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A catalog of stereo anaglyphs of comet 67P/Churyumov-Gerasimenko – Application to the detection of deep ice pits

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Abstract

The OSIRIS/NAC camera aboard the Rosetta spacecraft has acquired approximately 27000 images of comet 67P/Churyumov–Gerasimenko at spatial scales down to a few centimeters. We exploit the numerous sequences of images separated by a few minutes suitable for stereo reconstructions to produce anaglyphs offering three-dimensional views of the comet, complementary to other technics, as a tool to understand the topography of the nucleus. Each anaglyph is documented by a set of 17 parameters which provide the contextual information. Over 1400 anaglyphs have been produced and cataloged so far; they are available on a dedicated website and can be searched using the associated parameters. As a first application, we present direct evidences of sub-surface ice at the bottom of deep pits, so-called "ice pits" identified on high-resolution anaglyphs. Their geometry and size are obtained from stereographic reconstruction. Both their high reflectivity and their blue color substantiate the presence of ice.

1. Introduction

Three-dimensional rendering of the shape and surface of minor bodies of the solar system is essential to the understanding of their formation, to the characterization of their surface topography and to the study of their surface processes. Anaglyphs have seen a recent resurgence probably due to the need of conveniently presenting three-dimensional (3D) images to a general audience on computer screens via the Web, CDs, and DVDs. As a consequence, space agencies (NASA in particular) and space imager teams have released hundreds of anaglyphs of solar system objects conveniently archived on dedicated websites. In addition, it has recently been realized that anaglyphs have their own merits for scientific analysis, in particular to make small-scale topographic measurements. The OSIRIS NAC camera [1] aboard the Rosetta spacecraft has acquired approximately 27000 images at different distances and therefore at different spatial scales of comet 67P/Churyumov–Gerasimenko, from global images of the bi-lobed nucleus and its jets down to topographic details of a few centimeters on different regions of the nucleus. The bulk of these images have been obtained in sequences and the combined displacement of the Rosetta orbiter along its trajectory and the rotation of the nucleus allow associating many pairs of images appropriate to producing anaglyphs for stereoscopic viewing of the comet.

2. Construction of the anaglyphs

With a single high resolution camera, the NAC, the stereo effect had to rely on its displacement. In practice, two effects come into play: the motion of the spacecraft and the intrinsic rotation of the nucleus, they relative importance depending upon the distance between the camera and the nucleus. In order to reproduce human vision with a stereoscopic base of 7 cm, the typical distance between our two eyes, suitable pairs of images were selected on the basis of the parallax between the two images of ≈2° (in practice, we allowed a range of 0.5° to 4°). After thresholding and rotating the images to bring their relative displacement horizontal, the anaglyphs were created using the StereoPhoto Maker software in the standard red/cyan system: left image in red and right image in cyan (green+blue). An example is given in Fig. 1. Each anaglyph is documented by a set of 17 parameters which provide the contextual information. In addition one image of each anaglyph is projected on a 3D model of the nucleus [2] to show its location. At time a writing, 1400 anaglyphs have been produced and are accessible on a dedicated website: https://rosetta-3dcomet.cnes.fr/. It is estimated that a total of 3000 to 4000 anaglyphs could be produced

once the whole set of NAC images has been scrutinized.

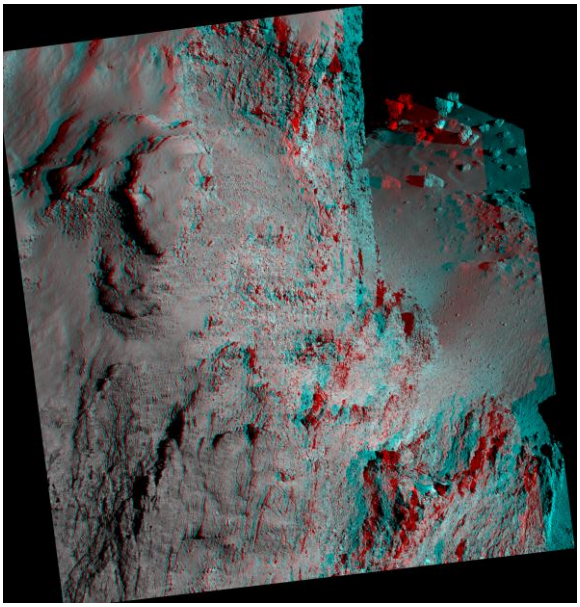


Figure 1: An example of anaglyph offering a dramatic perspective view over both the small lobe (Bastet and Maat) and the neck (Hapi)

3. Application to the detection of deep ice pits

Bright features are ubiquitous on the nucleus of comet 67P/Churyumov-Gerasimenko and are often interpreted as ice patches [3]. Evidences of the presence of sub-surface ice are only indirect based on the activity of the comet [4]. Several high-resolution anaglyphs of our catalog provide for the first time direct evidences of sub-surface ice at the bottom of three deep pits, so-called "ice pits", see Fig. 2 for an example (pit "A"). This pit has an elliptical shape with overall dimensions of 15x19 m. A stereographic reconstructions has yielded a depth of 47 m. The bright patches at the bottom of the pits have spectral reflectivity spectra conspicuously different from the surrounding terrains with shallower spectral slopes. The implied "blue" color together with the large reflectivity are indicative of material enriched in water-ice. This particular pit "A" has been associated with the highly collimated jet #14 listed by Vincent et al. [5].

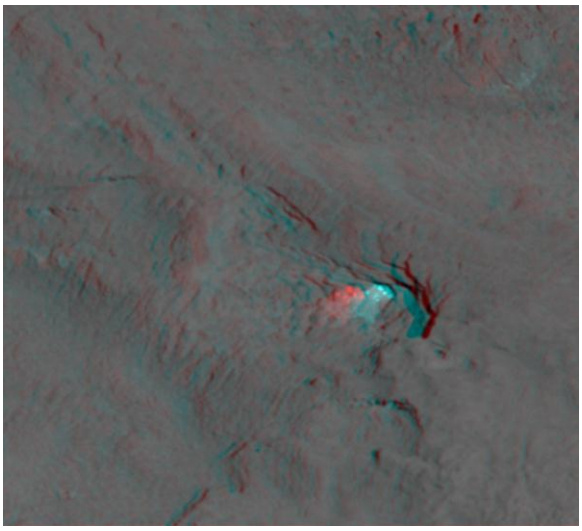


Figure 2: Anaglyph of pit "A" located in the Khepry region of the big lobe.

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