EPSC Abstracts
Vol. 13, EPSC-DPS2019-71-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

A Bayesian approach to the processing of stellar occultations

João F. Ferreira (1, 2), Paolo Tanga (1) and Pedro Machado (2)
(1) Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, Bd de l'Observatoire,CS 34229, 06304 Nice, France,
(2) Instituto de Astrofísica e Ciências do Espaço, Portugal
(jferreira@oca.eu)

Abstract

Star occultations by asteroids have traditionally offered an efficient method to study the properties of Minor Bodies. With the availability of stellar astrometry by the ESA mission Gaia [1], the frequency of observable events with good predictions is increasing, bringing new challenges for automated observations and data reduction properties. We adopt the example of a robotic 50 cm telescope to illustrate the properties of the signal and use of a Bayesian approach [2] to the data reduction of occultation lightcurves. We explore in particular difficult events, corresponding to low drop–to–noise ratios, to investigate the limits of our approach. We derive an acceptable range of applicability of the method, with clear indications of the expected errors in terms of timing uncertainties. Our results show that, if an accurate absolute timing is ensured, the limiting factor in the use of occultation astrometry is not the lightcurve uncertainty, but the knowledge of the asteroid shape and size. This conclusion is valid in a wide range of flux drops and magnitudes of the occulted star. [3]

1. Introduction

Transit and occultation phenomena have been exploited for decades as powerful tool to infer properties of the occulting or the occulted object. In the case of asteroids occulting a star, the main results are size and shape measurements, used to study specific targets or to calibrate other size-determination approaches.

So far, the main limitation of occultation observations resides in the accuracy of the predictions, as the uncertainty on an asteroid ephemeris usually exceeds by a large factor the size of the occultation track. However, the Gaia mission by ESA is completely changing the landscape by bringing a substantial enhancement on the prediction efficiency, thanks to the sub-mas precision astrometry of both target stars and asteroids [4].

The expansion of the number of usable stellar targets (the Gaia sample is ∼complete at all magnitudes G<20.5) and the strong quality improvement for $\sim 3.5\times10^5$ asteroid orbits are going to expand the number of potentially observable events by orders of magnitude. This change of perspective clearly suggests that fixed telescopes can become very efficient and observe several occultations per night. Such a systematic, massive exploitation clearly calls for automated systems to observe, process and store the collected data.

2. Method

On the base of the detection properties and the noise budget expected for a 50 cm robotic telescope with a specific camera/filter set-up, we built a large set of simulated lightcurves to cover the detection regime for our configuration, over a range of star magnitudes, flux drops and duration. As the bulk of the occultation events is dominated by the high number of faint stars, in order to get a meaningful sample we do not consider very bright stars (contributing only with rare events) and focus on the magnitude range $V_* = 11 - 14$.

We then fed our simulated data set into a Bayesian Inference Method (BIM) pipeline. We also checked for false positive events, where a flat signal, consisting of nothing but the flux of the star and its noise, was modelled to an occultation, to check at which ranges these false positives became significant. This was made in two separate runs, using either Gaussian or Uniform Priors, each run consisting of 8 000 tests.

3. Results

Since the simulated occultation signals for both sets of priors (Gaussian and Uniform) were exactly the same, their results are directly comparable. In terms of general performance, we observe a slightly better behavior of the Gaussian priors. In addition, it must be taken into account that, while the Gaussian priors always produce a final fit, the BIM with Uniform priors does not converge for 6% of the time, especially for low DNR values. The computational time is similar for both sets, averaging on 15 seconds per case.

The set of test corresponding to false positives results, after BIM analysis, results in very large uncertainties.

The distribution of the detection probability values for real and false events is particularly useful. In fact, it shows that false positives are systematically characterized by a low detection probability.

4. Summary and Conclusions

With a comprehensive, extended amount of simulations, we show the capabilities of detecting and measuring occultation signals by a specific telescope setup and a BIM approach. We demonstrated that BIM performs much better than the previously used Least Squares Fit on difficult signals, and that the Gaussian priors are a better choice than the Uniform priors in terms of accuracy and precision achieved on the final estimates of the fitting model parameters, as well as due to being closer to the real uncertainties of predictions, which are typically of Gaussian nature.

We can convert the precision that we expect on the centre epoch of the occultation to the corresponding along-track astrometric precision, by a simple procedure.

5 Acknowledgements

To Enrico Corsaro, for the development of the BIM code used throughout this work and all the help provided in order to adapt it to our needs.

References

[1] Gaia Collaboration et al.: Gaia Data Release 2. Summary of the contents and survey properties, Astronomy and Astrophysics, Vol. 618, 2018.

[2] Corsaro, E. and De Ridder, J.: DIAMONDS: A new Bayesian nested sampling tool, Astronomy and Astrophysics, Volume 571, 2014.

[3] Ferreira, J. F. et al.: A Bayesian approach to the processing of stellar occultations, Monthly Notices of the Royal Astronomical Society, submitted, 2019.

[4] Gaia Collaboration et al: Gaia Data Release 2: Observations of solar system objects, Astronomy and Astrophysics, Volume 616, 2018.

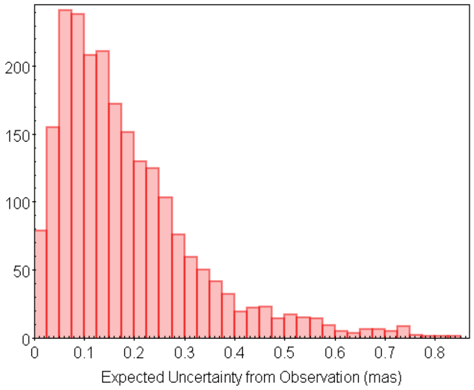

Figure 1: Astrometric precision expected for events predicted to be visible in Nice.

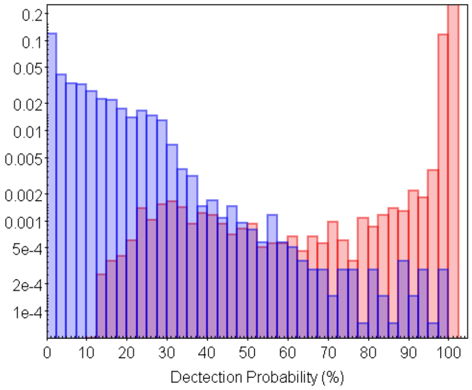

Figure 2: Distribution of the Bayesian detection probability obtained by the BIM, for the false positives (blue population rising towards the left) and the true events (red population rising towards the right). For the true events the distribution is strongly dominated by the peaked around the significance threshold of 99%. For the false positives the detection probability remains always very small.