EPSC Abstracts
Vol. 11, EPSC2017-781, 2017
European Planetary Science Congress 2017

Photometry as indicator of comets' surface roughness

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Abstract

We study the photometric behavior of the 67P/Churyumov-Gerasimenko comet by means of Rosetta/VIRTIS data. Comparison with other comets and among different regions of 67P/CG shows a relation between steepness of phase function and surface roughness.

1. Introduction

The VIRTIS imaging spectrometer [1] onboard the ESA/Rosetta spacecraft mapped the surface of comet 67P/Churyumov-Gerasimenko (CG), revealing a dark nucleus (geometric albedo is 0.06 at 0.55 μm [2]) and a widespread occurrence of opaque minerals associated with organic macromolecular materials [3]. Different morphological units have been identified on the comet surface [4], and a link between morphological and spectral properties has been identified [5].
In this work we study the photometry of the Churyumov-Gerasimenko comet, of its macro-regions (i.e. head, neck, head and bottom [4]), and the phase function variation across the surface, in particular between smoother and rougher regions. The obtained results are then compared with phase functions of other comets explored by space missions.

2. Method

Retrieval of phase function is based on the same approach used for Vesta [6], and currently applied on Ceres [7], i.e. a statistical analysis of the VIRTIS dataset. In particular, we considered Pre-Landing data, only, in order to avoid influence of cometary activity in the retrieval of the photometric properties.
Median values of reflectance at different phase angle bins were retrieved and fitted with a polynomial curve, to obtain phase functions at several wavelengths (for simplicity, here we show only results at 0.75 μm, but behavior is similar in the entire visible and NIR spectral range).
Phase function can be described by defining two parameters: R30, i.e. the retrieved reflectance at 30° phase angle, and PCS (Phase Curve Slope), i.e. the steepness of the phase function between 20° and 60° phase angle [8].
We calculated phase functions, R30 and PCS for the entire comet, for the four macro-regions and for specific regions of 67P/CG.

3. Results

The phase function of the Churyumov-Gerasimenko comet and of its four macro-regions are very similar and overlap within errors (Figure 1).

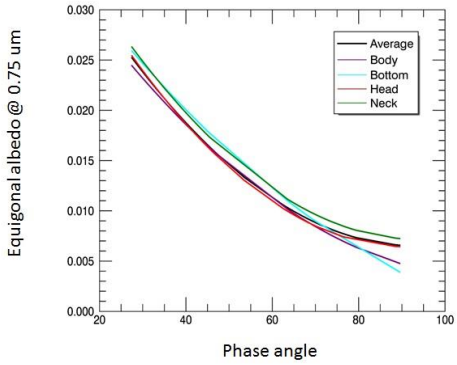

Figure 1. Phase functions of the 67P/CG average and its four macro-regions

The R30-PCS scatterplot including asteroids and comets currently explored by space missions (including 67P/CG) is shown in Figure 2.
Among comets, only Wild2 follow the anti-correlation trend (blue curve) between the two parameters, whereas the other comets show a PCS lower than expected (Table 1). In particular, the PCS is minimum for Churyumov-Gerasimenko.

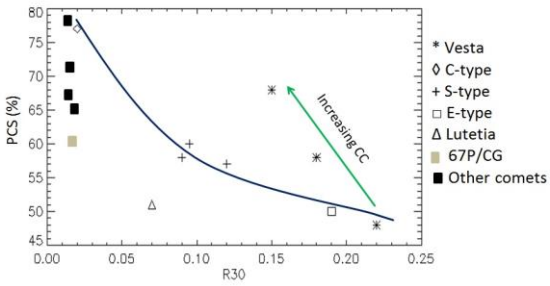

Figure 2. PCS vs R30 scatterplot for asteroids and comets explored by space missions.

4. Conclusions

Since R30 does not vary among comets, the different photometric behaviour of comets should be ascribed to different physical properties, rather than to optical ones.

According to [9] and [10], comets showing higher PCS (i.e. Wild2 and Tempel1) are rougher bodies, whereas 67P/CG shows on average a smoother surface. In order to verify this link between photometry and roughness, we calculated the PCS for 67P/CG surface regions belonging to different morphological classes.

We obtained that PCS of rougher regions (e.g., Anuket and Ash) is larger than the 67P average (67% and 64%, respectively against 60%). On the other hand, in smoother regions (Hapi and Imhotep), PCS is 58% and 55%, hence below the 67P average. A summary of PCS calculated on comets and on specific 67P regions is shown in Table 1.

The observed trend seems to suggest that morphology affects not only spectral properties, as found by [5], but also photometric ones.

Comet/region	PCS
Wild 2	78%
Tempel 1	71%
Hartley 2	67%
Borrelly	65%
Churyumov-Gerasimenko (average)	60%
Anuket	67%
Ash	64%
Hapi	58%
Imhotep	55%

Table 1: PCS of comets and 67P/CG regions.

Acknowledgements

The authors thank ASI, CNES, DLR, NASA for supporting this research. VIRTIS was built by a consortium formed by Italy, France and Germany. Team is leaded by INAF-IAPS and includes LESIA and DLR. The authors wish to thank the Rosetta Science Ground Segment and the Rosetta Mission Operations Centre for their continuous support.

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