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Information on asteroid taxonomy contained in phase curves

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Abstract

We report our findings on asteroid phase curves based on processing large amount of photometric data contained in the Lowell Observatory photometric database [1, 2]. We fitted phase curves [3] to about half a million asteroids contained in the database. We found homogeneity in G_{12} slope parameters [1] in asteroid families and correlation of G_{12} with asteroid taxonomic complexes [2]. We predict taxonomic complex preponderance in asteroid families based on G_{12} slope parameters and compare our results with those available in the literature.

1 Lowell Observatory photometric database

We made use of the Lowell Observatory orbital data file maintained by EB and LHW. As of December 2010 it contained data for about 536,000 asteroids [4]. The orbital data are used in combination with photometric data from the Minor Planet Center (MPC). Most of the photometric data [1] are of low precision (generally rounded to 0.1 mag) and low accuracy (rms magnitude uncertainties of $\pm$ 0.2 to 0.3 mag are typical). The photometric data are very numerous: in the present study we have used about $47,000,000$ individual, largely independent magnitude estimates. Our study provides photometric parameters for individual asteroids that represent time-averaged brightness characteristics. The data were calibrated using accurate broad-band photometry of asteroids observed in the Sloan Digital Sky Survey [5].

2. Methods

In the current study we made use of the H,G_{12} phase function [3]. To fit phase curves, we apply least-squares in the flux-density domain. To fit H,G_{12} we make use of simplex non-linear regression. Uncertainties in the photometric parameters are computed using Monte-Carlo and Markov-chain Monte-Carlo techniques [1]. In the current study, we used the Asteroid Phase Curve Analyzer - an online java applet, which we also made publicly available at `http://asteroid.astro.helsinki.fi/astphase/`. To determine taxonomic preponderance in asteroid families we make use of empirical Gaussian approximations to G_{12} distributions for the main taxonomic complexes (S, C, and X) and Bayesian statistics [2]. The majority of the H,G_{12} fits lead to uncertainties $|\sigma_H| < 0.05$ mag and $|\sigma_{G_{12}}| < 0.25$.

3. Results

Figure 1 presents distributions of proper elements [6] of about $100,000$ asteroids color-coded with G_{12} slope parameter values. Asteroids family members [1] stand out, and tend to have similar G_{12}s. Dots of other colors mixed into families pertain to asteroids having outlying G_{12}s, perhaps because they are interlopers, originate from a differentiated parent body, or result from differently evolved surfaces. Therefore, G_{12} values could contribute to understanding the origin and evolution of asteroid families. The separation of smaller and larger G_{12} values with location in the belt is also visible. Smaller G_{12} values are typical for the inner belt, and larger for the outer belt. This is consistent with the location of the preponderant C and S asteroids in the belt. We further investigated the correlation of G_{12} with taxonomy. C-complex asteroids tend to have larger G_{12} values (distribution mean $\mu_C = 0.64$ and standard deviation $\sigma_C = 0.16$), S-complex asteroids tend to have smaller G_{12} values (distribution mean $\mu_S = 0.41$ and standard deviation $\sigma_S = 0.16$) and X-complex intermediate G_{12} values (distribution mean $\mu_X = 0.48$ and standard deviation $\sigma_X = 0.19$). We plot G_{12} distributions for taxonomic complexes in Fig. 2.

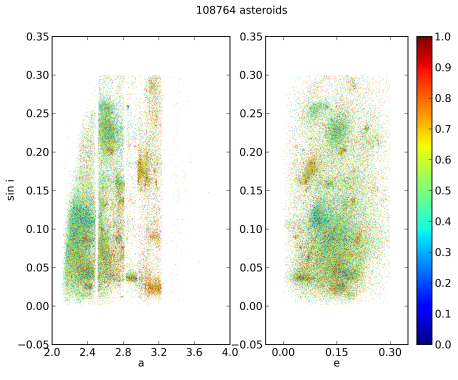

Figure 1: Distribution of proper elements of about $100,000$ asteroids color-coded with G_{12} slope parameter values.

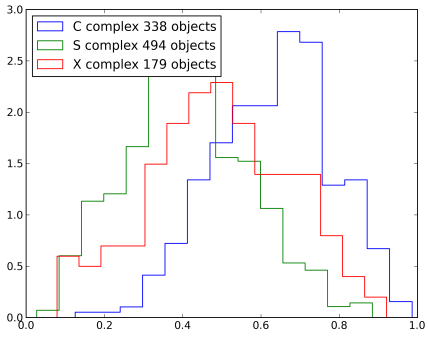

Figure 2: Normalized distribution of G_{12} slope parameters in taxonomic complexes.

Based on Gaussian approximations to the G_{12} distributions for asteroid taxonomic complexes, and using Bayesian statistics, we assess taxonomic preponderance in asteroid families. For example, the Iannini family is most probably dominated by S-complex asteroids (probability of a random asteroid from this family belonging to the C, S and X complexes are: $P_C = 0.27$, $P_S = 0.55$, $P_X = 0.18$), Dora by C-complex asteroids ($P_C = 0.6$, $P_S = 0.24$, $P_X = 0.16$) and Nysa-Polana is more mixed ($P_C = 0.42$, $P_S = 0.4$, $P_X = 0.17$). We found that taxonomic identification based on G_{12} values is most reliable for the C and S complexes (96% and 72% reliability) and least reliable for the X complex (22%). Therefore, family taxonomic preponderance is most reliable for the C and S complexes. We found several families to be dominated by the C complex, some dominated by the S complex. We compared our results with those available in the literature and found a good agreement with previous studies.

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