NEO OBSERVATIONS AT THE SBG TELESCOPE OF THE KOUROVKA ASTRONOMICAL OBSERVATORY

E. Kuznetsov, D. Glamazda, G. Kaiser, and Yu. Vibe

Ural Federal University, School of Natural Sciences and Mathematics, Kourovka Astronomical Observatory, 620000 Yekaterinburg, Russia, Email: eduard.kuznetsov@urfu.ru

ABSTRACT

At the SBG telescope of the Kourovka Astronomical Observatory of the Ural Federal University is carried out the astrometric and photometric observations of the near-Earth objects. The accuracy of the astrometric observations is from $0.5''$ to $1.0''$ for the near-Earth objects. The photometric observations have the accuracy from 0.05 to 0.15 mag. The software for observations processing, orbit improving, and orbital evolution modeling are described. The results of the astrometric and photometric observations for the near-Earth objects are presented. The research topics on the future are given.

Keywords: astrometric observations; photometric observations; near-Earth objects; potentially hazardous asteroids.

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 in Section 2. We discuss the astrometric and photometric observations accuracy in Section 3. We describe the software for observations processing, orbit improving, and orbital evolution modeling in Section 4. The results of the astrometric and photometric observations are presented in Section 5. We formulate the research topics on the future in Section 6.

2. SBG TELESCOPE

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 0.4 m diameter primary mirror.

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

The telescope was upgraded in 2005–2006 years [2]. An Alta U32 CCD camera with a KAF-3200ME-1 CCD matrix containing 2184×1472 elements, each of size 6.8×6.8 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 $65' \times 44'$. 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.

3. OBSERVATIONS

Astrometric and photometric observations of asteroids have been made with the filter R.

The accuracy of astrometric observations is analyzed in papers [5] and [7]. 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.

Proc. 1st NEO and Debris Detection Conference, Darmstadt, Germany, 22-24 January 2019, published by the ESA Space Safety Programme Office
Ed. T. Flohrer, R. Jehn, F. Schmitz (http://neo-sst-conference.sdo.esoc.esa.int, January 2019)

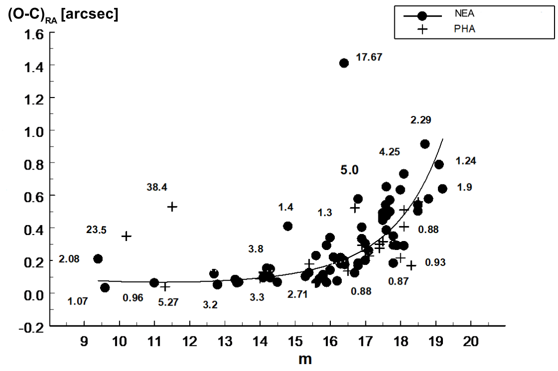

Figure 2. The RMS residuals (O-C)$_\alpha$ versus the magnitude for NEA and PHA. Additional labels are the angular velocities of NEO in arcsec/min.

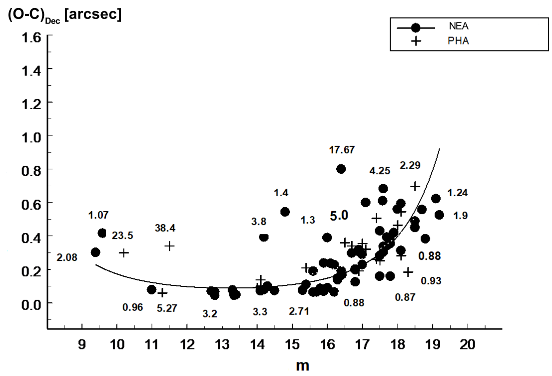

Figure 3. The RMS residuals (O-C)$_\delta$ versus the magnitude for NEA and PHA. Additional labels are the angular velocities of NEO in arcsec/min.

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.

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.

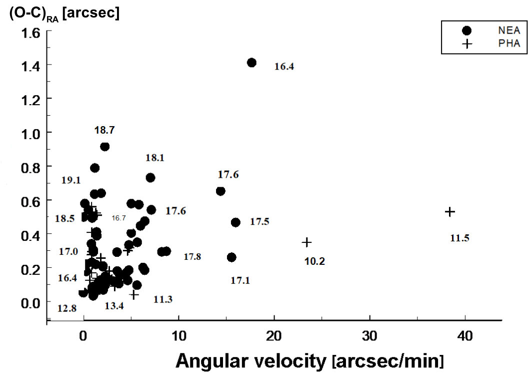

Figure 4. The RMS residuals (O-C)$_\alpha$ versus the angular velocities for NEA and PHA. Additional labels are the magnitudes.

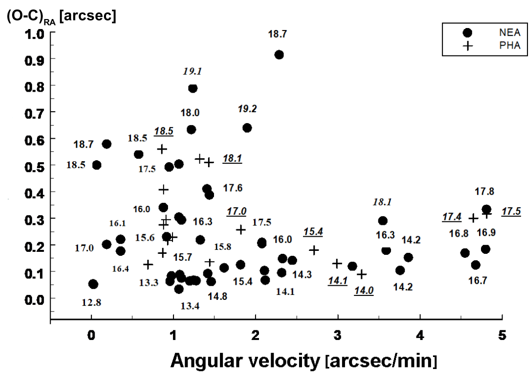

Figure 5. The RMS residuals (O-C)$_\alpha$ versus the angular velocities for NEA and PHA. Additional labels are the magnitudes.

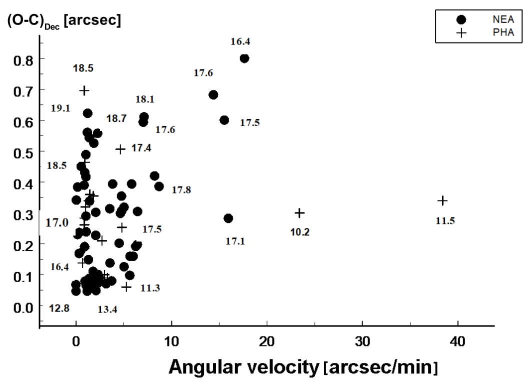

Figure 6. The RMS residuals (O-C)$_\delta$ versus the angular velocities for NEA and PHA. Additional labels are the magnitudes.

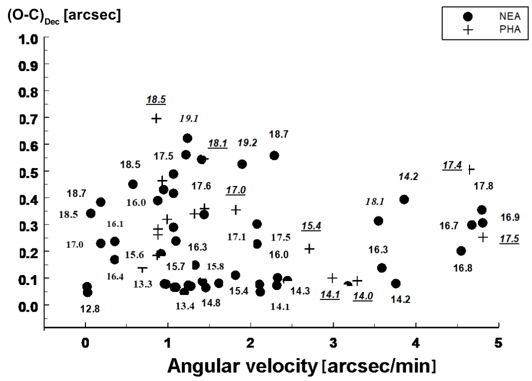

Figure 7. The RMS residuals (O-C)$_\delta$ versus the angular velocities for NEA and PHA. Additional labels are the magnitudes.

4. SOFTWARE

The SBG telescope and the CCD system are operated by the SBGControl software [3] developed at AO UrFU.

Astrometric processing of the observations has been made using IzmCCD [4] and AM:PM [6] Software Packages.

We used the IDA [1] Software Package to improve the orbital elements of the asteroids.

We consider the observations of NEA as support of the theoretical study of the dynamical evolution based on numerical simulation. We have researched the dynamical evolution of 121 asteroids with Lidov–Kozai effect. The code known as Orbit9 (OrbFit Software Package [8]) has been used to research the dynamical evolution of asteroids. Initial orbital elements of the asteroids were chosen from AstDyS[1] database. Initial orbital elements of planets were chosen from numerical ephemeris DE431. Equations of motion for asteroids, eight major planets and dwarf planet Pluto were integrated simultaneously. The effects of relativity, the Sun oblateness, and the Yarkovsky effect have considered.

5. RESULTS

From 2007 to 2018 we have observed 327 near-Earth asteroids with magnitudes from 9.5 to 19 mag. It consists of 149 Apollo asteroids including 74 potentially hazardous asteroids, 142 Amor asteroids with 13 PHA, 34 Aton asteroids including 12 PHA, as well two Atira asteroids — (163693) Atira and (367943) Duende.

[1] http://hamilton.dm.unipi.it/astdys/index.php?pc=0

6. DISCUSSION AND CONCLUSIONS

The Yarkovsky effect does not lead to quality changes of the evolution for most asteroids which have the dynamical evolution with the Lidov–Kozai effect. The Yarkovsky effect has considerable the orbital evolution effect for the near-Earth asteroids and the asteroids with the Lidov–Kozai effect. The dynamical evolution of NEA 2010 CU19 without the Yarkovsky effect has a change of the libration mode of the argument of perihelium. The libration relatively to the value of the argument of perihelium 270 degrees changes to the libration with respect to 90 degrees after 65 kyr. The libration relatively to the value of the argument of perihelium 270 degrees is preserved over 90 kyr when the rate of the semimajor axis drift is equal to 0.001 au/Myr due to the Yarkovsky effect.

Orbit evolution modeling of paired asteroids provides information about the dynamics of the objects at the moments of close encounters, an age of pairs, and, perhaps, the mechanisms of their formation: collision disruption, YORP-fission, binary or multiple breakups, incidental approach, etc. Accurate evaluation of past approach conditions between asteroids sharing close orbits requires precise initial conditions as additional awareness of their sizes, shapes, spin axes obliquity, surface thermal properties, etc. Intense positional and photometrical observations of asteroid pairs are needed for this task. Such observations could be implemented in Kourovka Astronomical Observatory of the Ural Federal University. We are planning to improve the estimations of the asteroid pairs ages using the evaluations of the semimajor axis drift rates due to the Yarkovsky effect.

ACKNOWLEDGMENTS

The reported study was funded by RFBR according to the research project no. 18-02-00015.

REFERENCES

1. Bykova L. E., Galushina T. Y., Baturin A. P., (2012). The application suite IDA for investigation of dynamics of asteroids, *Izvestiya Vysshikh Uchebnykh Zavedenij. Fizika*, **55**, 89–96
2. Glamazda D., (2012a). SBG camera of Kourovka Astronomical observatory, *Astrophys. Bulletin*, **67**(2), 230–236
3. Glamazda D., (2012b). Principal algorithms for the control of Kourovka Observatory SBG camera, *Astrophys. Bulletin*, **67**(2), 237–244
4. Izmailov I. S., Khovricheva M. L., Khovrichev M. Y., et al., (2010). Astrometric CCD observations of visual double stars at the Pulkovo Observatory, *Astronomy Letters*, **36**, 349–354.

5. Kaiser G., Wiebe Yu., (2017). Positional observations of small solar system bodies with the SBG telescope at the Astronomical Observatory of the Ural Federal University, *Solar System Research*, **51**(3), 233–244

6. Krushinsky V. V., (2017). AM:PM, automatic astrometry and photometry of asteroids. *Physics of Space: Proceedings of the 47*$^{\mathrm{th}}$ *Student Scientific Conference*, Ural University Press, 205–206 (In Russian)

7. Kuznetsov E., Glamazda D., Kaiser G., Wiebe Yu., (2017). Alerting observations of asteroids at the SBG telescope of the Kourovka Astronomical Observatory in the Gaia-FUN-SSO Network, *Astronomy and Astrophysics in the Gaia sky. Proceedings IAU Symposium No. 330*, Cambridge University Press, 403–404

8. OrbFit Consortium. OrbFit: Software to Determine Orbits of Asteroids, (2011). *Astrophysics Source Code Library*, arXiv:1106.015.