EPSC Abstracts
Vol. 12, EPSC2018-761-1, 2018
European Planetary Science Congress 2018

Asteroid photometric phase curves from Gaia observations

Karri Muinonen (1,2), Maria Gritsevich (1), and Alberto Cellino (3)

(1) Department of Physics, University of Helsinki, Finland (karri.muinonen@helsinki.fi) (2) Finnish Geospatial Research Institute FGI, Masala, Finland, (3) INAF, Osservatorio Astrofisico di Torino, Pino Torinese, Italia

Abstract

The photometric phase curve of an asteroid refers to the dependence of disk-integrated brightness on the phase angle (the Sun-Object-Observer angle). In the present work, we study the feasibility of constraining asteroid phase curve parameters from the sparse photometry available from Gaia Data Release 2. An asteroid's lightcurve, i.e., its observed disk-integrated brightness as a function of time, depends on the shape and spin state of the asteroid, as well as its surface scattering properties. It follows that these properties can be estimated from the observations, to an extent allowed by a given data set. In order to facilitate the rapid assessment of the phase curves, we utilize the so-called Lommel-Seeliger ellipsoids in the statistical inversion of Gaia photometry. We transform the resulting phase curves to reference equatorial illumination and observation of the given asteroid. These reference phase curves can have substantial value in asteroid taxonomy.

1. Introduction

Asteroids are irregularly shaped Solar System bodies typically rotating about their axes of maximum inertia. Their surfaces are typically covered by regoliths, that is, by layers of particulate material in the size scales of microns to meters, with the typical particle size being of the order of 100 microns. Asteroids offer information about the evolution of the Solar System, provide valuable space resources, and cause an impact hazard for life on the Earth.

The most common source of data on the asteroids is photometry: the measurement of the disk-integrated brightness of the asteroid. An asteroid's lightcurve, i.e., its 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 assessment of the uncertainties in the physical parameters. The inverse methods are based on the Lommel-Seeliger ellipsoids [2-5] suitable for the analyses of sparse data. The computational tools based on 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 an example of the validation for (21) Lutetia. Typically, the Gaia photometric data can be validated with numerical modeling at a root-mean-square difference 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: the Gaia data can have significantly smaller uncertainties.

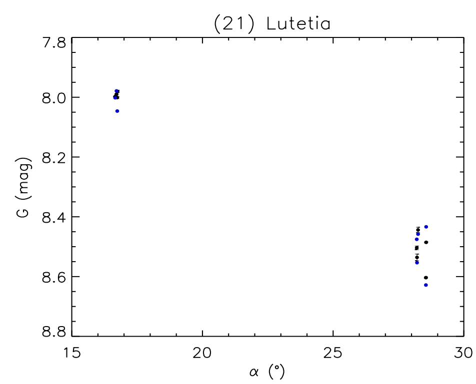

Figure 1: Photometry of asteroid (21) Lutetia from Gaia Data Release 2 (black dots) validated using a high-resolution shape model (blue dots, [7]) with a Lommel-Seeliger scattering law [2] reproducing the phase curve from ground-based observations [9].

We will carry out a systematic study of the Gaia DR2 asteroid photometry to estimate the parameters of the H, G_1, G_2 photometric function [10-12]. In doing so, we may be obliged to invoke informative a priori probability densities on the physical parameters, making the statistical inverse problem highly challenging.

3. Conclusion

We conclude that the present inverse methods can facilitate a meaningful phase curve retrieval from sparse Gaia DR2 photometry.

4. Acknowledgments

Research supported, in part, by the ERC Advanced Grant 320773.

References

[1] Gaia Collaboration, Spoto, F., et al. Astron. Astrophys., in press, 2018.

[2] Muinonen, K., and Lumme, K. (2015). Disk-integrated brightness of a Lommel-Seeliger scattering ellipsoidal asteroid. Astron. Astrophysics 584, A23, 2015.

[3] Cellino, A., Muinonen, K., Hestroffer, D., and Carbognani, A.: Inversion of sparse photometric data of asteroids using triaxial ellipsoid shape models and a Lommel-Seeliger scattering law. Planet. Space Sci., 118, pp. 221-226, 2015.

[4] Muinonen, K., Wilkman, O., Cellino, A., Wang, X., and Wang, Y.: Asteroid lightcurve inversion with Lommel-Seeliger ellipsoids. Planet. Space Sci., 118, pp. 227-241, 2015.

[5] Muinonen, K., Torppa, J., Gritsevich, M., Wang, X., Cellino, A. Asteroid lightcurve inversion with Bayesian inference. Astron. Astrophys., in preparation, 2018.

[6] Torppa, J., Granvik, M., Penttilä, A., Reitmaa, J. Tudose, V., Pelttari, L., Muinonen, K., Bakker, J., Navarro, V., O'Mullane, W. Added-value interfaces to asteroid photometric and spectroscopic data in the Gaia database. Adv. Space Res., in press, 2018.

[7] Sierks, H., et al. Images of asteroid 21 Lutetia: A remnant planetesimal from the early solar system. Science 334, pp. 487-490, 2011.

[8] Jorda, L., Lamy, P. L., Gaskell, R. W., Kaasalainen, M., Groussin, O., Besse, S., Faury, G. Asteroid (2867) Steins: Shape, topography and global physical properties from OSIRIS observations. Icarus 221, pp. 1089-1100, 2012.

[9] Belskaya, I. N., Fornasier, S., Krugly, Yu. N., Shevchenko, V. G., Gaftonyuk, N. M., Barucci, M. A., Fulchignoni, M., and Gil-Hutton, R. Puzzling asteroid 21 Lutetia: our knowledge prior to the Rosetta fly-by. Astron. Astrophys. 515, A29, 2010.

[10] Muinonen, K., Belskaya, I. N., Cellino, A., Delbò, M., Levasseur-Regourd, A.-C., Penttilä, A., and Tedesco, E. F. A three-parameter magnitude phase function for asteroids. Icarus 209, pp. 542-555, 2010.

[11] Penttilä, A., Muinonen, K., Shevchenko, V. G., and Wilkman, O. H, G_1, G_2 photometric phase function extended to low-accuracy data. Planet. Space Sci. 123, pp. 117-125, 2016.

[12] Shevchenko, V. G., Belskaya, I. N., Muinonen, K., Penttilä, A., Krugly, Y. N., Velichko, F. P., Chiorny, V. G., Slyusarev, I. C., Gaftonyuk, N. M., and Tereschenko, I. A. Asteroid observations at low phase angles. IV. Average parameters for the new . H, G_1, G_2 magnitude system. Planet. Space Sci. 123, pp. 101-116, 2016.