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Pluto’s ephemeris from stellar occultations

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Abstract

Between 1988 and 2016, several stellar occultations by Pluto have been observed to characterise its atmosphere and its evolution. For 19 of these stellar occultations, we derived an accurate astrometric position of Pluto at the occultation epoch. The precision of these positions, mainly depending on the precision of the occulted star position, is estimated at 2-10 milliarcsec (mas) thanks to Gaia DR2 [3]. These astrometric positions were used to compute an updated ephemeris of Pluto’s system barycentre using the NIMA code [1]. The precision of this ephemeris is accurate to the milliarcsec level over the period 2000-2020, allowing for better predictions for future stellar occultations.

1. Introduction

Stellar occultation is a unique technique to obtain the physical parameters of distant objects or to probe their atmosphere and surroundings. For instance, the evolution of the Pluto’s atmosphere between 1988 and 2016 has been analysed thanks to stellar occultations [2]. In addition, stellar occultations allow to derive an accurate astrometric position of the object at the time of occultation if the star position is also known accurately which is now the case thanks to Gaia DR2.

2. Astrometry from occultations

Eleven occultations between 2002 and 2016 have been analysed in [2]. Beyond the parameters related to the atmosphere, they also derived from the global fit of the atmosphere’s modelling, the relative position of Pluto’s centre compared to the position of the occulted star. Thanks to GaiaDR2, the star position is now very accurate with a precision below 1 mas.

For other publications, astrometric positions can be derived using a procedure based on Bessel method. From circumstances of the occultations : coordinates of the station, mid-time of the event and the impact parameter ρ (the distance of closest approach between the site, and the centre of the shadow in the Bessel plane), we can derive an astrometric position of Pluto’s centre at the time of the occultation. We applied this method for 8 occultations published in various articles.

Finally, we derived 19 astrometric positions from stellar occultations on the period 1988-2016, with an estimated precision of 2 to 10 mas, which is about 50-100 times better than classical CCD observations. The full method and the derived positions are given in [4].

3. Pluto’s ephemeris

The NIMA procedure [1] allows to determine an orbit given a set of astrometric observations and compute an ephemeris. Using this procedure, we determined an orbit of Pluto’s barycentre system based on the astrometric positions derived from occultations (NIMAv8). To link the positions of Pluto’s centre (given by the occultations) and Pluto’s system barycentre (given by the ephemeris), we used the JPL PLU055 ephemeris.

Figure 1 represents the difference between NIMAv8 and JPL DE436 ephemeris of Pluto’s system barycentre (black line) in right ascension (weighted by $\cos\delta$) and in declination. Blue bullets and their estimated precision in error bar represent the positions coming from the occultations studied in [2] and red bullets represent the positions deduced from other publications. The grey area represents the 1σ uncertainty of the NIMAv8 orbit. Vertical grey lines indicate the date of the position for a better reading on the x-axis. For compar-

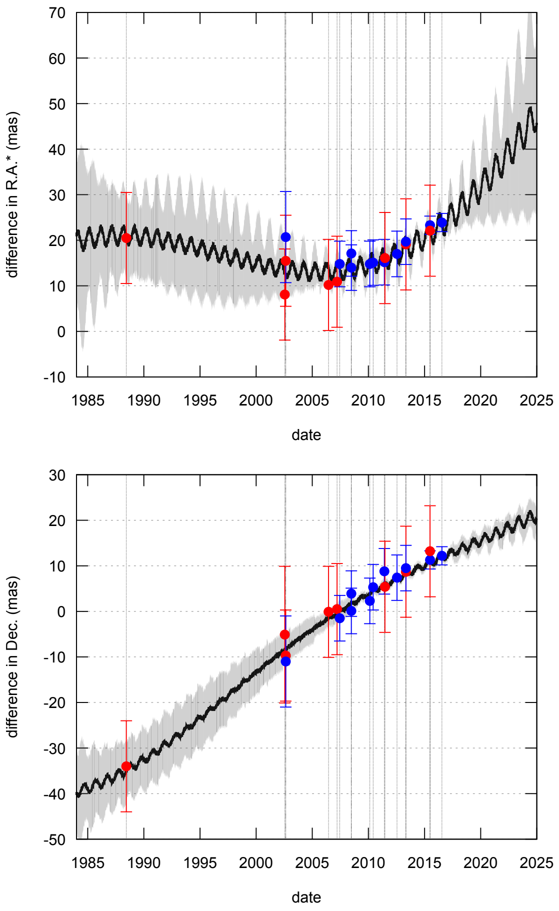

Figure 1: Difference between NIMAv8 and JPL DE436 ephemeris of Pluto's system barycentre (see text)

ison, the angular diameter of Pluto, as seen from Earth, is about 115 mas, while the atmosphere detectable using ground-based stellar occultations subtends about 150 mas on the sky.

The estimated precision of NIMAv8 over the period 2000-2020 reaches about 2 mas which is much better than any other ephemeris on this period.

Such a precision allows more accurate predictions in the future to the mas level accuracy. For instance, we used this ephemeris to predict the occultation by Pluto on 15 August 2018. According to preliminary results, the residuals of the prediction was only 3km which is only 0.12 mas at the distance of Pluto [4].

4. Summary and Conclusions

We derived 19 accurate astrometric position of Pluto's centre from stellar occultations on the period 1988-2016. These positions have an estimated precision of 2 to 10 mas depending on the period. From these positions, we determined an ephemeris of Pluto'system barycentre (NIMAv8) with a precision of few mas on the period 2000-2020. Such a precision allows to predict future occultations at a milliarcsec level precision. This method can be extended to every object observed by stellar occultation and illustrate the power of stellar occultation to improve orbits and ephemerides.

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