



Asteroid (16) Psyche's primordial shape: A possible Jacobi ellipsoid

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Introduction

Asteroid (16) Psyche is the largest M-type asteroid in the main belt and the only metal rich asteroid of this size ($D > 200$ km). It has been proposed that Psyche could be an exposed planetary core [S17,D18]. This hypothesis and the uniqueness of Psyche's characteristics are the main reasons for its selection as the rendez-vous target of a NASA Discovery mission that is scheduled to launch in 2022 [E17].

However, the true nature of Psyche remains enigmatic which leads to the formulation of several distinct formation scenarios. Psyche's density appears compatible with that of stony-iron meteorites such as mesosiderites [Vi18] as well as that of pallasites and CB chondrites [E20]. It is also unknown if its interior is intact or a rubble pile and if it is differentiated.

Observation

We obtained 35 images of Psyche at 7 epochs in July and August 2019 using VLT/SPHERE/ZIMPOL. They complement the first 25 images obtained in 2018 that were already presented in [Vi18], for a total of 60 images taken at 12 epochs. Psyche was observed near opposition with a pixel size corresponding to ~ 6 km/px. The first apparition in 2018 was limited to the northern hemisphere of Psyche but the second apparition in 2019 covered well the equatorial region and allowed us to achieve a complete coverage of the surface.

Methods

First, we generated an updated shape model of Psyche with the ADAM inversion algorithm [Vi15]. We used the same procedure as in [Vi18] and added the new SPHERE images and a new stellar occultation recorded in October 2019.

We then applied our Multi-resolution PhotoClinometry by Deformation (MPCD; [C13]) method on a selection of the SPHERE images to reconstruct the 3D shape of Psyche. The MPCD software gradually deforms the vertices of an initial mesh to minimize the difference between the observed images and realistic images of the surface. The ADAM model was used as input for the initial mesh and the spin parameters.

Results and conclusions

The ADAM and MPCD shape models are remarkably similar with a small volume difference and radial differences mean. The comparison between the SPHERE images and the corresponding synthetic images is given in Fig. 1. The densities derived from the volumes of both shape models combined with the average of available mass estimates are close to $\sim 4 \text{ g/cm}^3$ which is in agreement with other recent estimates [S17,D18,Vi18].

A shape analysis was performed by computing the radial differences between Psyche’s shape model and its best-fitting ellipsoid to obtain the average residuals relative to the mean radius. We then computed the sphericity index of Psyche using the same approach as in [V19]. We repeated the process for other large main-belt asteroids, the terrestrial planets and smaller asteroids visited in-situ by space missions. It revealed that Psyche’s shape appears intermediate between those of larger asteroids and those of smaller or similarly sized bodies. Psyche’s appearance is close to an ellipsoid with flat regions at the poles even though we identified three depression regions along its equator.

Finally, we investigated whether the shape of Psyche may be close to the equipotential shape of a hydrostatic body. The flatness and density of Psyche are compatible with a formation at hydrostatic equilibrium as a Jacobi ellipsoid with a shorter rotation period of $\sim 3 \text{ h}$. Later impacts may have slowed down Psyche’s rotation, which is currently $\sim 4.2 \text{ h}$, while also creating the imaged depressions. Our results open the possibility that Psyche acquired its primordial shape either after a giant impact while its interior was already frozen or while its interior was still molten owing to the decay of the short-lived radionuclide ^{26}Al .

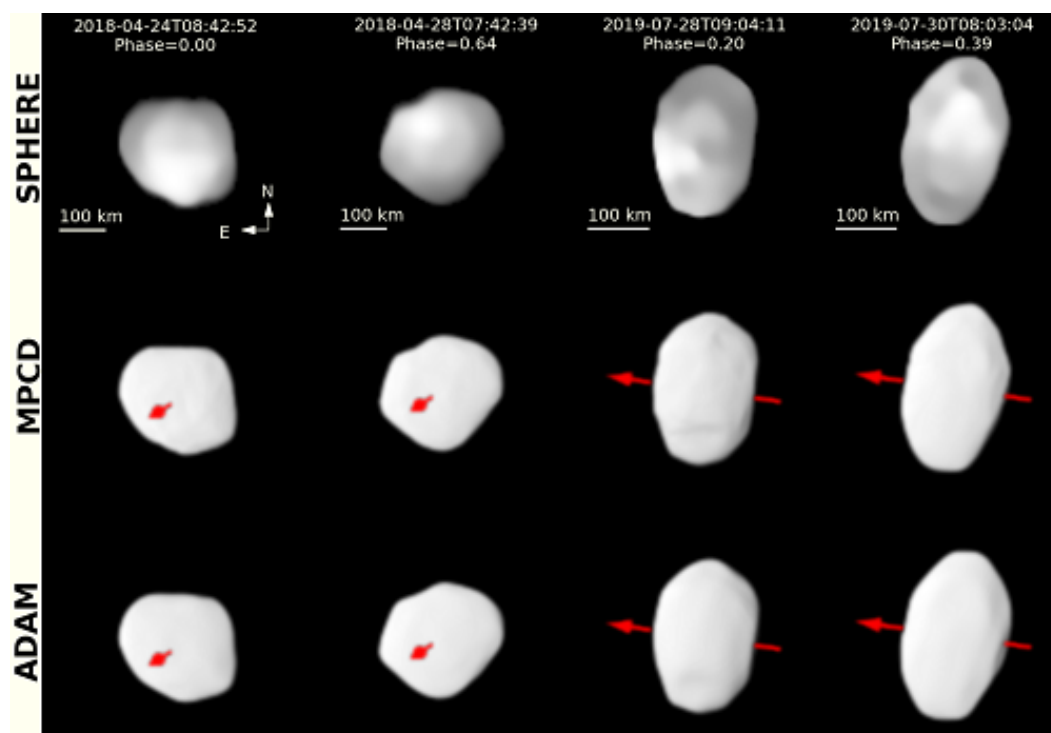


Figure 1: Comparison between VLT/SPHERE/ZIMPOL deconvolved images of Psyche (top row) and the corresponding synthetic images of our MPCD (second row) and ADAM (third row) shape models. The red arrows indicate the direction of the spin axis.

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