Asteroid Sizes by Combining Shape Models and Adaptive Optic Images

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Introduction: In the past decade, about 200 asteroid shape models were derived by the lightcurve inversion method developed by [1] and [2]. This technique makes only use of disk-integrated photometry of asteroids to derive a three dimensional shape models approximated by convex polyhedrons. These shape models are not scaled in size because we do not possess an accurate measurement of their absolute photometry and their albedo.

By combining resolved direct images of asteroids collected with Adaptive optics (AO) systems with the LC shape model we can infer the size of an asteroid. By scaling the shape model to fit the estimated size on the resolved asteroid, we are able to derive the equivalent diameter D_{eq} (diameter of a sphere of the same volume as the scaled shape model). In a few cases for which the mass of the asteroid in known, the density can be as well estimated. Additionally, as shown in [3], AO observations allow to remove the uncertainty between two possible mirror solutions derived from lightcurve inversion method, and can also identify large surface non-convexities (e.g. bilobated shape of 216 Kleopatra in [4]).

Adaptive optic observations: We used W.M. Keck AO images [5] recorded within a campaign of observation aiming at identifying and studying multiple asteroid systems [3]. The data, collected between 2003 and 2010 with near-infrared NIRC-2 camera in H, FeII or K filter (between 1.5 and 2.2 μm) reach an angular resolution between 40 and 55 milli-arcsec. To improve their sharpness and determine the silhouette (two dimensional projection of the shape onto the plane perpendicular to the line connecting the observer and the center of the asteroid), all images were deconvolved using AIDA deconvolution algorithm described in [3] and [6].

Model: We define the fundamental plane that passes through the center of the asteroid and is perpendicular to the line connecting the observer and the center of the asteroid, and also the coordinate system (ξ, η) on the fundamental plane in the same way as in [7]. We derive the asteroid silhouette with coordinates $(\xi_j, \eta_j)_{AO}$ directly from the AO observations. The convex hull of projected vertices (only both illuminated by the Sun and visible from the Earth) of the convex polyhedron onto the fundamental plane represents a silhouette of the model given by the coordinates $(\xi_i, \eta_i)_m$ which is calculated from our 3D shape model at the time of the AO observations. To determine the true size of the model, we minimize the difference between these two silhouettes. While the AO silhouette remains fixed in size, the dimension of the model silhouette is parameterized by three free parameters: scale c and an offset (ξ_0, η_0) as described in detail in [7].

Results: We present the equivalent diameters D_{eq} for three asteroids: (15) Eunomia, (40) Harmonia and (45) Eugenia. We have collected 14 disk-resolved observations with Keck AO for Eugenia and two observations for both Eunomia and Harmonia. All available AO observations for each asteroid were simultaneously used in the size optimization process. We adopted a mass estimate for Eunomia and Eugenia from the literature and computed their corresponding average densities.

Resolved AO images from Keck telescope are available for ~20 additional main-belt asteroids, for which convex shape models from lightcurve inversion were previously derived. Scaling the sizes of these asteroids is the goal of our future work.

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