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# COLLABORATIVE OBSERVATIONS OF ASYNCHRONOUS BINARY ASTEROIDS

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**Abstract.** Time-serie photometry of asteroids gives the possibility to discover and study the binary nature of some small bodies of the solar system. In this proceeding, we describe methods and tools developed by a group of French amateur astronomers to make measurements more reliable, characterize the physical properties of asynchronous binary asteroids, and coordinate observations using a collaborative tool.

Keywords: binary asteroids, photometry, lightcurves, collaboration tools

## 1 Introduction

From differential photometry measurements obtained over many nights, it is possible to determine the rotation period of an asteroid and measure the amplitude of its brightness variation. The shape of the lightcurves provide constrains on the spin orientation and 3D shape of the observed asteroid (Kaasalainen & Torppa 2001; Ďurech et al. 2015).

For the past twenty years, these measurements have been mainly produced by amateur astronomers (see their contribution, in, e.g., Hanuš et al. 2013, 2016). With a small diameter telescope and an entry-level CCD camera, it is indeed possible to obtain valuable photometry (0.01–0.05 mag) on asteroids up to magnitude 16 (Mousis et al. 2014).

The technique of differential photometry is easy to implement and many software used by amateur astronomers make this kind of analysis possible. This method gives the possibility to correct for typical atmospheric effects such as extinction since the target asteroid and the reference stars are in the same field of view. The measurements obtained have a very good fidelity which makes it possible to detect small relative variations in the lightcurve produced.

## 2 Detection of binary asteroids by photometry

A multi-periodic analysis of differential photometry measurements is a powerful way to detect mutual eclipsing or occulting phenomena on (asynchronous) binary systems. For that, lightcurve caused by the rotation of the primary target upon itself is subtracted from the data to reveal the brightness variation generated by the rotation of the primary asteroid (Pravec et al. 2006; Margot et al. 2015).

Mutual eclipses and occultations can then be characterized, and the orbital period of the system is determined by the repetition of these phenomena. The depth of the secondary occultation provides an estimate of the ratio of the diameters of the two bodies (Pravec et al. 2006; Scheirich & Pravec 2009). The elongation of the secondary body and its rotation period, generally synchronized with the orbital period, can also be detected by this method (Pravec et al. 2016).

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## 3 Development of methods and tools

To contribute to the discovery and study of binary asteroids, we federated a group of amateur astronomers and developed different tools to master the process of photometric reduction and analyze the data we produce.

A script has been developed in the Prism software[*] to optimize the aperture photometry technique and to master the color effects by an appropriate selection method and the management of the color indices of the reference stars. The script produces quality indicators and analysis charts to control the representativeness of the measurements. It ensures reproducibility, traceability, and standardization of the results produced.

To analyze the data of the different observers, an Excel$^{TM}$ macro was developed to generate lightcurves and to characterize the physical properties of the objects observed. This tool integrates different features to adjust the offset of each measurements series, to model the lightcurve by a non-parametric regression and to determine the main rotation period of the asteroid by an automatic search of the optimal modeling residue. Multi-periodic analyzes can also be conducted to detect and characterize eclipses and/or occultations of multiple systems. The macro is easy to use and offers many graphical and statistical indicators to check the results. A feature can also generate ephemerides to plan future observations.

The coordination of our group is ensured through a collaborative workspace (Asana$^{TM}$[†]). Each month, a selection of priority targets to be observed is published and the measurements produced by each member are instantly shared to cross-analyze, compare the results obtained and interpret them. When an observation campaign is conducted on a specific object (binary suspected asteroid for example), the observation resources are prioritized with responsiveness according to weather conditions and availability. The discussions between members and the training sessions provided through this workspace serves multiple purposes: each participant improves his knowledge, understand better the observed phenoma, and the quality of the measurements keeps improving.

## 4 Conclusion

Since the creation of this group of observers and the setup of the collaborative workspace in 2018, several binary asteroids have been discovered (Conjat et al. 2018; Christmann et al. 2019) and many asteroid rotation periods have been determined. The results obtained are published in Pro-Am collaborative programs like CdR&CdL (Behrend et al. 2006) or BinAstPhotSurvey (Pravec et al. 2006) and contribute to enrich the models explaining the formation and the evolution of these small bodies of the solar system (Pravec et al. 2010; Carry et al. 2015).

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[*] http://www.prism-astro.com/

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