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Dreams came true – the first results from inversion of Gaia DR2 asteroid photometry

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Abstract

The Gaia Data Release 2 from April 2018 contains observations of about 14,000 asteroids. These photometric data with a typical accuracy of $\sim 1\%$ can be used for reconstruction of the rotation state (the rotation period and the direction of spin axis) and shape of asteroids. We applied a triaxial ellipsoid model and a convex shape model [6] to fit Gaia photometry and to derive models of individual asteroids. We were successful in 338 cases, out of which 270 were new models.

1. Introduction

Sparse-in-time photometry of asteroids can be successfully used for the reconstruction of asteroid shapes and spin states [4, 2]. So far, the main problem has been the low quality of sparse photometry from ground-based sky surveys. For this reason, a reliable solution of the inverse problem based on sparse data was possible only when hundreds of data points were available and when the lightcurve amplitude was high enough not to be lost in noise. The situation has changed dramatically with the Gaia DR2 that contains also asteroid photometry [3]. Although the number of data points in DR2 for a given asteroid is a few tens at most, thanks to very good photometric accuracy of $\sim 1\%$ or even better, the unique solution of the inverse problem is possible for hundreds of asteroids.

2. Inversion of Gaia photometry

We tested the potential of Gaia data to reconstruct spin states and shapes of asteroids. We used essentially the same approach as with our analysis of sparse data from astrometric ground-based surveys [4, 5, 2]. Using a gradient-based optimization, we searched for the best-fitting shape/spin model. For each asteroid with more than 10 independent observations in DR2 (~ 5400), we scanned the period interval 2–1000 hours and for each trial period we looked for the best pole direction and the corresponding shape. Then we selected the globally best solution and tested its reliability with the approach described in [2]. We derived 328 unique models out of which 270 were new models. We compared the remaining 68 models with those derived from independent data and stored in the Database of Asteroid Models from Inversion Techniques (DAMIT, [1]). This comparison showed us that with our approach, the rate of false positive solutions is only few percent and that Gaia data alone can be used for reliable spin and shape reconstruction.

Not surprisingly, the success of the inversion process critically depends on the number of data points N. For $N \simeq 10-15$, unique solutions are rare, for $N \simeq 20$ they are common, and for $N \gtrsim 30$ they are frequent. This obvious dependence on the number of data points is demonstrated in Fig. 1, where we show the comparison between the best-fitting period computed from Gaia data (without any check of the reliability of the spin/shape solution) and the period taken from the Lightcurve Database (LCDB, [7]). The solutions based on a convex shape model sometimes produce false half periods, while the solutions based on ellipsoids do not have this problem. On the other hand, ellipsoidal models often produce wrong period solutions when $N \lesssim 20$.

3. Summary

It is possible to reconstruct correct spin states and coarse shapes of asteroids from Gaia photometry even if the number of observations $N < 20$, but the success rate is high only when $N \gtrsim 30$. The number of such high-cadence asteroids in DR2 is very small (~ 160), but this should change with next data releases and we can expect an order-of-magnitude increase of the number of reconstructed asteroid models. Another promising possibility is the combination of 'subcritical' Gaia data with other low-quality photometry or dense lightcurves form archives. With proper weight-

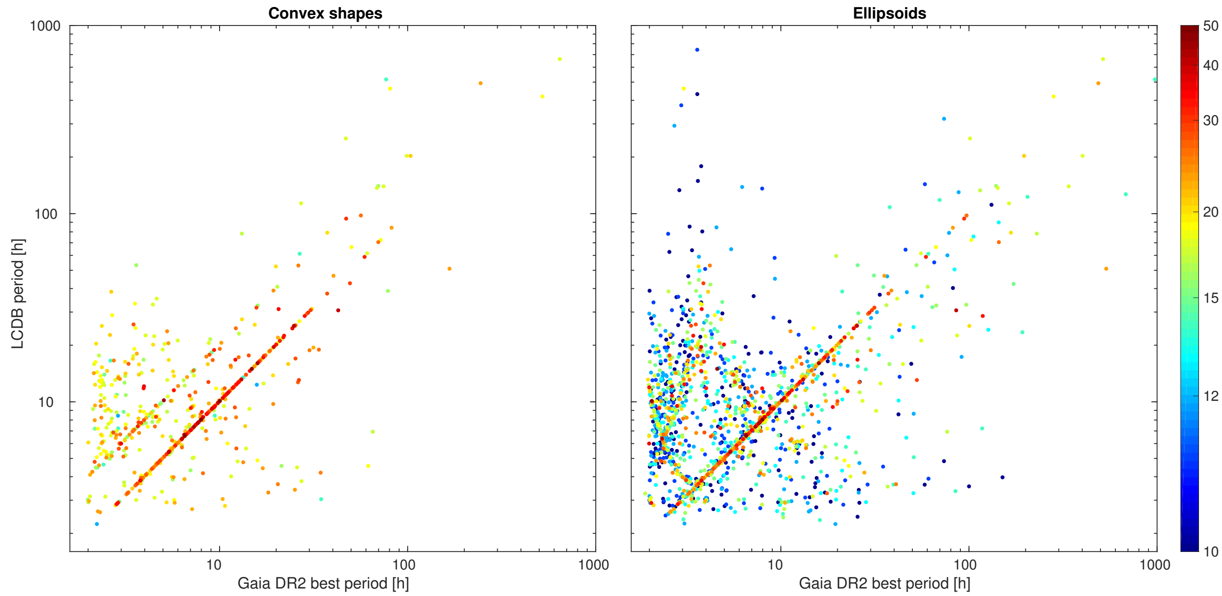

Figure 1: The comparison between the best period derived from Gaia photometry with convex models (left) and ellipsoids (right) with the period in the LCDB. The color corresponds to the number of data points.

ing of Gaia data, this should lead to other thousands asteroid models.

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