8th IAA Planetary Defense Conference – PDC 2023
3-7 April 2023, Vienna, Austria

IAA-PDC-23-0X-XX

ASTROMETRIC AND PHOTOMETRIC OBSERVATIONS OF PHAs WITH 70cm TELESCOPE

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Keywords: *Near Earth Objects, small telescope, astrometry, photometry*

A potentially hazardous asteroid (PHA) is a near Earth object (NEO) with an orbit that can make close approaches to the Earth and is large enough to cause significant regional damage in the event of impact. PHAs are defined as having a minimum orbit intersection with Earth of less than 19.5 lunar distance and being brighter than 22nd magnitude. Currently, there are over 2300 objects classified as PHA. None of the PHAs present a threat to the Earth in the near future. However systematic observation of these objects can broaden our understanding of their orbital and physical properties.

The Faculty of Mathematics, Physics and Informatics of Comenius University in Bratislava, Slovakia (FMPI) operates 70 cm Newtonian telescope (AGO70) situated at the Astronomical and Geophysical Observatory in Modra, Slovakia. Its field of research is dedicated to the observation of the space debris and NEOs.

Telescope was registered with Minor Planet Center database in November 2022 and received designated code M34. Telescope was built on the fork equatorial mount aligned with the Earth's rotational axis and has a focal length of 2.9m. Mount is controlled by two separate motors, allowing tracking with high speed up to 1deg/sec in each direction. AGO70 telescope is fully capable of tracking object with angular velocities up to 1.5deg/s, which enables long exposure observations even of fastest NEOs without trailing. The fastest PHAs have sky motion of up to 100s of degrees per day, which can be problematic for large and slow telescopes.

We are able to observe fast moving objects, which is useful when observing close approaches with Earth as shown on the case of NEO 2023 EY, which was a close approach of less than 1LD. Measured astrometric position for all observed NEOs are sent to MPC ephemeris service for orbit improvement.

Telescope is using FLI ProLinePL1001E Grade1 CCD camera with resolution of 1024x1024 pixels and has a field of view 28.5'x28.5'. Telescope is equipped with filter wheel containing Johnson-Cousin BVRI and Sloan *g,r,i,z_s,y* filters and is able to acquired color indices of observed objects.

Planning of the observation is performed using Python's JPL Horizons library. Script retrieves objects, that satisfy observational parameters and creates the list of observable objects for each night. AGO70 telescope is able to observe objects with magnitudes 17.5 and brighter. Telescope has a horizon limit 25 degrees. Another approach for observation planning is NEO toolkit developed by European Space Agency (ESA) (Moreta et al., 2023). NEO toolkit is able to filter observable object for chosen site using predefined constraints. Users are able to obtain high accuracy ephemeris, precisely locating asteroids and simulating the close approach of those objects with Earth.

AGO70 is capable of astrometric and photometric image acquisition of these fast objects. Precise astrometric observations of low brightness objects are used to improve orbital parameters and refine the ephemeris. Photometric light curves of rotating objects contain complex information about object's shape and reflective properties. Shape of the light curve is directly related to the rotational period, and with long term observations and light curves can be used to calculate object's absolute magnitude, size, and slope factor.

Images are processed using standard photometric methods such as bias and dark subtraction and flat field correction. Photometric reduction of images is a standard procedure, that removes unwanted signals in the raw data, and generate images that are suitable for doing science. The first step of photometric reduction is bias/dark subtraction from raw images. This process will remove noise caused by the electronics inside of the camera and thermal noise caused by random electrons. The second step will remove irregularities by flat field scaling. Irregularities are mostly caused by inequality of pixels and impurities caused by dust particles on camera or filters.

Target and stars are then measured in AstroImageJ (Collins et al., 2017) software using Data Processing option with aperture photometry method. The aperture photometry uses the standard system of three concentric apertures, where from the first one the target's signal is integrated, the second one is omitted to prevent the contamination with other frame objects, and the third one is used for the integration of the sky background intensity. Single point intensity is represented by subtraction of target's signal and sky background.

Photometric calibration to standard star system is achieved by comparing the measured instrumental magnitudes of stars in the image with the catalog magnitudes of stars and calculating the transformation parameters. These same parameters are later applied to the instrumental magnitude of the object and the standard object magnitude is determined. This process is performed using python libraries and all-sky ATLAS-REFCAT2 catalog (Tonry et al., 2018).

Observed light curves can be used to determine the rotation period of the observed object. Rotation periods are retrieved from the publicly available light curve database (Warner et al., 2009). To verify whether our photometric methods are correct, we observed object 1627 Ivar and reconstructed its light curve (see Figure 1). Object has known period 4.796 hours (Warner and Stephens, 2020) therefor it was a good candidate to test our analysis.

With target calibrated to standard magnitude system, it is possible to connect several different night of observation. This method helps with observation of objects with long rotation period and short observing window during each night. To test this method, we observed asteroid 98943 (2001 CC21) with known rotation period during 4 different nights and reconstructed the light curve of the object (see Figure 2).

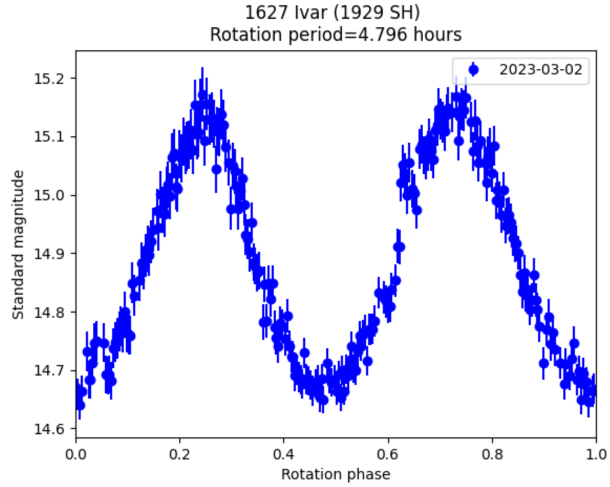

Figure 1: Light curve of NEO 1627 Ivar (1929 SH) observed by AGO70 telescope. Light curve consists of 5 hours of observation during the night 2023-03-02. Images have 60sec exposure using the clear C filter. Rotation period 4.796 hours (Warner and Stephens, 2020) was used for phase reconstruction.

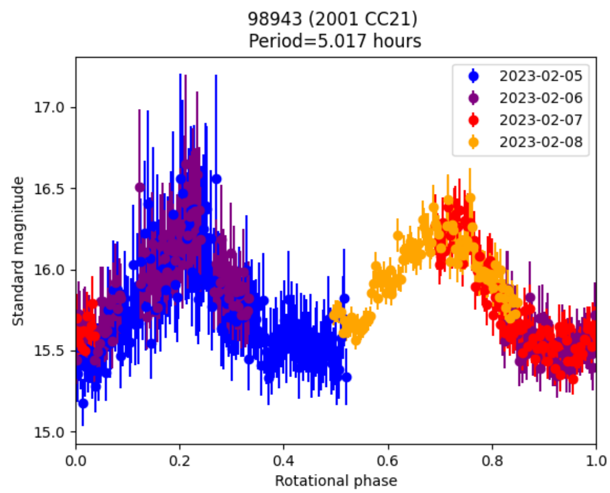

Figure 2: Light curve of NEO 98943 (2001 CC21) observed by AGO70 telescope. Light curve consists 4 different observation in consecutive nights from 2023-02-05 to 2023-02-08. Images have 15sec exposure using the Johnson-Cousins R filter. Rotation period 5.017 hours (Pravec et al., 2022) was used for phase reconstruction.