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Synergy between SAGE and SHAPE algorithms for modelling the physical parameters of asteroids.

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Introduction

Asteroids can be observed using distinct ground-based techniques, some allowing direct shape observations. In the optical spectrum, stellar occultations and adaptive optics imaging are an important resource for recovering shape outlines and some surface features. For some, particularly near-Earth asteroids, radar observations are possible by recording reflected radio beams from powerful ground-based transmitters. The technique provides information on the surface and subsurface properties, sizes, pole orientations, and shape details of asteroids down to a few metres (Ostro, 2012). The physical parameters obtained in the modelling process allow a better understanding of the structure and evolution of the small bodies of the solar system.

Methods

We present a new method for determining the physical properties of asteroid shapes based on the SAGE (Bartczak et al., 2014) and SHAPE (Hudson 1993, Magri et al. 2007) systems. Until now, the SAGE software has been used primarily on optical data, using genetic algorithms in the process of shape optimization. In the new method, we preserve the core of SAGE parameter optimisation procedure and handling of optical data but extend it by the radar-image rendering capabilities built into SHAPE. The synthetic lightcurves and radar images are calculated for comparison with observations and used simultaneously to drive the shape-determination process.

We start each shape optimisation run with a sphere and a selection of random pole orientation values and rotation periods. The best fit is then identified through comparison with observations. In subsequent steps, the current best solution is used to create a new population of solutions by making small random changes to the model parameters. Assuming a uniform mass distribution, we calculate each centre of mass and moment of inertia for each solution to ensure the model is physically feasible. We also adjust the weights assigned to each input data set by increasing weights for data sets with poorer fits to ensure even quality of fit across the available data. This includes both the light curve and the radar fits. We then repeat the process until we reach a stable solution.

This new method allows for a global approach to fitting shape features. In contrast, SHAPE was limited to fitting the parameters sequentially, adjusting the positions of individual vertices in small steps. This new method reduces the time to determine physical parameters while utilising the full extent of information contained in radar data.

Results

We will present the technical details of the modelling process and preliminary results for a selection of asteroids. Examples include asteroid (2102) Tantalus, for which we find evidence of high-albedo crater feature on the surface, and 1999 JV6, a contact binary object.

Our new method of combining radar and optical data to retrieve shape information also enhances the estimation of the errors of the obtained physical parameters and the uncertainty of the volume and the topology of the determined shape based on the radar data.

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