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Hyper Suprime-Cam Lightcurve Studies of Trans-Neptunian Objects from the Outer Solar System Origins Survey

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Abstract

Lightcurves can reveal information about the gravitational and/or collisional processes that have acted on small bodies since their formation. High quality lightcurves provide constraints on the material properties and interior structure of individual objects. In large samples, lightcurves can shed light on the formation source of small body populations. We have studied 71 TNOs from the Outer Solar System Origins Survey (OSSOS) using Hyper Suprime-Cam (HSC) on the 8.2-m Subaru Telescope, in a one-night study of 15 OSSOS TNOs in 2014 and a two-night lightcurve study of 65 OSSOS TNOs in 2016, with nine objects overlapping between the two studies. Subaru's large aperture and HSC's large field of view enables measurements of multiple TNOs with a range of magnitudes ($m_r = 22.5$ to 25.1) in each telescope pointing. The OSSOS objects span from several hundred kilometres to a few tens of kilometres in diameter, and have well-determined orbits and dynamical classifications. Our sample thus enables examining the variability in different dynamical sub-classifications (such as the cold classicals and hot populations) for smaller objects than previous lightcurve projects have typically studied.

1. OSSOS

OSSOS [1] is a large, well-characterised TNO survey on the Canada-France-Hawaii Telescope (CFHT), having surveyed 160 sq.deg. of sky, detecting over 900 TNOs down to $m_r \approx 25.1$. All detected objects are tracked to ensure well-determined orbits, allowing securely classified among the various TNO sub-populations (resonant, classical, scattering, etc.). We choose to observe TNOs from OSSOS because they are recently discovered (allowing multiple objects per field due to high on-sky density) and their well-determined orbits allows us to compare populations. Previous light curve studies have been reported for ~ 90 TNOs [5, 3, 2], but that sample has unknown selection biases and discovery circumstances. By targeting OSSOS TNOs, our discovery and selection biases are well understood and can be accounted for.

2. Data and methodology

All data was taken using HSC on Subaru Telescope. One night in 2014 obtained 300 second exposures of two fields (containing 12 and 7 TNOs) at 12 times over the course of 6 hours. In August 2016 we targeted six fields, observing each with a 300 second exposure time before repeating the fields, for a measurement separation of just over half an hour and SNR of about 60 for an $m_r = 23.8$ object. Two field were observed a total of 20 times while four fields were observed 24 times over two nights.

Our photometric measurements were done using the TRIPPy python package [4], thus correcting for the slight TNO movement during the exposure (movement is less than PSF FWHM) by using an elongated aperture. The photometry was subsequently calibrated relative to non-variable field stars to remove non-TNO related variability (such as weather). We use a Phase Disperion Minimization (PDM) code to estimate periods for the light curves, as described in [2]. This solution is usually degenerate, as light curves can be single peaked (albedo dominated) or double peaked (shape dominated), and aliasing is a problem, where some periods cannot be ruled out due to the timing of the observations.

3. Results

The Figure 1 histograms show that our sample spans a range of semi-major axis and absolute magnitude, H_r (CFHT r). Also plotted are histograms of the standard deviation and estimated amplitude of the light curve variation. Figure 2 shows a few examples of light curves from our sample. We will present our findings from comparing the light curve properties (period, amplitude) to orbital properties (dynamical class, orbital elements).

4. Summary and Conclusions

We have obtained one to three nights of light curve observations of 71 TNOs using HSC on Subaru Telescope. The large aperture and field of view observed up to 12 objects at once, with magnitudes from $m_r = 22.5$ to 25.1. The light curves have been photometrically calibrated and light curve periods and amplitudes have been estimated. A full analysis of correlations between light curve properties and orbital properties will be presented at EPSC.

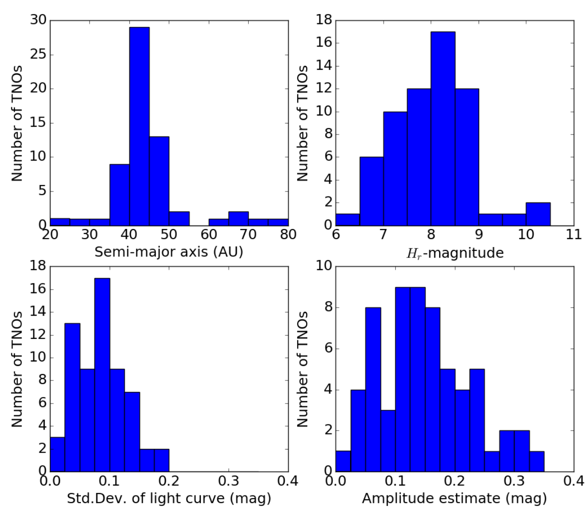

Figure 1: Histograms of semi-major axis, absolute magnitude, light curve standard deviation and estimated light curve amplitude for our HSC sample. In order to minimise spurious results caused by noise, the standard deviation and estimated amplitude are calculated ignoring the highest and lowest point in our data.

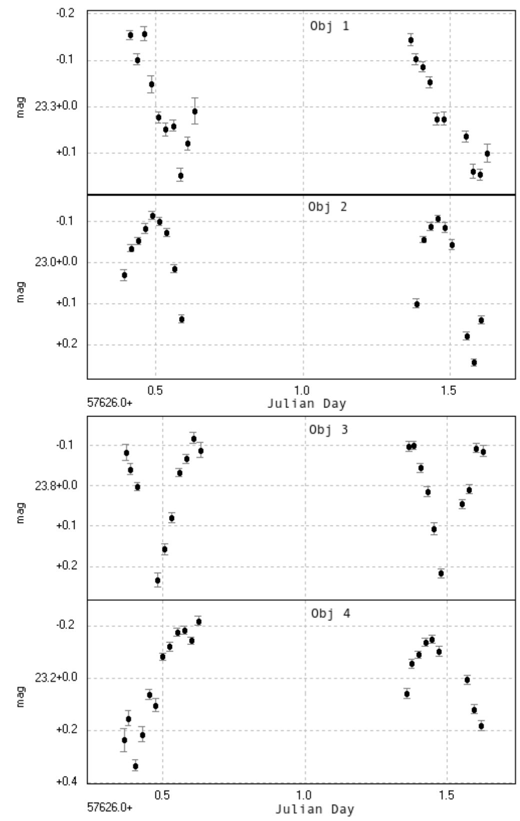

Figure 2: Light curves of four clearly variable objects from our 2016 HSC data.

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