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Studying Centaur and Trans-Neptunian objects using stellar occultation: precise astrometric positions

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Abstract

The first Trans-Neptunian object (TNO) discovered is recent, was (15760) Albion observed in 1992. As it is believed that TNOs are remnants of our system formation and dynamical evolution, their physical properties may have information that can contribute to the Solar System's evolution theories. Stellar occultation is a ground-based technique which has been used to study Centaurs and TNOs, and has presented interesting results [1-7]. This observational technique can provide a precise profile of the occulting body, allowing the determination of its size, shape and astrometric position. The *Gaia* Data Release 2 (DR2) catalogue [10] provides star positions with uncertainties below 1 milli-arcsencond (mas), which improve the stellar occultation efficiency. Here we used stars from *Gaia* DR2 to determine the Centaur and TNOs positions with uncertainties under 16 mas for the worst cases. We present 31 accurate astrometric positions to 16 TNOs and 4 Centaurs, involved on stellar occultation events between 1993 and 2018. Those positions will be used to update their ephemerids and have better predictions on future stellar occultations.

1. Introduction

Stellar occultation allows precise determination of an object size, shape and astrometric position. It can also detect features like rings, satellites or atmosphere around it. After the two releases of *Gaia* catalogs in 2016 and 2018 [9, 10], the main error bars of the prediction of a stellar occultation comes from object's ephemeris. So, obtain accurate astrometric positions of the Solar System objects is important to have better orbit determination and by consequence better predictions. This work analyzed data from single and double chords occultations having *Gaia* DR2 star positions propagated to event's date as reference, as well update position presented in the literature, which were reduced with old astrometric catalogs. Precision under the mas level are obtained for multi-chord events and up to 10 mas for double and single chord events.

2. Method

To precisely determine an object size and shape at projected sky plane we need at least three measurements of the object profile, called chords. With that, other information can be used to determine its albedo, density and three dimensional shape. To achieve this, precise predictions are needed, and they can be made with the use of accurate stellar catalogue and good orbit determination for the object of interest. Since April 2018 Gaia DR2 stellar catalogue [10] provides us star positions with accuracies (at catalog epoch) below 1 mili-arcseconds for the most cases. For the object ephemeris, a numerical integration is made with NIMA [11], that uses object's astrometric positions available in MPC, as well as our own positions, to calculate new ephemeris.

From an observation of an occultation event a light curve is derived, which is the variation of the target star flux over time. It provide us the duration of the event in seconds, and so the length in km of the observed chord. If a set of multi-chords are detected to the same event (3 or more chords, one for each station) an ellipsis can be fitted to the chord's extremities, giving the object's projected size, shape and position. In the most cases all these results can be obtained with kilometer accuracies, which is translates in an angular error of sub-mili-arcseconds on sky plane.

A detection of two chords allows the use of the equivalent radius present in literature to adjust an circle and the position is determined. For single chord events the diameter of the circle is fixed based on the equivalent radius published. Then, two solutions are possible since the chord may be a measurement of the northern or southern hemisphere. In these events the average position is provided, where the errors bars represent the half distance between these two positions. Results from single chord events are the less precise that we have, but most of the final right ascension and declination still have uncertainties smaller than 10 mas, which can be compared with results from classic astrometry, that are limited to about 20 mas.

Besides that, for 2 events the position were obtained from literature and updated. The *Gaia* DR2 star position was propagated to event's date, using the parallax and proper motion effects. So, the offset between this current star position and old one was calculated. Once the offset value are know, they were applied to the object's published position.

3. Summary and Conclusions

From 66 stellar occultation events recorded between 1993 and 2018 (Figure 1), we applied the procedure described above for 31 stellar occultations by 16 TNOs and 4 Centaurs. This data set is made of 19 single chord, 6 double chord and 6 multi-chord event detections. The new Centaur and TNOs positions derived from stellar occultations, using star positions from *Gaia* DR2, have average errors of 1.76 mas and 3.98 mas in right ascension and declination, with a standard deviation of 2.33 mas and 4.33 mas, respectively.

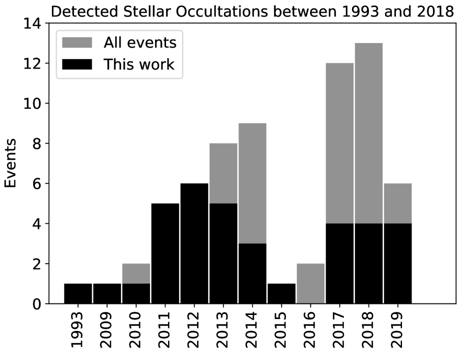

Figure 1: in grey, all stellar occultations by Centaurs and TNO detected so far, and in black the ones present in this work.

These positions will be used to upgrade the ephemeris of each involved object. So future stellar occultation predictions will profit of smaller uncertainties, thus enabling more efficient observational campaigns. All this will lead to a better physical characterization of these intriguing distant small bodies.

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