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Asteroid proper phase curves from Gaia photometry

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Abstract

The photometric lightcurve and phase curve of an asteroid refer to the dependences of the asteroid's disk-integrated brightness on time and on the phase angle (the Sun-Object-Observer angle), respectively. They depend on the shape and rotation state of the asteroid, as well as the surface scattering properties. It follows that the shape, rotation state, and scattering properties can be estimated from the observations, to an extent allowed by the data available. We study the feasibility of retrieving phase curve parameters via statistical lightcurve inversion from the sparse asteroid photometry available from Gaia Data Release 2. We utilize triaxial Lommel-Seeliger ellipsoids as well as convex and non-convex shapes. With the help of the H, G_1, G_2 photometric function, we devise a surface scattering phase function that gives rise to realistic disk-integrated phase curves. This allows us to derive so-called proper phase curve parameters that allow for photometric classification of asteroids.

1. Introduction

Asteroids are nonspherical Solar System bodies typically rotating about their axes of maximum inertia. Their surfaces are assumed to be covered by regoliths, layers of particles in the size scales of microns to meters, with the typical particle size being of the order of 100 microns. Asteroids offer insight into the evolution of the Solar System, provide valuable space resources, and cause a significant impact hazard.

Photometry, the measurement of the disk-integrated brightness of asteroids, is the most common source of data for the asteroids. The lightcurve, i.e., the observed brightness as a function of time, depends on the shape and spin state of the asteroid, as well as its scattering properties. In the present work, we consider sparse photometric data from the ESA Gaia mission made available by Gaia Data Release 2 (Gaia DR2, [1]). We utilize statistical inverse methods for the retrieval of rotation periods, pole orientations, and scattering properties from the photometric observations. This entails a complete Markov chain Monte Carlo (MCMC) assessment of the uncertainties in the physical parameters. The inverse methods are based on the Lommel-Seeliger ellipsoids and convex shape models [2-5] suitable for the analyses of sparse data. The present inverse methods are available through a web-based Gaia Added Value Interface [6].

2. Results and discussion

We have validated the Gaia photometric data by using high-resolution shape models of (21) Lutetia [7] and (2867) Steins [8]. Figure 1 shows the validation for Steins. Typically, the Gaia photometric data can be validated with numerical modeling at a root-mean-square level (RMS) of 0.01-0.02 magnitudes. We would like to point out that a large part of the RMS difference is likely to derive from the modeling and that the Gaia data can have significantly smaller uncertainties.

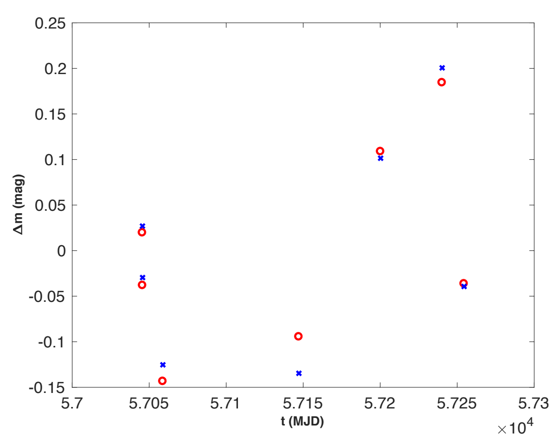

Figure 1: Photometry of asteroid (2867) Steins from Gaia DR2 (red circles) validated using a high-resolution shape model (blue crosses, [8]) with a Lommel-Seeliger scattering law [2] and E-class G_1, G_2 phase curve parameters [9].

In Fig. 2, we show the MCMC inversion for the proper phase curve parameters of Steins using the Gaia DR2 data and the high-resolution Rosetta shape model. It turns out that the small number of seven Gaia DR2 observations allow us to state that Steins does not have a steep phase curve. Based on our preliminary study, without a priori information about the shape and rotation state, the Gaia DR2 data can allow us to constrain the proper H, G_1, G_2 parameters for asteroids [9-11] with more than 15 observations, that is, for more than 2100 asteroids.

3. Conclusion

We conclude that the present inverse methods can facilitate a meaningful retrieval of proper asteroid phase curves from sparse Gaia DR2 photometry. The retrieval can lead to photometric classification of asteroids.

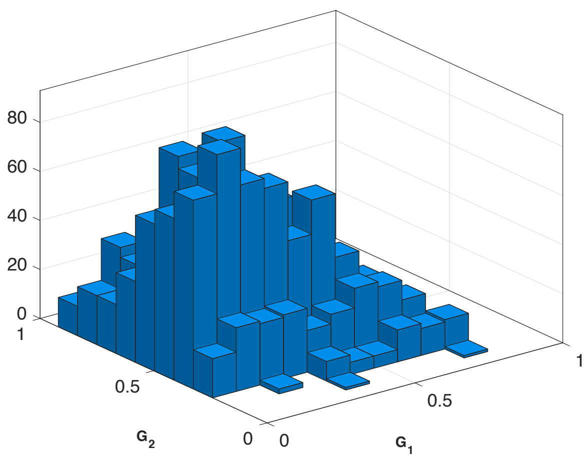

Figure 2: Preliminary MCMC inversion for the proper phase curve parameters of asteroid (2867) Steins using seven photometric observations from Gaia DR2 [1] and the high-resolution shape model from the Rosetta mission [8]. The result suggests that (2867) Steins does *not* belong to the class of asteroids with steep photometric phase curves.

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