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.

A COORDINATED FRENCH NETWORK OF OCCULTATIONS OBSERVERS

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Abstract. Stellar occultations are an effective tool for characterising the small bodies of the solar system. They allow us to measure sizes and shapes with kilometre-level accuracy and low atmospheric pressures, or to probe the close environment of these objects (satellite, rings), or to provide an accurate astrometric position. In recent years, the Gaia catalogue has revolutionised this method by allowing very precise predictions and a concentration of observation resources. It is now possible to obtain a large number of chords for some objects (around 80 chords for Triton in 2017, 17 chords for 2002TC302 in 2021) or even to observe occultations by small objects (less than 1 km, such as Apophis in 2021). These observations are made possible thanks to the mobilisation of amateur astronomers and the close collaboration with professionals. To support and structure this collaboration and centralise resources, we are developing a coordinated network of occultation observers in France. During autumn 2022, a serie of occultations visible from France by some targets of the Lucy mission will serve as a first test.

Keywords: Occultations, Minor planets, asteroids: general, Methods: observational

1 Introduction

Occultations are the passage of a solar system object (asteroid, satellite, comet, etc) in front of a distant star. The phenomenon is only visible on a portion of the Earth's surface and for a short period of time. It can be recorded with modest equipment (telescope, high speed camera, timing system). For each station, the photometric observation gives a light curve that allows to derive immersion and emersion times. Finally the global analysis of the occultation observed in several stations allows to measure the physical characteristics (size, shape) with a kilometric precision, to probe the environment (satellite, rings), or the atmosphere (pressure at nanobar precision). Also the occultation provide an accurate astrometric position of the body at the time of the occultation helping to improve orbit and ephemeris (Desmars et al. 2019).

Scientific programmes such as Lucky Star * study the solar system objects using the occultation technique. Observational campaigns usually involve amateur astronomers recording occultations. International Occultation Timing Association (IOTA) and its European section (IOTA-ES) is an association of observers that provide alerts on occultation campaigns, information and recommendations on observing equipment and techniques, report and publish their data in scientific journals.

In this document, we will present some statistics about the observation of occultations in Europe, in particular the increasing of positive occultations thanks to Gaia, the new scientific cases possible using occultations and a plan to better coordinate observers in France and more generally in Europe.

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*https://lesia.obspm.fr/lucky-star/

2 Statistics of the European network and new targets of occultations

The Gaia catalogue (Gaia Collaboration et al. 2016) has revolutionised the science of occultations with more accurate predictions. Figure 1 shows the number of positive chords reported on Euraster[†]. The Gaia catalogues allow the detection of more positive chords. In fact, according to Desmars et al. (2019), positions of stars are now better determined (below the mas precision) as well as the ephemeris (around few mas for some objects to 50 mas for most of them). In addition, more positive multi-chords are also recorded (Fig. 2) giving a better determination of the size and the shape.

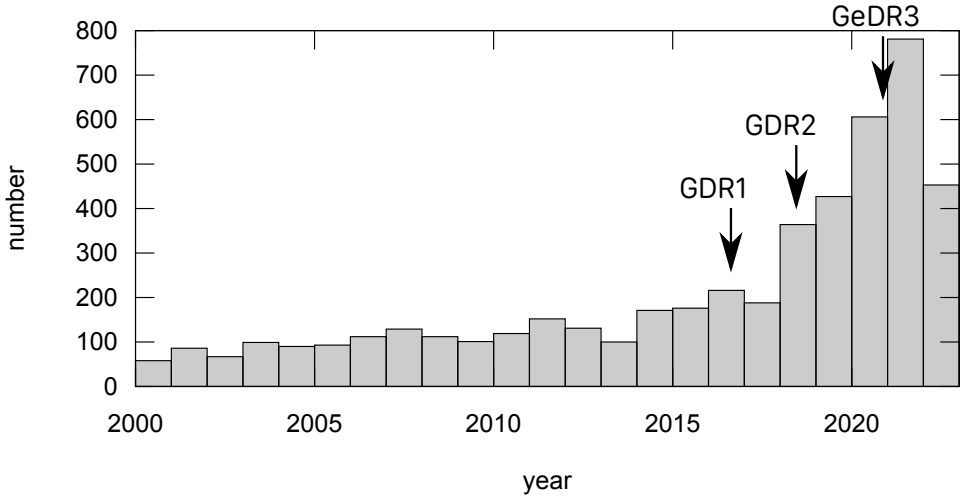

Fig. 1. Number of positive chords observed with the European network (Euraster data) and date of the different Gaia data releases

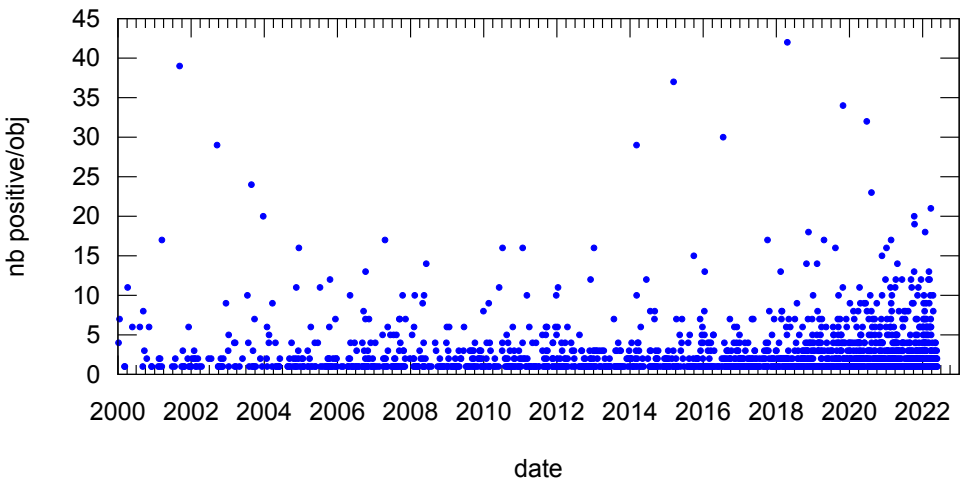

Fig. 2. Number of positive chords per object observed with the European network (Euraster data)

This shows that a coordinated campaign can provide a large number of chords for one event. For examples, within the Lucky Star program, the occultation by Triton in 2017 was observed by more than 80 stations (Marques Oliveira et al. 2022) and the occultation by 2002TC302 on November 11, 2021 was recorded by 17 stations[‡].

[†]Euraster is a database of occultation results managed by E.Frappa.
[‡]https://www.euraster.net/results/2021/index.html#1111-84522

Furthermore, better predictions now allow to attempt occultations by small bodies (at the kilometre size). In particular, in 2019, several occultations by Phaeton, a 5km Near Earth asteroid were recorded (Dunham et al. 2020). In 2021, several occultations by Apophis, a 400m-NEA, were also positively recorded[§]. These occultations provide accurate astrometric positions at the mas level, allowing to determine thin dynamical effects such as the Yarkovsky effect and to better assess impact probabilities. In that context, the ACROSS programme[¶] is now predicting and organising campaigns to observe occultations by NEAs.

Thanks to accurate predictions, scientists can now dedicate an observation campaign for a small object or to scan a specific part of the target. For this scientific cases, a coordinated network of observers is necessary, because observers can not only observe from their observatory but now have to observe on a specific location determined by the scientific case. In the next section, we will specifically discuss the case of the French network.

3 French network

According to Euraster website, French observers are usually the most active in Europe. On average, there are about 30-40 different observers each year and they observe about 60 to 130 positive chords each year.

To take advantage of the French network and in order to manage new perspectives of occultation science presented in previous section, we propose to coordinate the network by identify the equipped amateurs. In particular, amateurs usually have a telescope and a camera for their own use but they miss a correct timing system which is fundamental to correctly analyse the data.

In that context, we applied at the API ProAm [‖] at Observatoire de Paris and we received funds to acquire TimeBox which is a system allowing an accurate timing of the images thanks to GPS.

This equipement will be distributed for the forthcoming campaigns (see next section). In the future, we will identify the needs for the community in terms of equipement and formation making the network operational for future specific campaigns.

4 LUCY targets occultation campaign

The LUCY mission[**] has been launched in 2021 to explore several trojans. Trojans are asteroids located at Lagrange points of the Jupiter orbit. They are remanants of the Solar System and their exploration will help in studying the planetary formation and evolution.

Six objects are targets of the mission: Eurybates, Polymele, Orus, Leucus in L4 will be visited between 2027 and 2028 and Patroclus and Menoetius in L5 will be visited in 2033. To prepare the mission, several occultation campaigns are organised towards the world by South West Research Institute (SwRI) under the coordination of Marc Buie. In addition some of these 6 objects have satellites like Shaun for Polymele and Queta for Eurybates.

On 2022, four of these occultations will be visible in France (see Figs. 3&4): Polymele (August 26), Eurybates (October 23), Orus (December 16) and Polymele (December 27). The positions of the satellites of Polymele and Eurybates are not well determined but they can be also detected during these occultations, leading to better knowledge of their orbits.

These occultations will also serve as a test for the coordination of the network regarding the path prediction and its uncertainty.

For Eurybates on October 23, 2022, the star involved in the occultation is bright (magnitude 8) so the event can be recorded with a small equipement, *i.e.* a small telescope or even a camera with a long focal lens. With the support of Société Astronomique de France (SAF) and Association Française d'Astronomie (AFA), we organise a public event in France to promote and encourage to observe and record the occultation.

5 Conclusions

Thanks to Gaia catalogues, we now have more accurate predictions of occultations allowing to have new scientific targets (NEAs or multichords occultations for large objects). Occultation science is only possible with the support of the amateur community. In that context, we start to develop and coordinate the existing network of

[§]https://www.observatoiredeparis.psl.eu/l-asteroide-apophis-observe.html?lang=en
[¶]https://lagrange.oca.eu/fr/home-across
[‖]Action Pluri-Annuelle Incitative: https://saf-astronomie.fr/action-pluri-annuelle-incitative-proam-de-lobservatoire-de-paris/
[**]http://lucy.swri.edu/

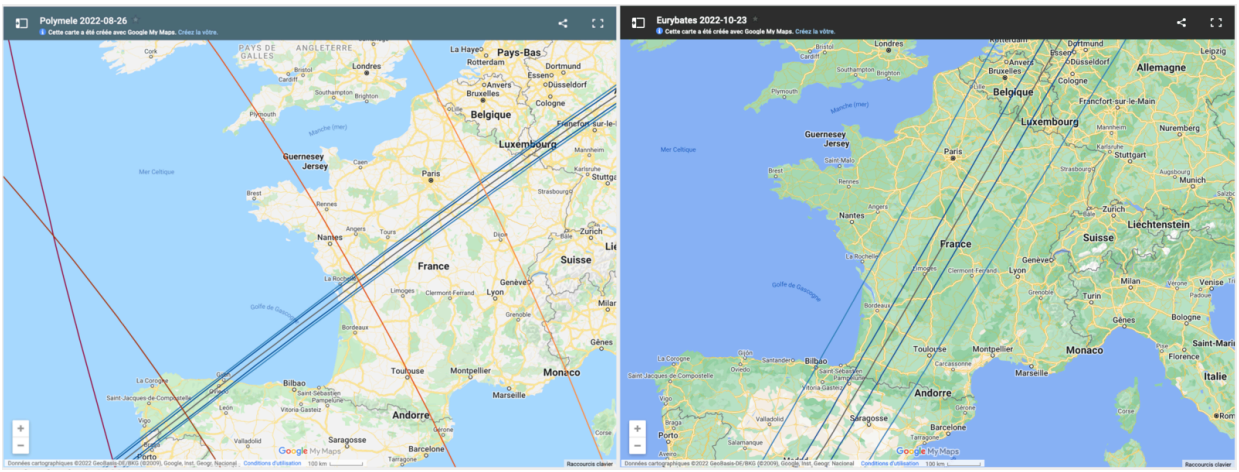

Fig. 3. Left: Path of the occultation by Polymele on August 26, 2022. **Right:** Path of the occultation by Eurybates on October 23, 2022.

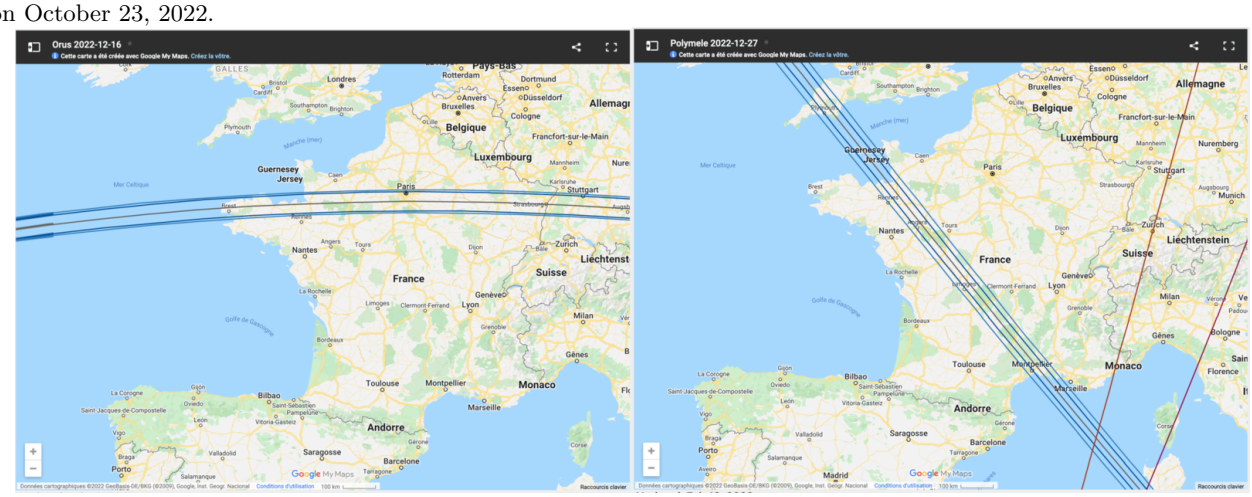

Fig. 4. Left: Path of the occultation by Orus on December 16, 2022. **Right:** Path of the occultation by Polymele on December 27, 2022.

amateurs that observe occultations in France. We already get some fundings to equipe amateurs with timing systems. As a test, we will coordinate four occultations by the Lucy targets visible from France during the 2022 second semester. These coordinations will support the network from the preparation of the observers, including the chord attributions, up to the final reports checking.

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