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Asteroids as tracers of solar system formation: Probing the interior of primordial main belt asteroids

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Abstract

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. 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 achieve this goal, we will - *via an ESO Large Program (LP) that was awarded 152h on VLT/SPHERE (the observations will be spread over 4 semesters from April 1st, 2017 till March 30, 2019 in service mode)* - carry out a survey of a substantial fraction of all D≥100 km main-belt asteroids for the four major compositional classes (8 to 10 objects per class for the following groups of classes: S, Ch/Cgh, B/C and P/D; objects belonging to these classes represent more than 90% of the mass of the asteroid belt, see DeMeo & Carry 2013) at high angular-resolution with VLT/SPHERE throughout their rotation in order to derive their volume (via their 3-D shape; see Fig. 1), which combined with already existing mass estimates will allow us to determine their bulk density. The high-resolution 3-D shapes will 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 will allow us to characterize their internal structure. This information, in turn, will allow 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 will 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.

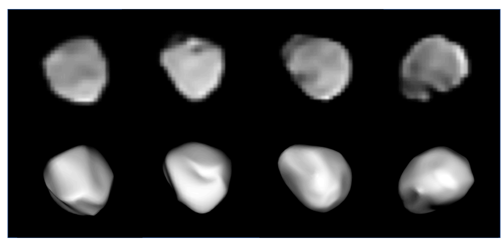

Figure 1 (from Marsset et al. 2017, submitted): **Expected output from our survey: high-resolution shapes, accurate densities and reconnaissance of the largest craters for ~40 D>100km main belt asteroids.** Here, SPHERE images of (6) Hebe acquired throughout its rotation and used for reconstruction (top) and corresponding model views (bottom).

Importantly, our survey will provide key constraints to solar system formation models such as the Nice and Grand Tack ones (e.g., Morbidelli et al. 2005, Levison et al. 2009, Walsh et al. 2011). These models propose that today's asteroid belt may not only hosts objects that formed in situ (hence, rocky-rich), typically between 2.2 and 3.3 AU (probably the case for the so-called S-types), but also a substantial fraction of bodies (≥50%) that were formed in the giant planet region and beyond (hence, water/ice-rich). Our density estimates will allow testing this hypothesis as we should find a substantial fraction of bodies with densities compatible with those of comets and trans-Neptunian objects (density≤1.2 g/cm^3).

Here, we will present the very first results of our survey that started April 1st, 2017.