope for instance increasing from 11 to 16% per 100 nm in the 1.3 $^\circ$ to 54 $^\circ$ phase angle range.

At the time of writing, we have performed spectrophotometry analysis on different surface regions for the close fly-by data of February 2015, and we are working on the phase functions in three filters. The opposition effect is clearly visible on the mapped surface. The results of this analysis will be presented.

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