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Serendipitous occultations by kilometer size Kuiper Belt with MIOSOTYS

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Abstract

MIOSOTYS (Multi-object Instrument for Occultations in the SOlar system and TransitorY Systems) is a multi-fiber positioner coupled with a fast photometry camera. This is a visitor instrument mounted on the 193 cm telescope at the Observatoire de Haute-Provence, France and on the 123 cm telescope at the Calar Alto Observatory, Spain. Our immediate goal is to characterize the spatial distribution and extension of the Kuiper Belt, and the physical size distribution of TNOs. We present the observation campaigns during 2010-2013, objectives and observing strategy. We report the detection of potential candidates for occultation events of TNOs. We will discuss more specifically the method used to process the data and the modelling of diffraction patterns. We, finally present the results obtained concerning the distribution of sub-kilometer TNOs in the Kuiper Belt.

1. Introduction

As the Kuiper belt is located far from the sun, it is difficult to observe the small objects that are composing it. To understand how the Kuiper belt was formed, we need to study the size distribution of its objects. We have to be able to detect sub-kilometric objects. This is possible only by random stellar occultations. In order to perform those observations, we have an instrument called MIOSOTYS.

2. The instrument

MIOSOTYS consists of three parts : 30 fibre positioning arms (MEFOS) fixed on a platform, an Acquisition and Guiding Image System (AGIS) above the arm platform, and a CCD camera (ProEM CCD). It has been mounted as a visitor instrument on the 1.93-m telescope at Observatoire de Haute-Provence (OHP) in France since February 2010, and on the 1.23-m telescope at Calar Alto (CAHA) in Spain since November 2012.

The instrument has been upgraded from a past instrument, MEFOS (Meudon ESO Fibre Optical System, [1]). MIOSOTYS is a multi-fiber positioner coupled with a fast photometry camera. It is an arm positioner using 29 arms in a 26 arc-minute field. Each arm is equipped with an individual viewing system for accurate setting and carries one individual fiber that intercept 13" arcsec on the sky. All the 29 fibers are aligned on a CCD for fast photometry acquisition.

3. Observation and data analysis

Observations have been obtained during MIOSOTYS campaigns at OHP in 2010-2013 and at Calar-Alto afterwards at an acquisition rate of 20 Hz and with total median SNR of 25 (median SNR for OHP : 16 ; median SNR for Calar Alto : 34). Photometry has been obtained in a standard manner and lightcurve information has been extracted from the data. A total of 85 nights, that is about 9840 star-hours has been investigated for occultation events.

The search for outliers events is based on the detection of any data point deviant from the mean. A small size window is used in a middle of a large window used for computing mean and standard deviation in the stellar flux.

4. Modelling and fitting

The model : We consider that we are in the Fraunhofer diffraction regime [2]. The stellar flux is diffracted and smoothed on the observed bandwidth, on the stellar disc and on the integration step. The simulated pattern depends on several parameters (size and distance of the TNO, size of the star…).

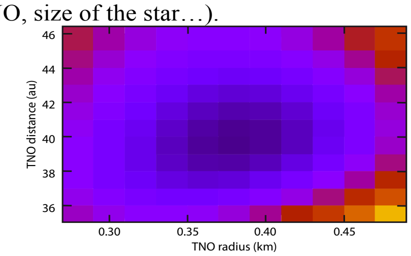

Figure 1 : (Left) X^2 map in relation with the radius and the distance of the TNO (violet : good fit, yellow : bad fit) (Right) Observation versus model (radius : 0.38 km ; TNO distance : 41 au)

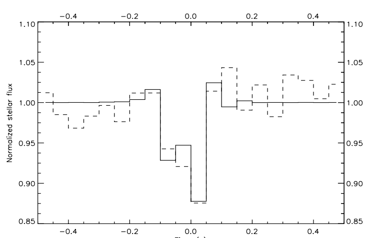

Figure 2 : Observation versus model (radius : 0.38 km ; TNO distance : 41 au)

The fit : We simulate several patterns with different sets of parameter values (the radius of the TNO varies between 0 and 1 km and its distance between 30 and 60 AU). Then, we compare the observation and the simulation by calculating the X^2. We search the set of values that minimize the X^2 . Below is an example of the procedure for one event.

5. Conclusions

Results of the fit and validation critrerion :

The algorithm detected 42 . On the 42 POEs, we found solutions for 7 of them in the following range :

- for the distance to the Sun : from 30 to 70 au

- for the radius of the TNO : from 0.01 to 1 km.

According to the validation criterion, only one of the 7 POEs with a solution can be considered as a real event (see Figure 6 ; distance : 41 ua and radius 380m).

Density in the sky plane :

Thanks to this detection, it is possible to deduce an estimation of the density of TNOs with a radius larger than 380m (see Figure 7 and see Liu et al. 2015 for the computation of the density). The value of this estimation is 6.40 $x10^7deg^{-2}$. As we just obtain one positive POE, this value has to be considered as an upper limit. As we can on Figure 7, our result is consistent with the other determination.

References and Ackknowledgement

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