Thesis subject

Name of the laboratory: Laboratoire d'Astrophysique de Marseille (LAM)

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Subject's title: Constraining the formation and evolution of the largest main belt asteroids

Subject description: Asteroids in our solar system are metallic, rocky and/or icy objects, ranging in size from a few meters to a few hundreds of kilometers. Even though asteroids represent only a tiny fraction of the total mass of the planets, their large numbers, diverse compositions, and orbital distributions provide powerful constraints for planetary system formation models that complement - not duplicate - those collected from exoplanets and disks observations. Whereas we now possess constraints for the surface composition of most D>100 km primordial main-belt asteroids, little is known regarding their internal structure. Yet, this is a fundamental property whose characteristics result directly from (a) their formation location, (b) their time of formation, and (c) their collisional history. Characterizing the internal structure of the main compositional classes of asteroids would therefore allow us to address entirely new questions regarding the earliest stages of planetesimal formation and their subsequent collisional and dynamical evolution.

To make progress in our understanding of the internal structure of the main compositional classes of asteroids, we are currently conducting a survey (PI: P. Vernazza; Vernazza et al. 2018) via an ESO large program (ends in June 2019) of a substantial fraction of all D≥100 km main-belt asteroids covering the major compositional classes. Specifically, we perform high angular-resolution imaging observations of these bodies with VLT/SPHERE throughout their rotation in order to derive their volume (via their 3-D shape), which combined with already existing mass estimates allows us to determine their bulk density. The high-resolution 3-D shapes also allow us to detect craters larger than ~30 km and thus use their morphology (crater diameter and depth) to characterize the density of the outer shell. The knowledge of both their bulk density and the density of their outer shell allows us to characterize their internal structure. This information, in turn, allows us to determine: (a) the nature of the initial building blocks (rock only, or a mixture of ice and rock) and (b) which compositional classes experienced differentiation. These constraints serve as direct inputs to thermal evolution models and allow us determine the time of formation as well as the formation location (inward or outward of the snowline) of the main compositional classes.

By the start of the PhD, all the data will have been acquired so that the modeling part – to be taken over by the PhD student – will start right away. Specifically, the first main task of the thesis will be to adapt the 3D shape reconstruction MPCD procedure (already applied to targets of the ESA/Rosetta mission; Jorda et al. 2012, 2016; see Fig. 1) to the VLT/SPHERE data and produce high-resolution shape models. This will allow drastically improving current shape models. The second task will be to perform a quantitative analysis of the shape models and derive key topographic properties for individual targets as well as for each compositional class in order to reach broad conclusions regarding their early formation and evolution.

Importantly, new doors into ground-based asteroid exploration, namely geophysics and geology, are being opened thanks to the unique capabilities of VLT/SPHERE (see Fig. 2). In the fields of geophysics, geology, and asteroid family studies, the future will only get brighter with the forthcoming arrival of 30–40m class telescopes like ELT, TMT, and GMT. This implies that the topic of the present thesis is not only timely but also that the student would establish himself in a new promising scientific niche.

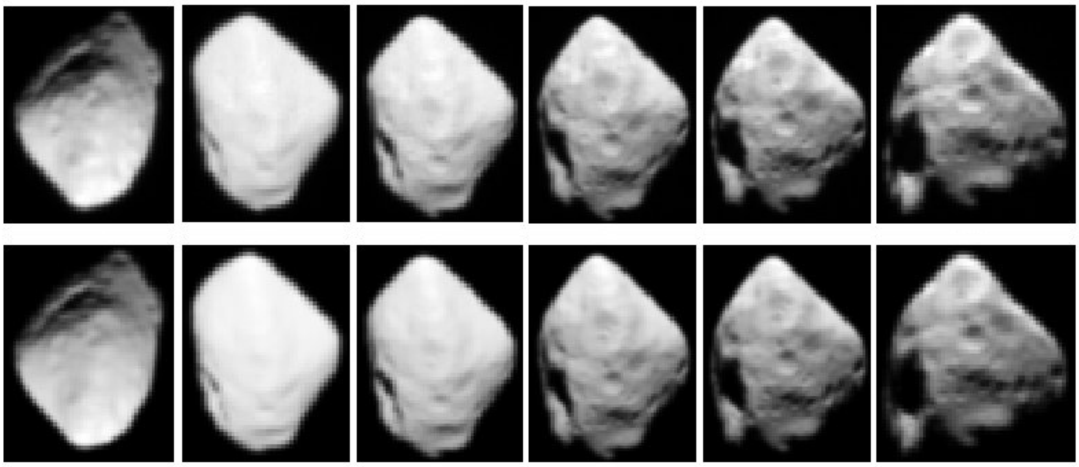

Figure 1. Series of images acquired by the OSIRIS camera onboard ESA's Rosetta spacecraft (top row) during the flyby of asteroid 2867 Steins and the corresponding synthetic images (bottom row) generated with the MPCD shape model reconstructed from the images (Capanna et al., 2013). These images have a number of pixels across comparable to those of images acquired by the SPHERE/ZIMPOL instrument at the VLT.

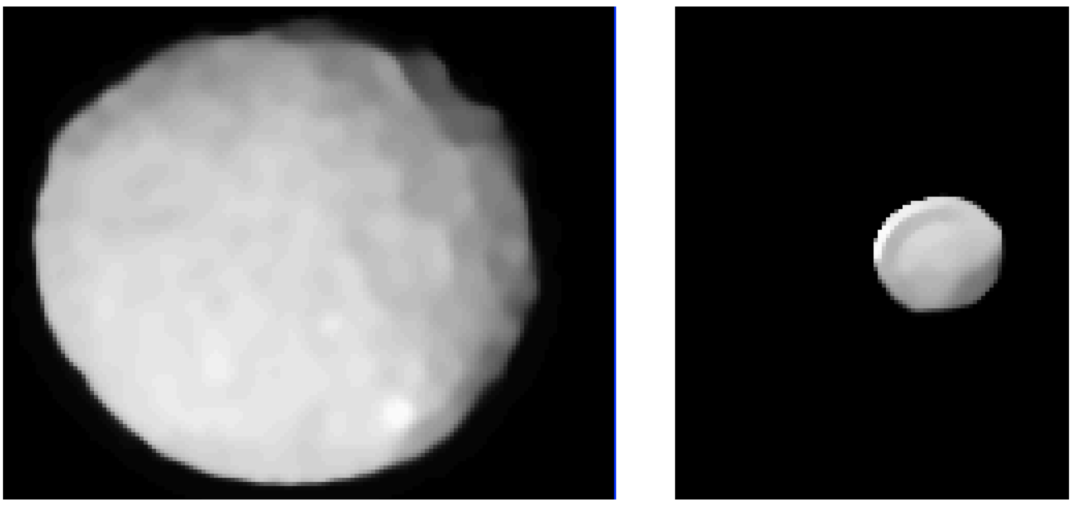

Figure 2: Pallas (D~515km) seen close to opposition by the new-generation visible adaptive-optics instrument VLT/SPHERE/ZIMPOL (left) and by the former near-infrared adaptive-optics instrument VLT/NACO (right).

Bibliography:

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