7th IAA Planetary Defense Conference – PDC 2021
26-30 April 2021, Vienna, Austria

IAA-PDC-21-0X-XX

NEA CHARACTERISTICS BASED ON THE RESULTS OF ASTROMETRIC AND PHOTOMETRIC OBSERVATIONS WITH THE SBG TELESCOPE AT THE KOUROVKA ASTRONOMICAL OBSERVATORY

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Keywords: *NEOs, photometry, color index, rotation period, improved orbit*

1. Introduction

The research programme of the Kourovka Astronomical Observatory of the Ural Federal University (AO UrFU) includes the observations of the small Solar System bodies traditionally. The astrometric and photometric observations of the near-Earth objects (NEO) is a part of this programme.

The paper outline follows. We describe the telescopes and detectors, discuss the astrometric and photometric observations accuracy and describe the software for observations processing, orbit improving, and orbital evolution modeling in Section 2. The results of the astrometric and photometric observations are presented in Section 3. We formulate the research topics on the future in Section 4.

2. Methods

The SBG telescope (see Figure 1) of AO UrFU is the four-axis telescope with a 0.8 m focal length is equipped with a Schmidt optical system and a 0.4m diameter primary mirror.

The telescope was upgraded in 2005–2006 years (Glamazda 2012a). An Alta U32 CCD camera with a KAF-3200ME-1 CCD matrix containing 2184 x 1472 elements, each of size 6.8 x 6.8 μm is mounted at the main telescope focus. The scale of the

CCD image is 1.8 arcsec/pixel. The field of view of the system is 65' x 44'. Limiting magnitude is 19 mag. Observations with filters of the wideband UBVRI system are available. The precision timing system uses a 12-channel GPS receiver Acutime 2000 GPS Smart Antenna.

Figure 1. The SBG telescope of the Kourovka Astronomical Observatory of the Ural Federal University

Astrometric observations of asteroids have been made with the filter R. The accuracy of astrometric observations is analyzed in (Kaiser and Wiebe, 2017) and (Kuznetsov et al., 2017). The astrometry root-mean-square (RMS) residuals (O–C) for equatorial coordinates consist of 0.01''–0.3'' for bright objects when the magnitude is less than 18.5 mag and 0.5''–0.7'' for faint objects with magnitude from 18.5 to 19 mag.

The RMS residuals (O–C) for equatorial coordinates is increased for the NEO and potentially hazardous asteroids (PHA) (see Figures 2–7). In case of the angular velocity of NEO is less than 0.5''/min, the astrometry RMS residuals (O–C) comprised of 0.1''–0.5'' for bright NEO when the magnitude is less than 16.5 mag, and 0.9''–1.0'' for faint objects with magnitude from 16.5 to 18 mag. The astrometry RMS residuals (O–C) consist of 0.5''–0.6'' for NEO with magnitude from 9.5 to 11.5 mag and angular velocity from 20'' to 40'' per minute. The comparison with the Minor Planet Center data shows that residual differences (O–C) are less than 1'' for more than 95% observations which carried out at the SBG telescope.

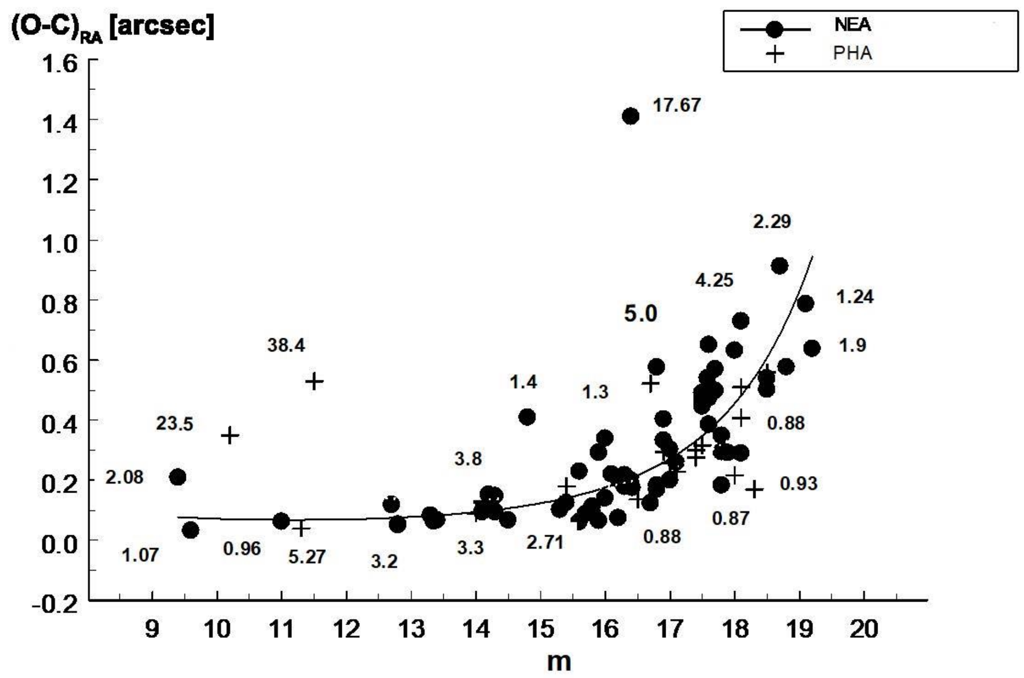

Figure 2. The RMS residuals (O–C)RA versus the magnitude for NEA and PHA. Additional labels are the angular velocities of NEO in arcsec/min.

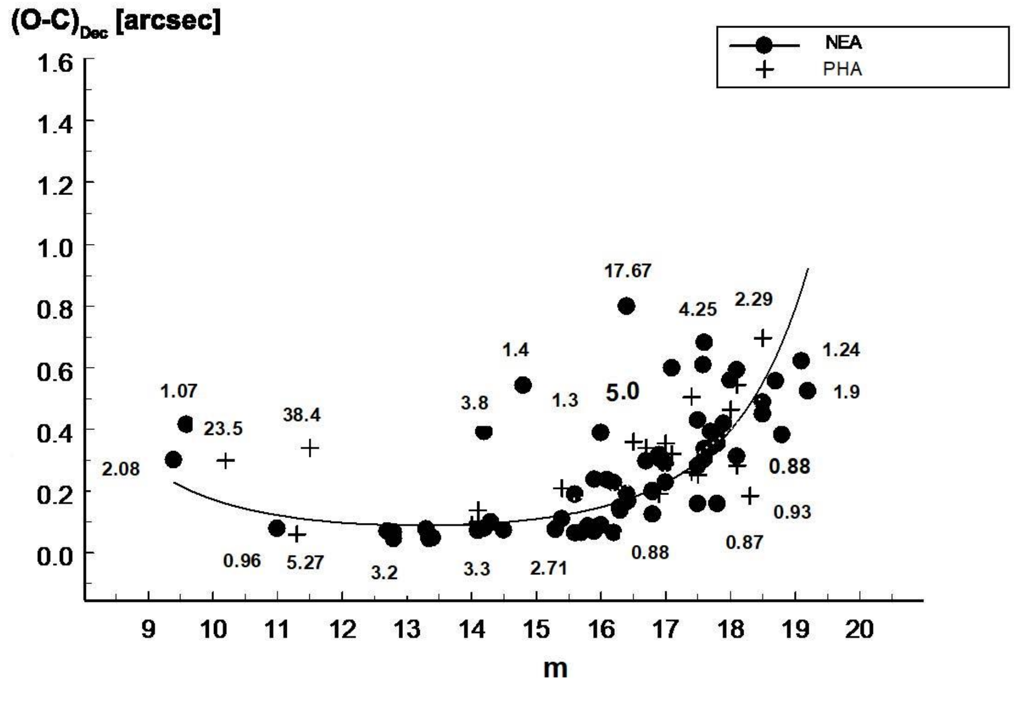

Figure 3. The RMS residuals (O–C)Dec versus the magnitude for NEA and PHA. Additional labels are the angular velocities of NEO in arcsec/min.

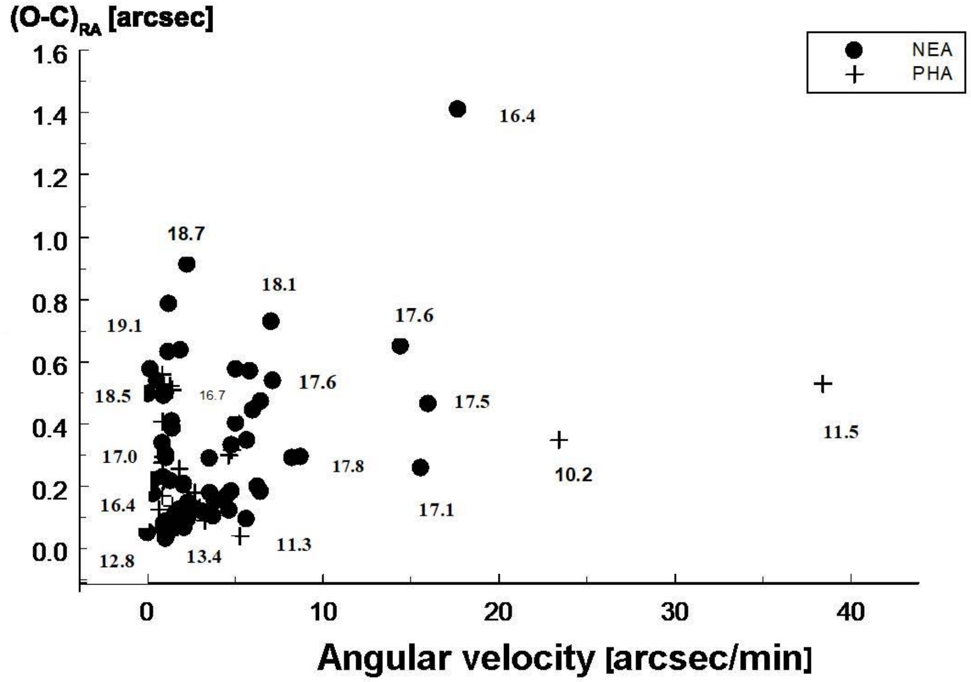

Figure 4. The RMS residuals (O–C)RA versus the angular velocities for NEA and PHA. Additional labels are the magnitudes.

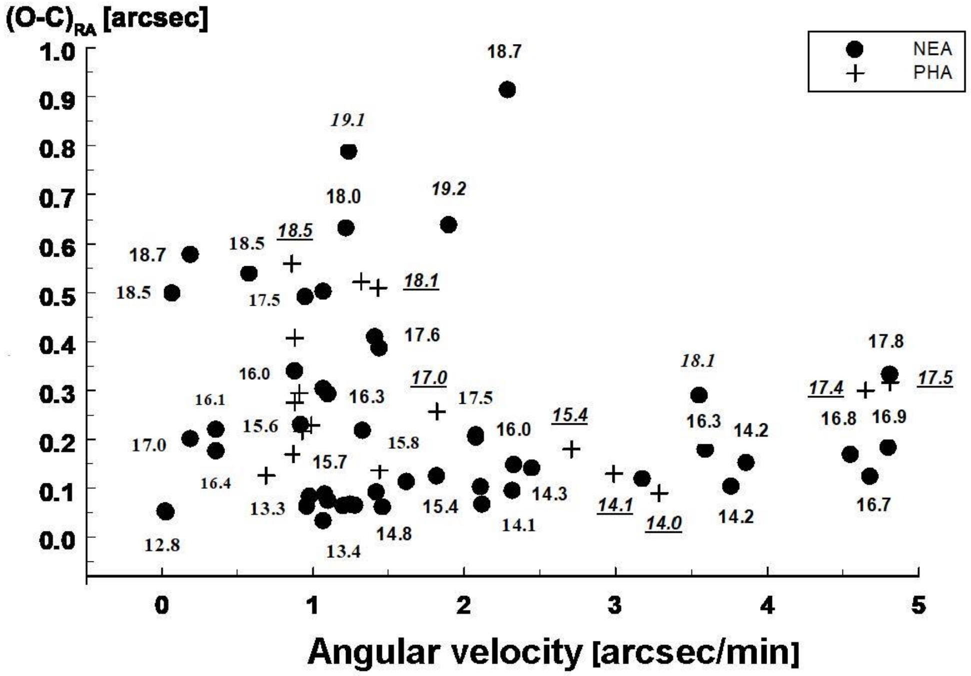

Figure 5. The RMS residuals (O–C)RA versus the angular velocities for NEA and PHA. Additional labels are the magnitudes.

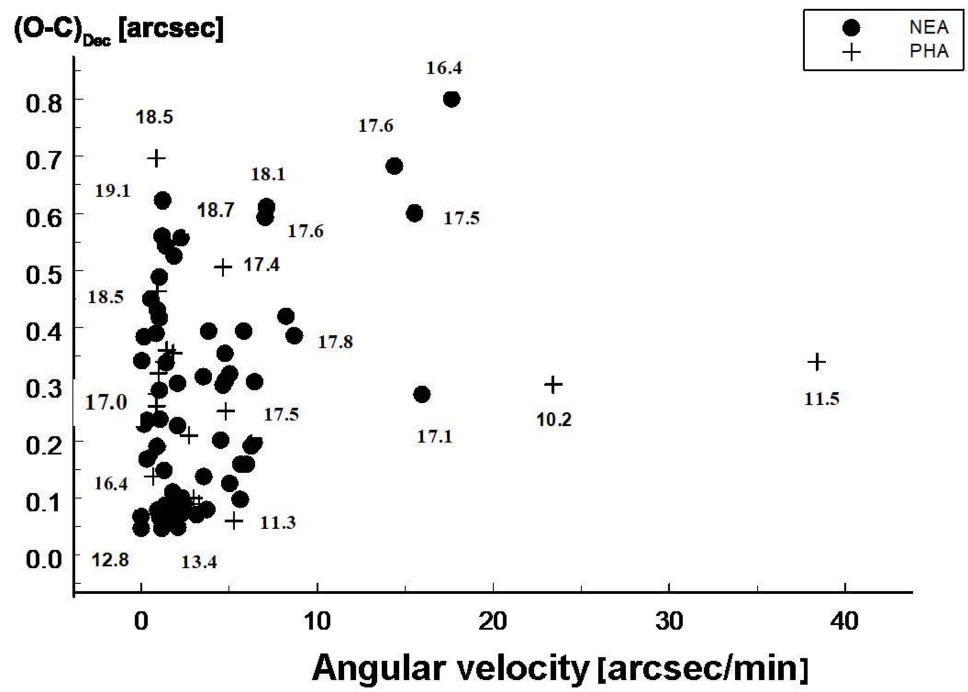

Figure 6. The RMS residuals $(O–C)_{Dec}$ versus the angular velocities for NEA and PHA. Additional labels are the magnitudes.

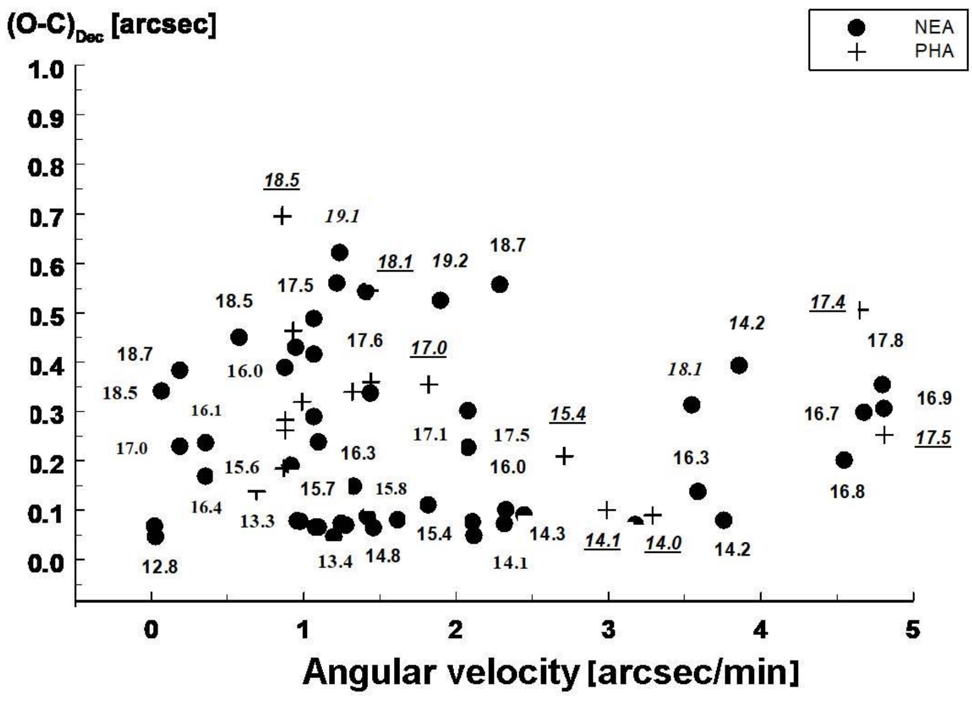

Figure 7. The RMS residuals $(O–C)_{Dec}$ versus the angular velocities for NEA and PHA. Additional labels are the magnitudes.

Photometric observations of asteroids have been made with the filters B, V and R. Photometry RMS errors consist of 0.05 mag for bright objects when the magnitude is less than 16.5 mag, and 0.07–0.15 mag for faint objects with the magnitudes from 16.5 to 18 mag.

The SBG telescope and the CCD system are operated by the SBGControl software (Glamazda, 2012b) developed at AO UrFU. Astrometric processing of the observations has been made using IzmCCD (Izmailov, 2010) and AM:PM (Krushinsky, 2017) software packages. We used the IDA (Bykova et al., 2012) software package to improve the orbital elements of the asteroids.

3. Results

From 2007 to 2020 we have observed 338 near-Earth asteroids with magnitudes from 9.5 to 19 mag:

- 157 Apollo asteroids including 74 PHA,
- 144 Amor asteroids with 13 PHA,
- 35 Aton asteroids including 12 PHA,
- two Atira asteroids – (163693) Atira and (367943) Duende.

We have got improved elements of the NEA’s orbits and evaluated the axial rotation periods and color indices. Table 1 gives estimates of the periods of axial rotation and color indices obtained from the photometric observations. The values from the ALCDEF (http://alcdef.org/) are also given. As an example, Figure 8 shows the phase light curve of the NEA (2061) Anza (six nights, R filter).

Table 1. Periods P and color indices V-R of the NEA

NEA	P [hour]	P [hour] (http://alcdef.org/)	V–R [mag]	V–R [mag] (http://alcdef.org/)
(2061) Anza	11.62 ± 0.31	6.7121 ± 0.0041 or 11.4607 ± 0.0005	—	—
(2102) Tantalus	2.5 ± 1.2	2.3839 ± 0.0010	0.46 ± 0.10	—
(3200) Phaethon	3.6250 ± 0.0007	3.5971 ± 0.0019	0.35 ± 0.14	0.33 ± 0.01
(52768) 1998 OR2	4.11 ± 0.11	4.1100 ± 0.0036	0.38 ± 0.06	—
(65690) 1991 DG	7.10 ± 0.98	7.1112 ± 0.0007	0.35 ± 0.14	0.40 ± 0.01
(68216) 2001 CV26	2.235 ± 0.088	2.4290	—	—
(152931) 2000 EA107	4.03 ± 0.29	4.1366 ± 0.0002	—	—
(153201) 2000 WO107	5.64 ± 0.14	5.64 ± 0.14	—	—
(155140) 2005 UD	—	—	0.38 ± 0.05	0.35 ± 0.02
(163373) 2002 PZ39	—	—	0.43 ± 0.14	—
(388945) 2008 TZ3	—	—	0.41 ± 0.10	0.39 ± 0.02
(523788) 2015 FP118	3.07 ± 0.72	3.0917 ± 0.0007	—	—

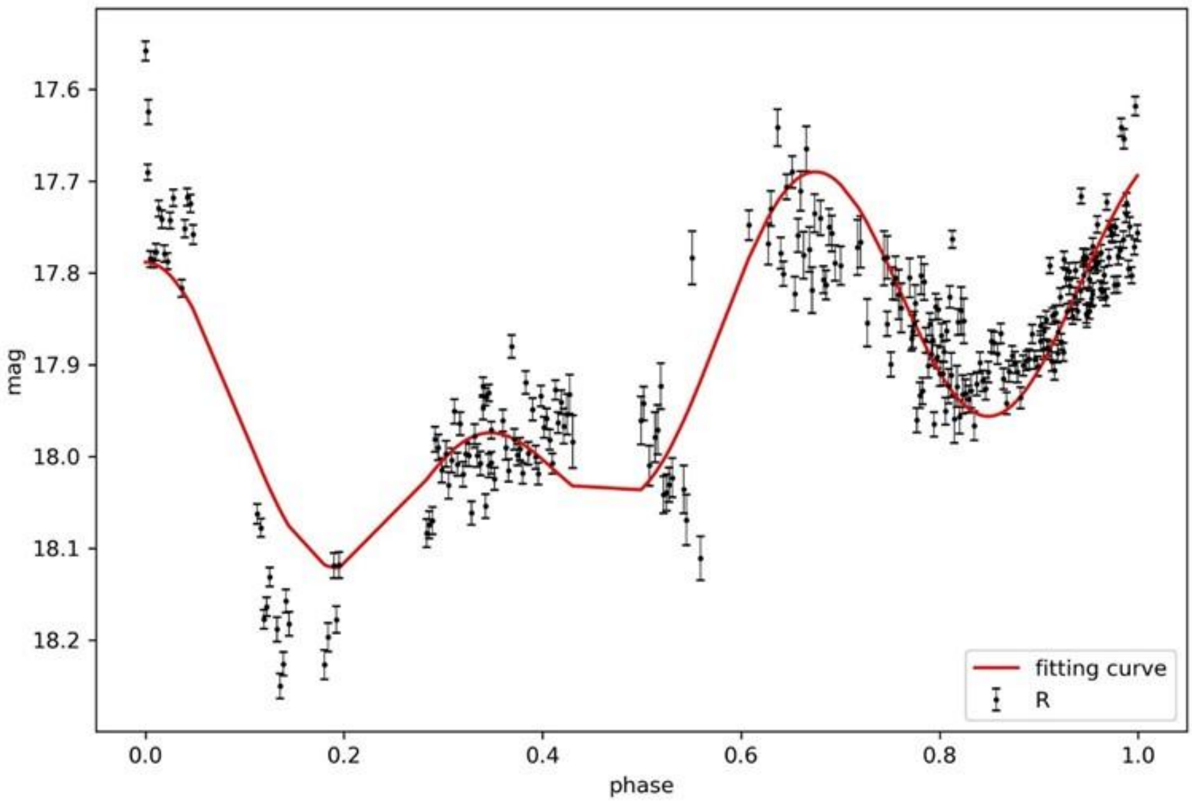

Figure 8. Phase light curve of the NEA (2061) Anza (six nights, R filter)

4. Discussion and Conclusions

Intense positional and photometrical observations of NEAs are needed to improve the accuracy of NEAs ephemeris. It is necessary to take into account the influence of the Yarkovsky effect. In the future, we plan to refine the values of the A_2 parameter and the semimajor axis drift rates due to the Yarkovsky effect based on astrometric observations. Determining the position of the NEA's axis of rotation based on photometric observations will make it possible to correctly take into account the influence of the Yarkovsky effect.

Acknowledgements
This work was supported by the Russian Ministry of Science and High Education, FEUZ-2020-0030.

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