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Astrometry and photometry of Orcus from a 33-day campaign

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Abstract

The binary trans-Neptunian Object (90482) Orcus (formerly known as 2004DW) was observed while it traversed a large star field. The CCD images of the large and fixed field allowed us to carry out high precision relative photometry and relative astrometry of this large trans-Neptunian object with respect to numerous background stars, and for a longer time span than is usual in regular observing runs. We present a preliminary study of the astrometry residuals that were obtained when the astrometric positions were compared to the predicted orbital positions of Orcus' system around the Sun. The presence of Orcus' satellite is revealed in the residuals but not in the direct images because they lack the needed spatial resolution. From those results we discuss the prospects for using the astrometry technique to find new binary TNOs and to study already known binaries with uncertain orbital periods. From the analysis of the time series photometry, a periodicity of 9.7 $\pm$ 0.3 day is found in the data, with a peak to peak brightness variation of only 0.07 $\pm$ 0.02 mag, although apparent aliases of very similar spectral power are present in the periodogram, making the correct identification of the true period difficult. Besides, other periodicities might exist as well. Therefore we cannot conclusively claim that the system is in double synchronous state like Pluto. We discuss the implications of this regarding basic physical properties of Orcus and its satellite.

1. Introduction

Trans-Neptunian Objects (TNOs) are a large ensemble of interesting solar system bodies because they are believed to be remnants from the dynamical process of Solar System formation, and they carry important information on the early stages of the solar system. They are also thought to be icy bodies from which the short-period comets originate [5] and therefore they are a source for objects that sometimes come close to the Sun or close to the Earth, and can even collide with our planet. In fact, the late heavy bombardment has been linked to this kind of objects in the "Nice" model [6].

Among the diversity of TNOs, there are objects of special interest: the dwarf planets. Large TNOs can retain very volatile ices and are supposed to also retain primordial information on the original spin rate distribution because they are apparently the least collisionally evolved objects [4, 2]. However, some degree of spin evolution due to tidal interactions in binaries can alter this concept and Orcus may represent a good example like Pluto. This is specially important because a large fraction of the TNOs can be binary [7]

The trans-Neptunian object (90482) Orcus is one of the brightest known TNOs discovered so far and possibly one of the largest (even assuming large albedos). In fact, Orcus qualifies to become a dwarf planet because of its large diameter. Orcus is an interesting object for other reasons: It is known to posses a satellite, Vanth, which orbits Orcus in around 9.5 days and whose orbital plane is almost perpendicular to the line of sight [3]. Water ice has been found on its surface through near infrared spectroscopy and perhaps even ammonia [1].

Orcus' short term variability was studied in [8] who found a likely rotation period of 10.08hr (although periods at around 7 hr and 17 hr were also possible). Later, [9] included more data and obtained a rotation period of 10.46hr. In such works the brightness variability was very low ($\leq$ 0.04). Those results already seem to indicate that Orcus rotation is not tidally locked to its satellite but since the satellite orbital pe-

riod is much longer than the usual observing windows for rotational variability studies, there is the possibility that Ortiz et al. and Thirouin et al. works could not have detected a rotation period as long as 9.5 days. In other words, the observing windows in [8] and [9] might have been too short to detect a 9.5 day rotation period. Therefore we decided to plan and execute a specific observing run spanning more than 30 days in order to study the photometric behavior of Orcus to check whether a long 9.5 day rotation period was possible or not.

Another goal was to check if the presence of Orcus' satellite could be revealed in our unresolved images of Orcus by means of high precision relative astrometry with respect to fixed background stars, in order to test the technique for future detection of new binaries using telescopes other than the highly demanded Hubble Space Telescope (HST). On the other hand, the technique might help to determine the orbital periods of the known binaries whose orbits around the primary are very uncertain. Because Orcus' satellite separation is around 0.3 arcsec and the mass ratio of the system is approximately 0.03, the goal might seem challenging but Orcus is also among the brightest TNOs and therefore the technique might be attempted with a relatively small telescope (which can easily accomodate the needed large field of view for relative astrometry).

2. Observations and data reduction

The CCD images of the unresolved Orcus+Vanth pair were obtained by using a remotely controlled 0.45m f/2.8 telescope located on top of Cerro Burek (Complejo Astronómico el Leoncito, CASLEO) in Argentina. The telescope was equipped with a large format 11 Megapixel CCD camera. The observations were obtained through a very broad band filter in order to maximize the signal to noise ratio (wavelength range 390-700nm). Integration times were fixed to 300s and the telescope was tracked at sidereal rate. The observations were taken on 18 nights spanning a period of 33 days. A total of around 200 images were taken for this project. The typical signal to noise of the Orcus+Vanth system was ~ 30. The images were taken near the meridian so that the object was at its highest elevation as seen from Cerro Burek. By doing this the signal to noise ratio that can be achieved is maximized and at the same time this minimizes the differential refraction. Seeing ranged from 2 to 4 arcsecs and therefore the Orcus-Vanth pair was always unresolved, as already stated.

The images were corrected for dark current and flatfieded using standard procedures. No cosmic ray removal algorithms were used. The photometry was extracted in a similar way as in [8] but with some refinements made in [9]. The astrometry was also obtained using standard procedures. A polynomial of order 3 was used to fit the observational to the reference star positions. The UCAC2 catalog was used, but this choice was not relevant because the goal was to obtain relative astrometry.

3. Results

More detailed analysis will be presented at the conference, but here some brief preliminary findings are reported.

The analysis of the right ascension residuals obtained from an orbital fit to the astrometry indicates that the satellite signature is present in the data. From this experience one is tempted to conclude that detecting new binaries or studying many other already known binaries seems possible for many binaries using larger telescopes. The goal can potentially be achieved provided that large fields of view can be used (in order to be able to apply relative astrometry, which is not subject to star catalog problems etc, as is the case for absolute astrometry).

On the other hand a periodogram analysis of the time series photometry presents several peaks of very high spectral power, far above the 99% significance level. Therefore one can be confident that the periodicity seen in the data is real. However there are several peaks separated by the typical ~ 1 cycle/day and therefore it is difficult to asses which is the true frequency and which are the 24-h aliases. A 9.7 ± 0.3 day period (corresponding to a frequency of 0.1029 cycles/day) is potentially the preferred peak. A sinusoidal fit to the data results in a 0.07 mag peak to peak variability. If 9.7 day is the true period, this would seem to imply that the system is in double synchronous state, but a period of around 10hr has been shown in the literature and one cannot reject it from the present photometry. There are several physical scenarios that might result in several photometric periodicities, but the system would not have reached the double synchronous state.

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