SF2A 2017
C. Reylé, P. Di Matteo, F. Herpin, É. Lagadec, A. Lançon, Z. Meliani, F. Royer (eds)

SEARCHING FOR COMETARY ACTIVITY IN CENTAURS OF THE OSSOS SURVEY

N. Cabral[1], P. Rousselot[1,] and A. Guilbert-Lepoutre[1,]

Abstract. To date, about 200 Centaurs have been detected of which only 29 are active and have a cometary designation. In order to better constrain the origin of Centaurs' cometary activity, it is necessary to increase the sample of studied targets. The Outer Solar System Origin Survey (OSSOS) observed a large sample of targets at large heliocentric distances, providing photometric and astrometric data. We implemented an automatized method to constrain the cometary activity of the OSSOS objects with heliocentric distances lower than 30 au. We describe here our image analysis method for one typical object. Our approach allows to compute the sky background, the surface brightness radial profile and the upper limit of the $Af\rho$ parameter.

Keywords: comets: general; Kuiper Belt; solar system: general; Centaurs

1 Introduction

Centaurs are an intermediate population between Jupiter Family Comets (JFCs) and trans-Neptunian Objects (TNOs). They are usually defined as bodies whose orbits have their perihelion, q, and their semi-major axis, a, larger than the semi-major axis of Jupiter ($a_{\rm J}$=5.2 au) and lower than the semi-major axis of Neptune ($a_{\rm N}$=30 au). Numerical simulations show that their orbits are chaotic and dynamically short-lived compared to the age of the solar system, with a median lifetime near 10 Myr (Tiscareno & Malhotra 2003). They are therefore believed to be recently escaped from the TNOs of the Kuiper Belt through gravitational scattering from giant planets (Levison & Duncan 1997; Horner et al. 2004; Volk & Malhotra 2008). They are potentially the key to understand the process that transforms TNOs to short period comets.

Despite the pivotal role of Centaurs, the sample of detected objects remains relatively small. Only about 200 Centaurs have been detected of which 29 are active and have a cometary designation. For our study, we selected targets from the release 8 of the OSSOS survey, with a simple criterion satisfying heliocentric distance r <30 au. This corresponds to a sample of 23 objects including 9 Centaurs, 8 resonant objects, 5 scattered objects and 1 non-classified object. In order to describe our method, we apply the latter to a typical object of this sample. We basically constrain the cometary activity by computing the upper limits of the $Af\rho$ parameter for the *o3e01* target. The tools developed here will be applied in future for the whole selected sample, which represents a total of 390 photometric images.

2 Cometary activity

2.1 The OSSOS survey

OSSOS is a Large Program on the Canada-France Hawaii Telescope surveying eight ∼21 deg^2 fields in r-band. Initially OSSOS was allocated for 8 semesters of the period 2013-2016, but it has been extended up to the beginning of 2017. The imaging observations of the survey were taken at the University of Hawaii with the MegaPrime camera on the 3.6 m Canada-France-Hawaii Telescope. The r-band observations used the 0.90 deg^2 field of view of the camera. A full description of OSSOS can be found in Bannister et al. (2016). The photometric data used in this work come from the release 8 of OSSOS.

[1] Institut UTINAM, CNRS UMR6213, Univ. Bourgogne Franche-Comté, OSU THETA Franche-Comté-Bourgogne, Observatoire de Besançon, BP 1615, 25010 Besançon Cedex, France

2.2 Data analysis

We developed routines to determine the brightness radial profile of a target, from which we can search for cometary activity by comparing it to the Point-Spread Function (PSF) radial profile adjusted in intensity. We did not manage to find any clear evidence of cometary activity in any image of the object *o3e01* but we tried to estimate an upper limit for the $Af\rho$ parameter (see section 2.3). All these steps are automatized to treat a large sample.

We basically proceed to 4 preparatory steps:

- *Centroid:* We use the IRAF* functions of the daophot package to determine the target centroid.
- *Sky background:* To determine the sky background we segment the image in squares of 30×30 pixels and we compute the median of pixel intensities. We use the minimum of these medians as the sky background.
- *Radial profile:* We compute the surface brightness profiles for the targets and we adjust the PSF. Fig. 1 shows a typical example of the radial profile for the target *o3e01*.
- *Upper limit for the coma flux:* Since there is no apparent cometary activity we can only put upper limit on the coma flux, in order to compute upper limit for the $Af\rho$ parameter (section 2.3).

In Fig. 1 we display the radial profile of the object *o3e01* observed during the night of 8 february 2013. At the time of observation, *o3e01* was located at 23.4 au from the Sun. The two profiles, the psf one (mauve line) and the target one (green points with errors bars) are very close, meaning there is no cometary activity detected.

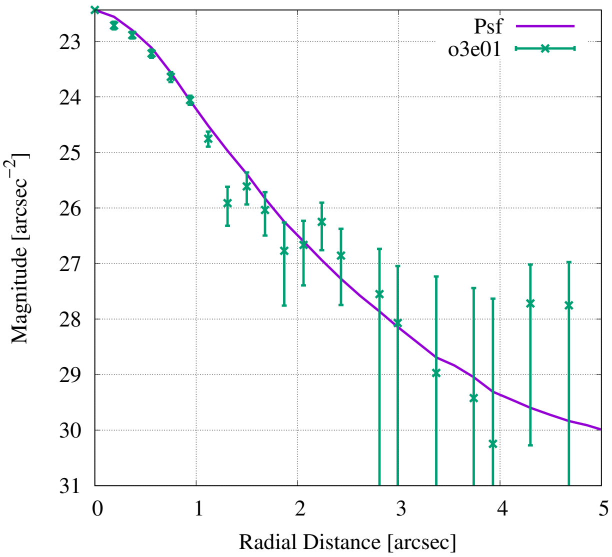

Fig. 1. Surface brightness profile for the target *o3e01* observed on 8 February 2013. Magnitude as a function of the radial distance for the target (green points with errors bars) and the psf (mauve line). Close Psf and target profiles indicates the target has no detectable cometary activity.

2.3 The $Af\rho$ parameter

The $Af\rho$ parameter has been introduced by A'Hearn et al. (1984), it enables to quantify the cometary activity. This parameter is more or less independant of unknown parameters such as grain albedo or grain size and independent of the field of view (if we assume that the radial profile follows a ρ^{-1} dependance). It is possible to

*Image Reduction and Analysis Facility `http://iraf.noao.edu/`.

	r(au)	Δ(au)	$Af\rho_{max}$(cm)	mjd
1	23.279	22.335	64	56387.56945
2	23.279	22.335	97	56387.57336
3	23.279	22.335	107	56387.57724
4	23.279	22.335	62	56387.58112
5	23.279	22.335	38	56387.58503
6	23.277	22.327	48	56388.60299

Table 1. $Af\rho_{max}$ and the corresponding heliocentric distance r, geocentric distance Δ, and the modified julian day mjd, for the observations of the *o3e01* OSSOS target. The orbital parameters for this object are: semi-major axis a=34.421 au, perihelion distance q=14.125 au, and eccentricity e=0.590.

compute $Af\rho$ with the magnitude of the Sun and the magnitude of the coma in the same band (Korsun et al. 2014):

$$Af\rho = [2.4686 \times 10^{19} \times r^2 \times \Delta \times 10^{0.4(m_{\odot} - m_{\rm coma})}]/D \tag{2.1}$$

where r is the heliocentric distance (expressed in au), Δ is the geocentric distance (in au), $m_{\odot}$ is the magnitude of the Sun, $m_{\rm coma}$ the global magnitude of the coma and D the apparent diameter of the field of view in arcsec. The resulting $Af\rho$ is expressed in cm.

Because we did not manage to detect any cometary activity around our targets we computed only upper limits for the $Af\rho$ parameter. Our estimate of this upper limit is based on the radial profile, and based on a three steps computation:

1. We compute lower limits for the magnitude per square arcsec in a range of radial distance outside the inner part of the radial profile (i.e. typically around 2 to 3 arcsec). This lower limit is computed from the radial profile minus the errorbar (see Fig. 1) and converted in units of flux. We subtract, then, the corresponding flux of the PSF profile. We obtain, consequently, the flux value for a range of radial distance outside the center and inside the region where the sky background is important.

2. We extrapolate this flux for the other radial distances on the basis of a $1/\rho$ law, ρ being the radial distance. We sum all the resulting flux in order to get the maximum possible flux.

3. This maximum possible flux is converted in an overall coma magnitude and this magnitude is used in the above formula (Eq. 2.1) to compute $Af\rho_{\rm max}$.

Table 2.3 summarizes the upper limits with corresponding orbital parameters and date of observation for a sample of observations of the *o3e01* target. The values of the $Af\rho_{\rm max}$ parameter refer to the upper limit.

3 Conclusions

The few number of known Centaurs prevents a statistical analysis crucial to constrain cometary models. Hence, the ultimate goal of this work is to increase the number of Centaurs with constrained cometary activity. Here, we implemented a methodology to determine the upper limit of the $Af\rho$ parameter. We described our analysis focusing on the *o3e01* target from the release 8 of the OSSOS survey. We did not find evidence of cometary activity for this object. In a forthcoming paper we will pursue this study with the whole sample of the OSSOS survey (for r <30 au).

References

A'Hearn, M. F., Schleicher, D. G., Millis, R. L., Feldman, P. D., & Thompson, D. T. 1984, AJ, 89, 579

Bannister, M. T., Kavelaars, J. J., Petit, J.-M., et al. 2016, AJ, 152, 70

Horner, J., Evans, N. W., & Bailey, M. E. 2004, MNRAS, 355, 321

Korsun, P. P., Rousselot, P., Kulyk, I. V., Afanasiev, V. L., & Ivanova, O. V. 2014, Icarus, 232, 88

Levison, H. F. & Duncan, M. J. 1997, Icarus, 127, 13

Tiscareno, M. S. & Malhotra, R. 2003, AJ, 126, 3122

Volk, K. & Malhotra, R. 2008, ApJ, 687, 714