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Vesta seen by VLT/SPHERE

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Abstract

The NASA Dawn interplanetary mission has characterised in detail the topography and albedo variegation across the surface of asteroid (4) Vesta down to a spatial resolution of $\sim$20 m pixel^{-1} scale. Here our aim was to determine how much topographic and albedo information can be retrieved from the ground with VLT/SPHERE in the case of Vesta, having a former space mission (Dawn) providing us with the ground truth that can be used as a benchmark.

We observed Vesta with VLT/SPHERE/ZIMPOL as part of our ESO large programme (ID 199.C-0074) at six different epochs, and deconvolved the collected images with a parametric point spread function (PSF). We then compared our images with synthetic views of Vesta generated from the 3D shape model of the Dawn mission, on which we projected Vesta's albedo information. We show that the deconvolution of the VLT/SPHERE images with a parametric PSF allows the retrieval of the main topographic and albedo features present across the surface of Vesta down to a spatial resolution of $\sim$20–30 km. Contour extraction shows an accuracy of $\sim$1 pixel (3.6 mas). The present study provides the very first quantitative estimate of the accuracy of ground-based adaptive-optics imaging observations of asteroid surfaces.

1. Introduction

The surface topography of Vesta, the second largest main belt asteroid after the dwarf planet Ceres, has been characterised in detail by the framing camera (FC) on board the NASA Dawn mission. These images revealed the complex topography [5, 2, 4] including two overlapping giant impact basins Rheasilvia & Veneneia (originally observed with HST), regions with elevated topography (e.g. Vestalia Terra), numerous troughs [2] (especially in the equatorial and northern regions) and a north–south craterization dichotomy [4].

Here we present a new set of ground-based images of Vesta acquired with VLT/SPHERE/ZIMPOL as part of our ESO large programme (ID 199.C-0074; [7]). These observations, through direct comparison with the Dawn in situ measurements, were performed with the aim of testing the ultimate resolution achieved for images acquired with this new-generation adaptive-optics (AO) system [1] and the robustness of our deconvolution algorithm, which uses a synthetic point spread function (PSF) as input. These observations were also used to determine which of the geologic features discovered by Dawn can already be identified from the ground, and to place a size limit above which these features can be retrieved. Finally, these observations were used to produce an albedo map that could be directly compared with that based on the images of the Dawn FC [6]. In summary, Vesta was used as the benchmark target for our large programme, allowing us to test and ultimately validate our different techniques of image analysis.

2. Results

The OASIS [3] algorithm was used to project the NASA/Dawn high-resolution images into our SPHERE observation frame (same angle of view illumination and pixel size). We can then compare pixel per pixel SPHERE deconvolved images and the ultimate resolution given by OASIS fed with Dawn data.

2.1. Contour extraction

Contours of an asteroid are important for 3D reconstruction algorithms and can be correlated with star occultations by the asteroid. Using the same contour extraction algorithm between our SPHERE deconvolved images and OASIS synthetic images, we find a RMS error of approximately 1 pixel.

2.2. Topographic features

It appears that most of the main topographic features present across Vesta's surface can already be recognised from the ground (Fig. 1). This includes the south pole impact basin and its prominent central mound, several D$\sim$ 25 km sized craters and Matronalia Rupes. From these observations, we can determine a size limit of $\sim$30 km for the features that can be resolved with VLT/SPHERE (i.e. features that are 8–10 pixels wide). We constrain the detection rate for the largest craters with diameter greater than 40 km. Except the large Rheasilvia basin, Vesta hosts 21 such craters and 9 of them were covered by our observations. Of these nine craters, we could identify seven of them in our images, implying a detection rate of $\sim 80\%$.

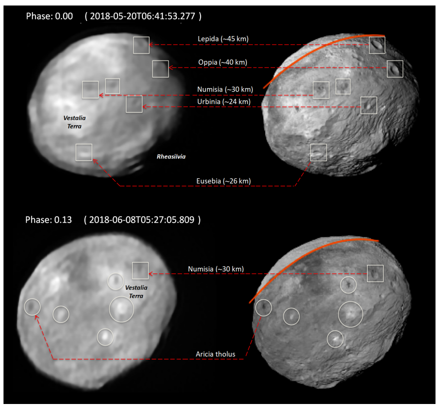

Figure 1: VLT/SPHERE/Zimpol images of Vesta after deconvolution (left) and OASIS synthetic model based on NASA/Dawn observations (right). Schröder's albedo map [6] is applyied on OASIS images. Albedo information above 30° N (orange line) is missing.

2.3. Albedo features

After correcting of gradient illumination, we extracted albedo information from SPHERE observations to derive an albedo map to be compared with the ground truth Schröder's albedo map [6]. Vesta's albedo in the Johnson V-band ranges from 0.30 to 0.46 using Dawn data. On deconvolved images we recognize the main albedo features of the asteroid, in a range slighly narrower (from 0.34 to 0.45) that can be attributed to residues of convolution smoothing albedo details.

3. Summary and Conclusions

The present study demonstrates for the very first time the accuracy of ground-based AO imaging observations of asteroids with respect to in situ observations. We show that the deconvolution of the VLT/SPHERE images with a parametric PSF allows the retrieval of the main topographic and albedo features present across Vesta's surface.

Future generation telescopes (ELT, TMT, GMT) could use Vesta as a benchmark to catch all of the main features present across its surface (including the troughs and the north–south crater dichotomy), provided that these telescopes operate at the diffraction limit.

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