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PROBING THE OUTER SOLAR SYSTEM SMALL BODIES WITH STELLAR OCCULTATIONS

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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. 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 2010-2012, 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.

Keywords: Occultations, TNO, Kuiper belt

1 The instrument

MIOSOTYS (Multi-object Instrument for Occultations in the SOlar system and TransitorY Systems) is a newly refurbished instrument designed at Observatoire de Paris and now mounted as a visitor instrument on the 193-cm telescope at Observatoire de Haute-Provence (France) and 123-cm telescope at Calar Alto in the south of Spain (see fig. 1).

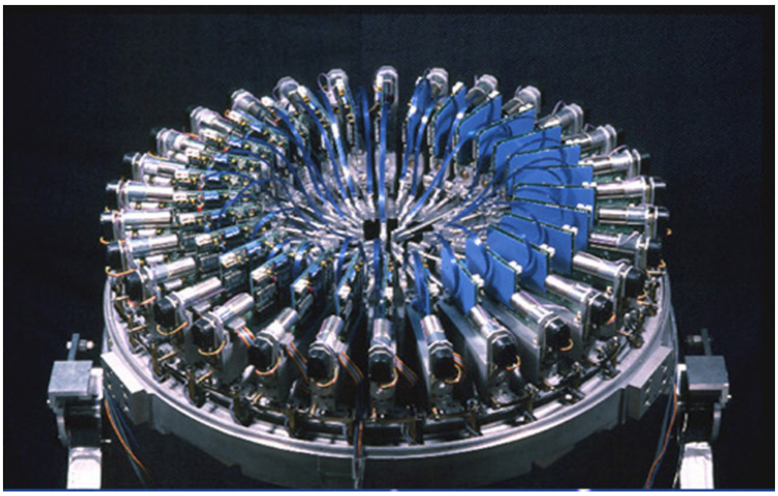

Fig. 1. The system is set in a circle like "fisherman around a pool"

The instrument has been upgraded from a past instrument, MEFOS (Meudon ESO Fibre Optical System, Felenbok et al. (1997)). MIOSOTYS is a multi-fiber positioner coupled with a fast photometry camera. It is an arm positioner using 29 arms in a 26 arcminute 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.

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2 Science case and method

The scientific aim of this project is the detection of the diffraction shadow of serendipitous stellar occultations by small (numerous) Trans-Neptunian Objects (TNOs). For that, we are able to simulate this diffraction patterns (Roques & Moncuquet 2000). You can see two examples of diffraction patterns in fig. 2.

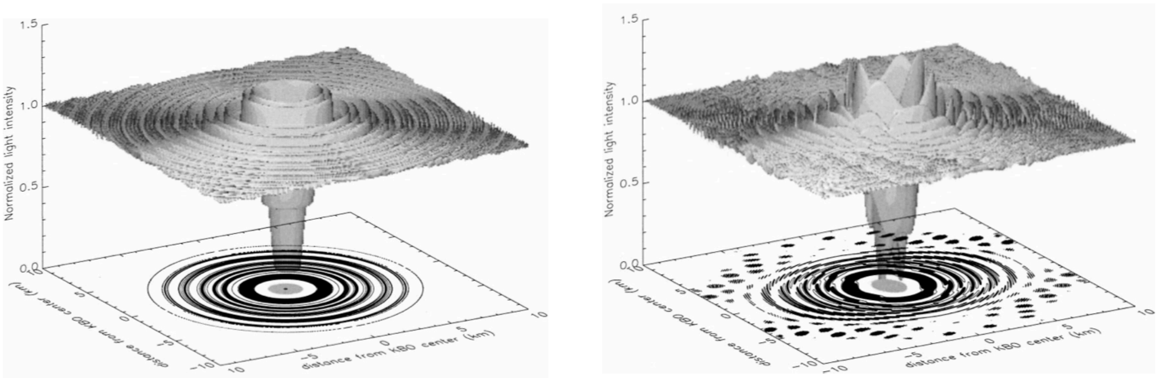

Fig. 2. Examples of diffraction patterns (see Roques & Moncuquet (2000)). **Left:** The TNO is circular. **Right:** The TNO is irregular (the limb is about 6% corrugated) and elliptical (the eccentricity is 0.7 and the semi major axis is $\frac{4}{3}$ km).

We observe small size stars in fast photometry to optimize the detectability of hundreds meters TNOs. The goal is to constraint the radial and azimuthal distribution of the objects size in the Kuiper disk.

3 Observations an data analysis

3.1 *Observations*

Observations have been obtained during MIOSOTYS campaigns at OHP in 2010-2012 at an acquisition rate of 20 Hz and with median SNR of 20. Photometry has been obtained in a standard manner and lightcurve information has been extracted from the data (see fig. 3).

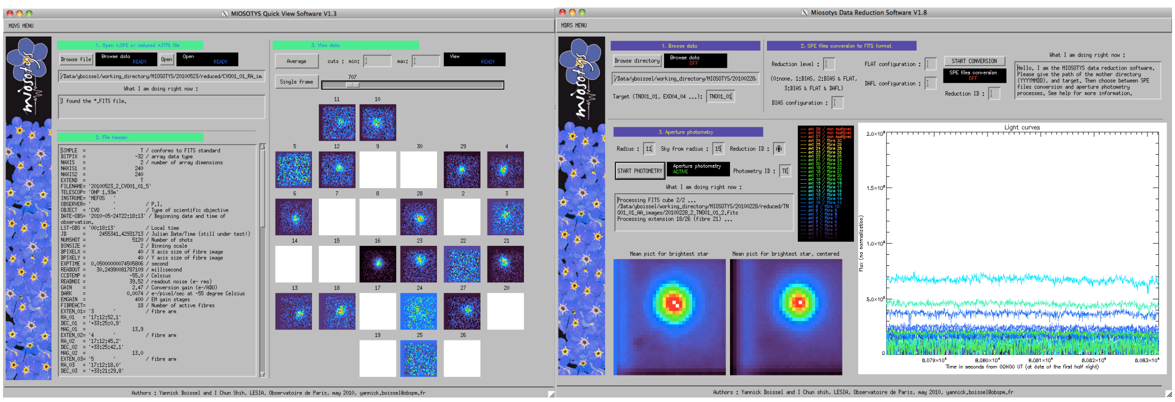

Fig. 3. Left: MIOSOTYS quick view software. **Right:** MIOSOTYS data reduction software.

A total of 38 nights, that is 3782 star-hours has been investigated for occultation events.

3.2 Search method

The search method consists in computing the variance over a running window of 2 seconds:

$$var = \frac{\sum_{j=1}^{n}(x_{ij} - \bar{X}_{we_i})}{n} \tag{3.1}$$

With the current time resolution of 0.05 sec of MIOSOTYS and based on the size of small TNOs and their relative velocity to the observer on the Earth, we estimated we to range between 3 and 7 points (0.15 and 0.30 sec).

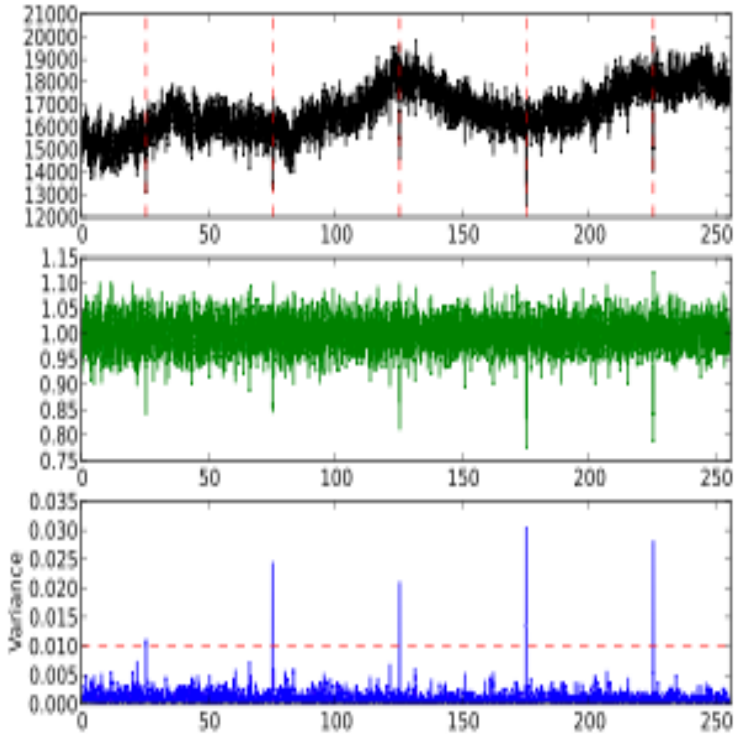

Fig. 4. Search test on synthetic events implanted in real data (red vertical lines)

Then, this first-pass selection of positive events are reviewed against spurious effects that can mimic real events: cosmics, seeing variations, detector artifacts, transparency variations,.

4 Modelling and discussion

4.1 The model

We consider that we are in the Fraunhofer diffraction regime. 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)

4.2 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 $\chi^2 \propto \sum(observation - model)^2$. We search the set of values that minimize the χ^2. The figure 5 show an example of the procedure for one event.

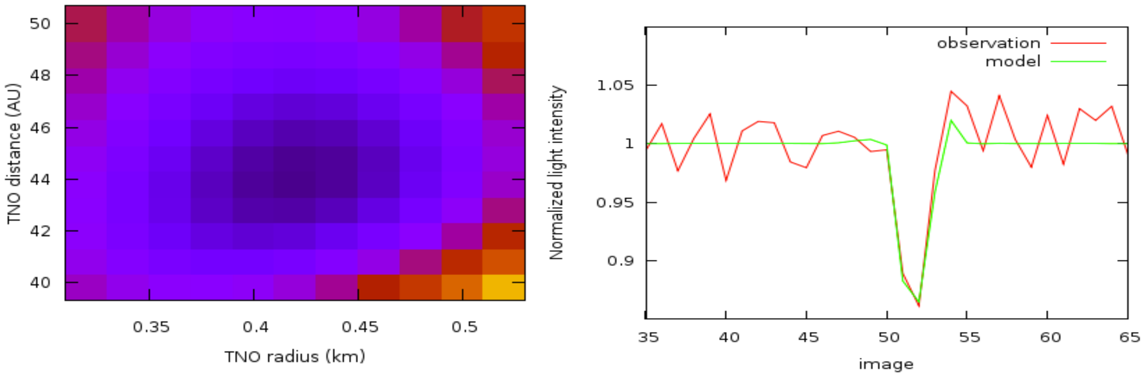

Fig. 5. Left: χ^2 map in relation with the size and the distance of the TNO. Blue colors are low χ^2 (good fit), yellow colors are high χ^2 (bad fit). **Right:** Observation (red line) versus model (green line). The fitted parameters are the TNO radius (0.42 km) and the TNO distance (44 UA)

4.3 *Criterion of detection*

To consider that an event is compatible with an occultation, the difference between observation and the modeled patterns have to be less than the value of the noise.

5 Conclusions

We have explored the Kuiper disk through stellar occultation and have found a couple of events that could be fitted by hectometer size TNOs. These results, to be further refined, put some constraint on the size distribution of the Kuiper Belt.

References

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