Non-convex shape models of asteroids based on photometric observations

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We present the SAGE algorithm (Shaping Asteroids with Genetic Evolution) able to derive 3D non-convex shapes of asteroids and solving for their spin parameters using only disk-integrated photometry. A triangular mesh of 62 vertices is used as a seed during the parameters minimization, and the Catmull-Clark method (Catmull-Clark 1978) is applied to generate bodies with higher resolution. The subroutines search for the sidereal period of rotation in a given range, and the spin-axis orientation on the whole celestial sphere. A step-iterative algorithm is used to make the shape evolve under the minimization constraints between the synthetic generated photometry and the real observations. In order to generate the simulated lightcurves, we propose the virtual frames algorithm. The algorithm simulates the pictures visible on hypothetical CCD frames and, using only elementary vector operations or quadratic algebraic equations, it takes into account all phase-angle effects. Publicly available lightcurve data has been used to obtain a new non-convex model for (9) Metis, (21) Lutetia, and (433) Eros. The resulting body shapes are compared with the ones obtained using other observational techniques, such as adaptive optics and stellar occultations (Timerson et al. 2009) or the NEAR Shoemaker observations of Eros during its rendezvous (Zuber et al. 2000). We also assess the problem of the solution uniqueness for non-convex models, generating a family of shape solutions and studying the stability of the model features. Moreover, following the investigations presented in Kaasalainen & Torppa (2001) we study the discrepancy on the lightcurves between a non-convex shape model and its convex hull as a function of the phase angle. Finally, we compare the lightcurve fits obtained with other existing models for both "classic" and sparse-in-time photometry.

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References: Catmull E., Clark J., 1978, Computer-Aided Design, 10, 350; Kaasalainen M., Torppa J., 2001, Icarus, 153, 24; Timerson B. et al., 2009, Minor Planet Bull., 36, 98; Zuber M.T. et al., 2000, Science, 289, 2097.