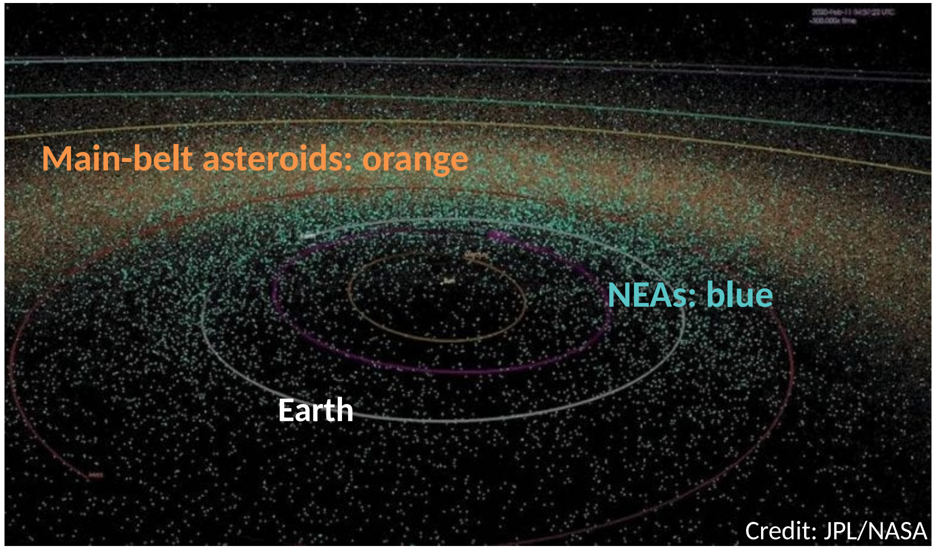
Characterisation of Small, Close-Approaching Near-Earth Asteroids

Petro Janse van Rensburg[1,2] and Nicolas Erasmus[2]
(1) Department of Astronomy, University of Cape Town, South Africa (2) South African Astronomical Observatory, Cape Town, South Africa


Sutherland plateau

Abstract: We present preliminary results from multi-band photometry of 14 small (diameter between 30 m and 300 m) and 6 large (diameter > 300 m) close-approaching Near-Earth Asteroids (NEAs), observed with the South African Astronomical Observatory (SAAO) 40-inch telescope and the Sutherland High-Speed Optical Camera (SHOC). We use the photometric data to characterise the NEAs by extracting rotation periods and classifying them according to the Bus-DeMeo taxonomic scheme, and thereby infering its most probable composition.

Near-Earth Asteroids



NEAs have orbits that bring them close to or cross the Earth's orbit - some have impacting trajectories and could pose a threat.

Small NEAs pose a large threat because they are big enough to cause significant damage on impact but also more abundant compared to larger NEAs.

Small NEAs are not well studied - they can only be observed with 1-m class telescopes near their close-approach.

The vapor trail of the Chelyabinsk Meteor in 2013. Even though the asteroid only had a diameter of 20 m, it still caused significant damage when it exploded [1].

Telescope

SAAO 40-inch telescope & Sutherland High-Speed Optical Camera (SHOC)

Specifications [2]:

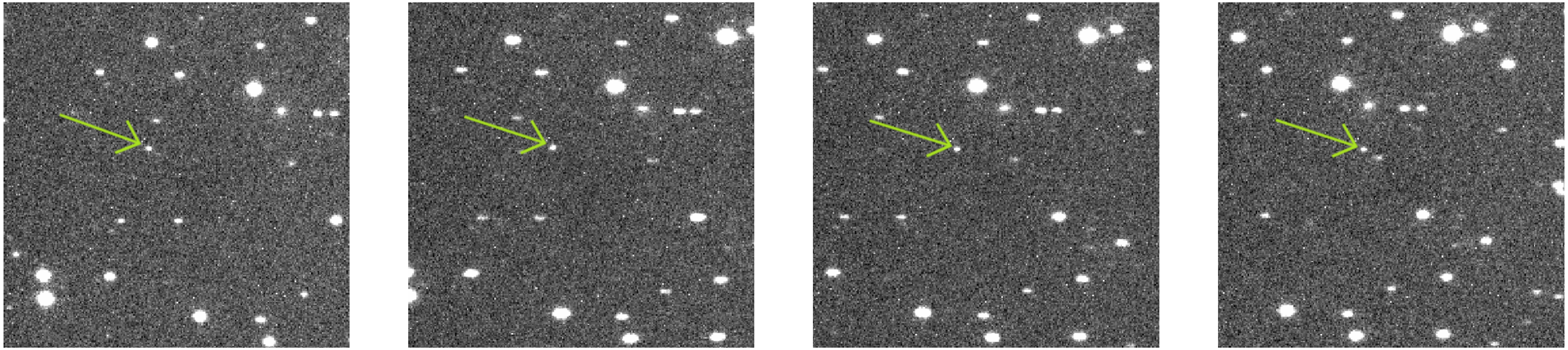
Location:
Sutherland, South Africa
Remote observing from Cape Town

Telescope:
40 inch (101.6 cm) f/16,
Cassegrain design

Camera:
1024 × 1024 CCD,
field-of-view of 2.85 × 2.85 $arcmin^2$,
platescale of 0.167 arcsec/pixel for 1×1 binning

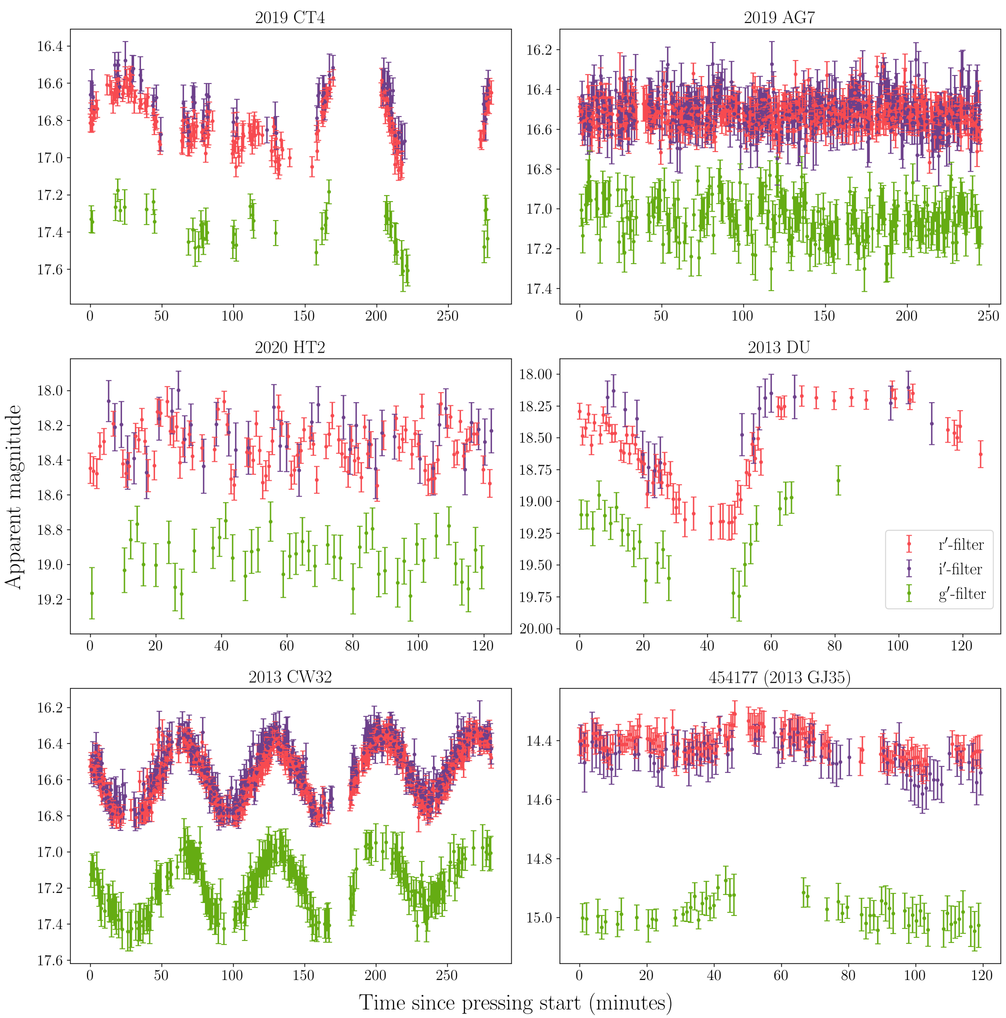
Filters:
Bessel *U B V R I*,
SDSS u′ g′ r′ i′ z′,
Hα, O[III] and a clear filter

Observations



The targets were observed in three filters: SDSS r′, g′ and i′ in the sequence r′-g′-r′-i′, with exposure times between 5 and 30 seconds. Shown is an example of 4 exposures in the r′-filter of a 70m NEA, observed when it was 15 lunar distances from the earth. The green arrow indicates the target near the centre of the field-of-view, with the field stars moving to the left of the page from the first to the last image. The exposure time for each image was 20 seconds, with approximately 2 minutes between each exposure.

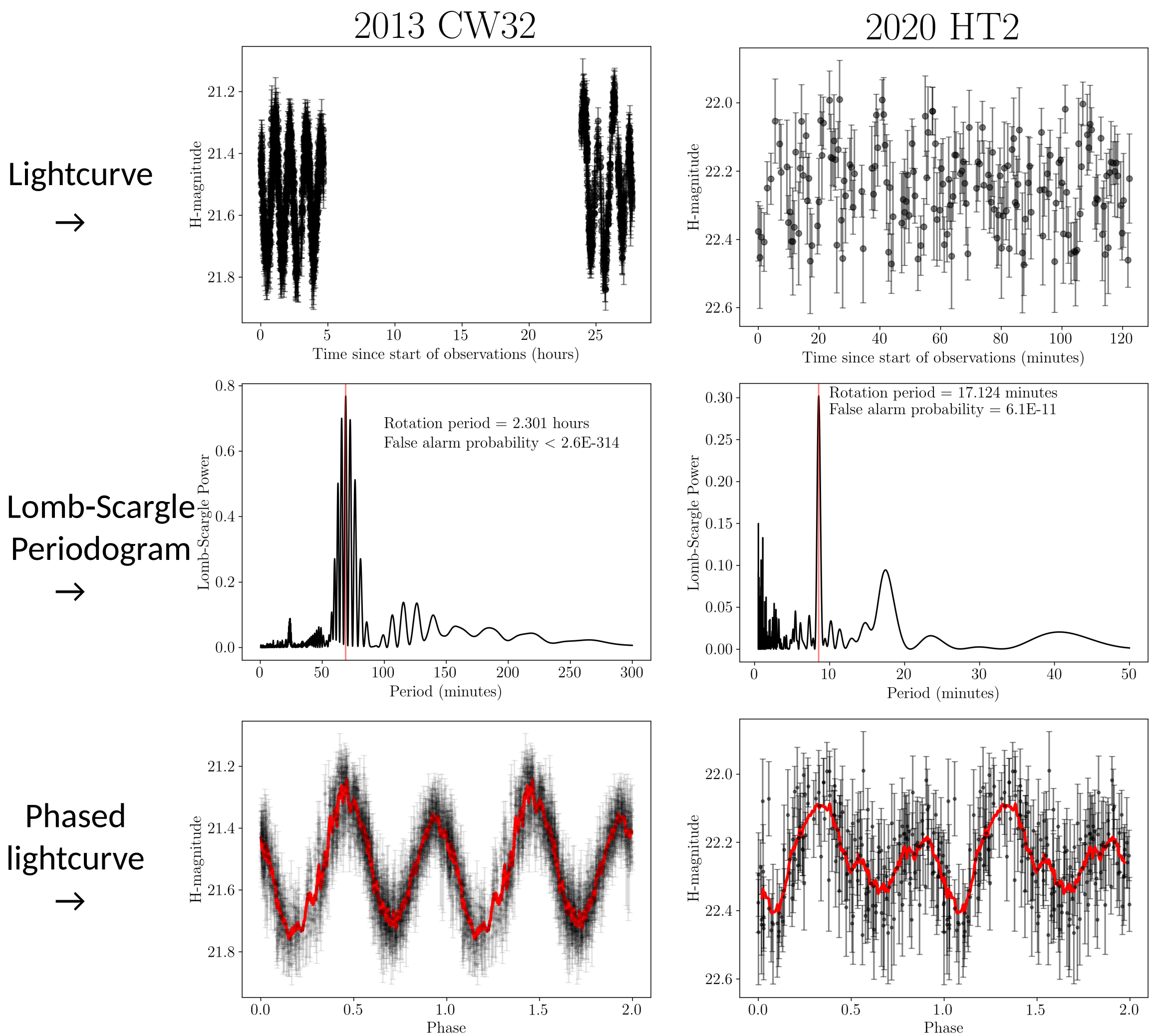
Photometry Data



Example lightcurves (magnitude vs time) of 6 of the NEAs (2019 CT4, 2019 AG7, 2020 HT2, 2013 DU, 2013 CW32 and 454177), where the red points are the data in the r′-filter, the purple points are the data in the i′-filter and the green points are the data in the g′-filter.

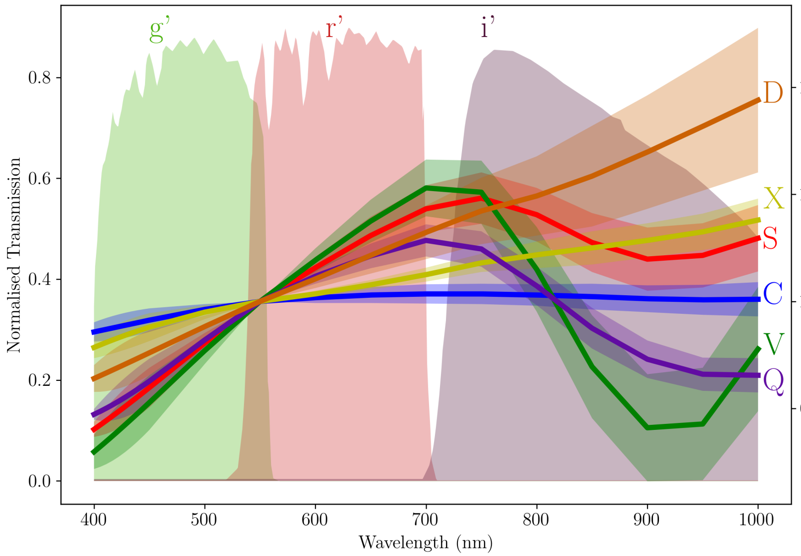
The calibrated, multi-band photometry was extracted by making use of PHOTOMETRYPIPELINE, developed by Michael Mommert [3].

Rotation periods



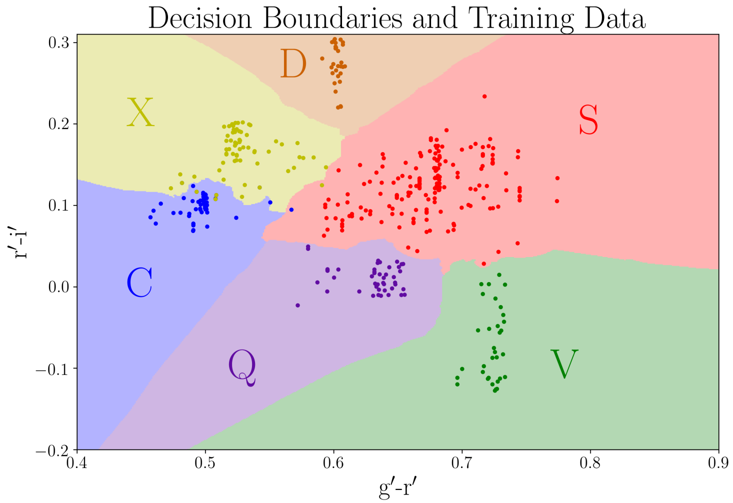
Lightcurves of two targets: 2013 CW32 and 2020 HT2 (top). The g′ and i′ data were shifted with the colours g′-r′ and r′-i′, respectively, to normalise them to the r′ data. The rotation period (2 × lightcurve period) was extracted from the period at the highest peak in the Lomb-Scargle periodogram of the lightcurve (middle). The uncertainty in the period was given as the false-alarm probability. The lightcurves were phased at the rotation period (bottom), where the red line is a running mean to guide the eye.

Multi-band photometry

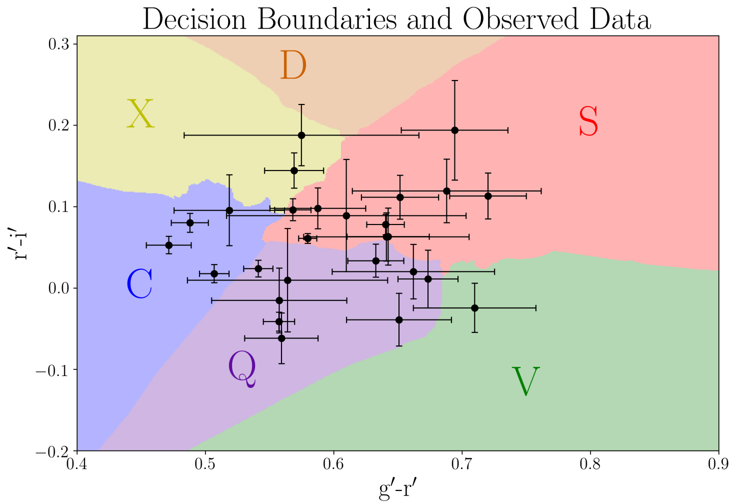


Normalised transmission of the g′-, r′- and i′-filter are shown in transparent green, red and purple, respectively. The average reflectance spectra of S-, C-, X-, Q-, D- and V-type asteroids in the Bus-DeMeo taxonomic scheme [4] are also plotted. Asteroids are divided into different taxonomic types based on their spectra and therefore their composition. But photometry is easier to perform on faint, moving targets, and since each taxonomic type has a different spectral slope in the visible wavelength range, we can differentiate between the different types by using the colours g′-r′ and r′-i′ instead.

Taxonomy



Colour-colour plot (r′-i′ vs g′-r′) separating the different taxonomic types. Decision boundaries were generated by training a machine learning algorithm on synthetic colours from observed spectra available at [5]. The spectra were classified by S. Navarro-Meza. The training data are also plotted.



Colour-colour plot with the same decision boundaries, but now with the measured colours of the NEAs plotted in black. This was used to determine the taxonomic type of the asteroid and thereby infer its most probable composition.

Conclusions and Future Work: Through observing and analysing multi-band photometry from the SAAO 40-inch telescope and SHOC, we can characterise small, close-approaching NEAs by extracting rotation periods and determining their taxonomic type. Future work includes combining the results with other NEA surveys, thereby providing valuable insight into the most likely properties of potential future impactors.

[1] Brown, P. G., Assink, J. D., Astiz, L., et al. 2013, Nature, 503, 238
[2] Coppejans, R., Gulbis, A. A. S., Kotze, M.M., et al. 2013, PASP, 125, 930
[3] Mommert, M. 2017, Astronomy and Computing, 18
[4] DeMeo, F. E., Binzel, R. P., Slivan, S. M., & Bus, S. J. 2009, Icar, 202, 160
[5] http://smass.mit.edu/minus.html

Contact:
Petro Janse van Rensburg
Email: petro@saao.ac.za
Twitter: @petro_jvr

NRF National Research Foundation | SAAO South African Astronomical Observatory | University of Cape Town