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ACCURACY OF MYKOLAIV ASTEROID OBSERVATIONS WITH DIFFERENT REFERENCE CATALOGUES

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ABSTRACT. The results of astrometric reductions of main belt asteroid observations with usage of 3 different reference catalogues are presented. The high precision catalogs CMC15, UCAC4 and GAIA DR1 were used as reference catalogues for calculation asteroid equatorial coordinates. The asteroid observations were carried out at KT-50 telescope of the RI "MAO" Mobitel complex during 2016. The array contains 1666.positions of 68 asteroids mainly in range of (11 – 15) magnitudes. The differences (O – C) were calculated by comparing the obtained topocentric positions with the HORIZONS ephemerides of the JPL laboratory. The mean square errors of the (O – C) values were used for comparison of the different reductions model. The influence of the choice of the reference catalog on the random and systematic asteroid position errors is shown.

Keywords: CCD observations, reference catalogs, main belt asteroids, topocentric positions, ephemerids.

1. Reference Catalogs for Asteroid Astrometric Reductions

For a now the main source of asteroid positional data is the Minor Planet Center (MPC) database [http://www.minorplanetcenter.net/iau/mpc.html]. The database contains almost all available observations of asteroids beginning from 1896. The format of the records of modern observations includes information about of the reference catalog that was used to obtain the positions of the asteroids. Unfortunately, despite the recommendations of the MPC to use UCAC4 catalog [Zacharias et al., 2013] as the reference catalog, the number of used reference catalogs is increasing even for modern CCD observations. Although most of these catalogs nominally reproduce the ICRS system, the existing systematic differences between affect the uniformity of the data obtained by combining long-term observations to investigate slowly evolving effects. The previous study of the influence of the reference catalog on the accuracy of long –term time asteroid positional data showed that the errors of individual observatories exceed errors caused by the use of different reference catalogs [Maigurova rt al., 2017].The main goal of the presented work was to compare the results of the uniformly made astrometric reductions with 3 different high-precision reference catalogs: UCAC4, CMC15 [http://svo2.cab.inta-csic.es/vocats/cmc15/], GAIA DR1 [Gaia collaboration, 2016].

2. Asteroid Observations and Reductions

The array of main belt asteroid CCD observations obtained on the telescope KT-50 of the Mobitel complex RI "MAO" during 2016 was used to perform uniform astrometric reductions in 3 different reference catalogs. Mobitel complex was operated for observations since 2011. The telescope KT-50 (F = 3000mm, D = 500mm) is equipped with Alta U9000 camera (3Kx3K, 12x12mkm, 42.5'x42.5' FOV, 0.83"/pixel) in photometric band OG-14 (near standard R_c band). The detailed description of the complex is given in [Shulga et al., 2012]. The processing of the received observations was carried out by the package "Astrometrica" version 4.10.0.431 [http://www.astrometrica.at] with usage spherically symmetric Gaussian function as the PSF function, the fourth-degree polynomial as a model for linkage between measured and tangential coordinates and the usage of UCAC4 catalog as the reference one. 1666 positions of 68 asteroids were received during 2016 in UCAC4 catalog system, that sent to the MPC database. This array was reprocessed with usage the CMC15 and GAIA DR1 catalogs as reference one. The distribution of the obtained observations over the celestial sphere is shown in Fig. 1.

Uneven distribution is explained the fact that due to weather conditions and technical reasons, observations were only made during the period from April to October. Observations of each object were performed by series. The number of frames in the series was from 5 to 15. The histogram of the distribution of objects on the stellar magnitude is shown in Fig. 2. As can be seen from the histogram, the main part of the observed asteroids were objects in the range of (14 -16) magnitude.

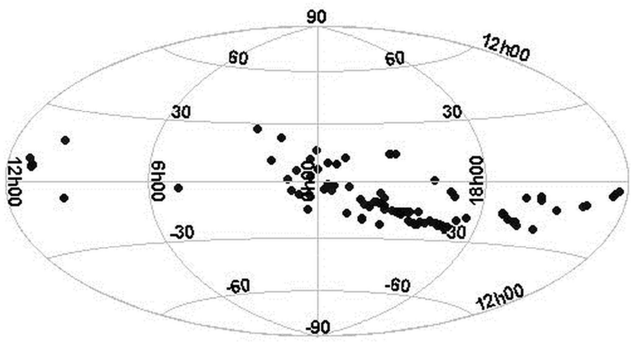

Figure 1: Distribution over the celestial sphere

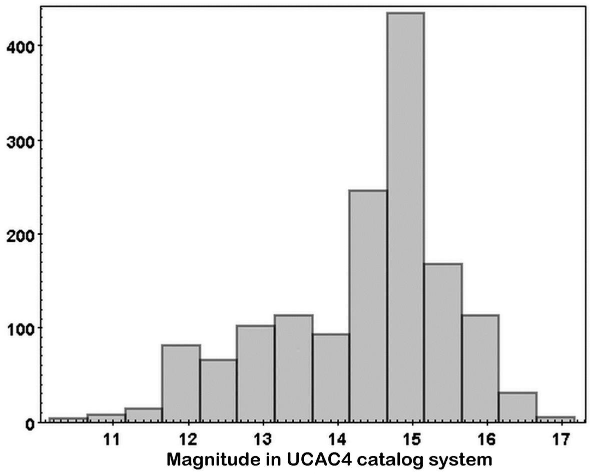

Figure 2: Histogram of the asteroids distribution on the stellar magnitude.

3. Accuracy Analysis

3.1. HORIZONS Ephemeris Comparison

The duration of a series of frames of one object usually didn't exceed 30 minutes, so the positions of the object in a series of frames were calculated with fixed set of reference stars on a small arc of the orbit. These circumstances make it possible to use the mean square error (MSE) of the residual differences (O-C), where (O) is the position obtained from the observations, (C) – the ephemeris position at the time of observation, as an estimate of the intrinsic precision of our measured positions. The online service HORIZONS of the NASA JPL laboratory [https://ssd.jpl.nasa.gov/?horizons] was used to obtain the ephemeris value (C).

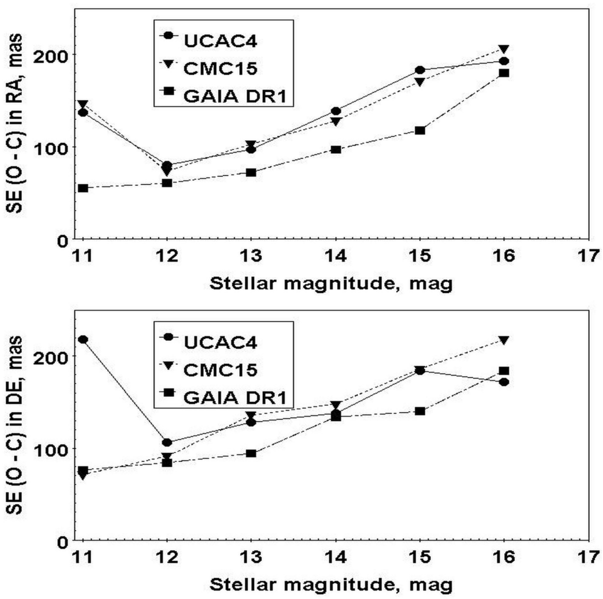

Figure 3: MSE on right ascension (up) and on declination (down) versus asteroid apparent magnitude

Fig. 3 shows the relation of the averaged MSE on the right ascension (up) and the declination (down) as a function of the asteroid stellar magnitude in the instrumental band for 3 different reference catalogs. As can be seen from the figure, in addition to the dependence on the stellar magnitude, there is a dependence on the reference catalog.

The results of comparing the residual differences (O-C) for individual asteroids with 3 reference catalogs are shown in Figure 4. Only asteroids with a number of observations more than 15 times were selected for the figure 4. The obtained results showed that the use of the GAIA DR1 catalog as a reference one in calculating topocentric positions reduces both random and systematic errors.

The mean values of residual (O-C) differences and their MSE obtained with usage different reference catalogs, when performing astrometric reductions, are shown in Table 1.

Table 1: The mean values of residual (O-C) differences and their MSE

Catalog	$(O\text{-}C)_{RA}$	CKO	$(O\text{-}C)_{DE}$	CKO
UCAC4	0.04	0.14	0.03	0.15
CMC15	0.02	0.13	0.13	0.14
GAIA DR1	0.02	0.10	0.05	0.13

The table data also show that the positions calculated with the reference catalogs UCAC4 and CMC15 have practically the same internal precision, but there is a significant difference from zero in values (O – C) in declination with reference catalog CMC15, that probably due to the lack of proper motions in the catalog. The position accuracy with the UCAC4 catalog is somewhat worse due to decreasing accuracy of the reference stars weaker than 15^{mag} in the UCAC4 catalog. As can be seen from the Table 1, the use of the GAIA DR1 as reference catalog allows improving the precision of the obtained positions by 15-20% compared with the use of UCAC4 and CMC15 catalogs. It should be noted, that UCAC4 is the MPC recommended catalog.

3.2. External Accuracy

In this paper, the results of performing of the astrometric reductions of the observational array of the main belt asteroids obtained at KT-50 Mobitel complex in 2016 are presented. As already noted above, all asteroid positions with UCAC4 catalog were sent to the MPC database. To estimate the external accuracy of our observations and compare them with the data of other observatories, we used the MPC statistics results for all observatories over 2011-2017 [http://www.minorplanetcenter.net/iau/special/residuals.txt]. Total 967 observatories were sent asteroid observations during this period. Only 486 of them had sent to MPC more than 100 asteroid positions during year. The Figure 4 shows the histogram of distribution of total MSE of the mean annual residual differences (O-C) for these observatories. It should be noted that value for RI "MAO" observations (Code MPC 089) is 0.35″ (0.23″ in right ascension and 0.26″ in declination).

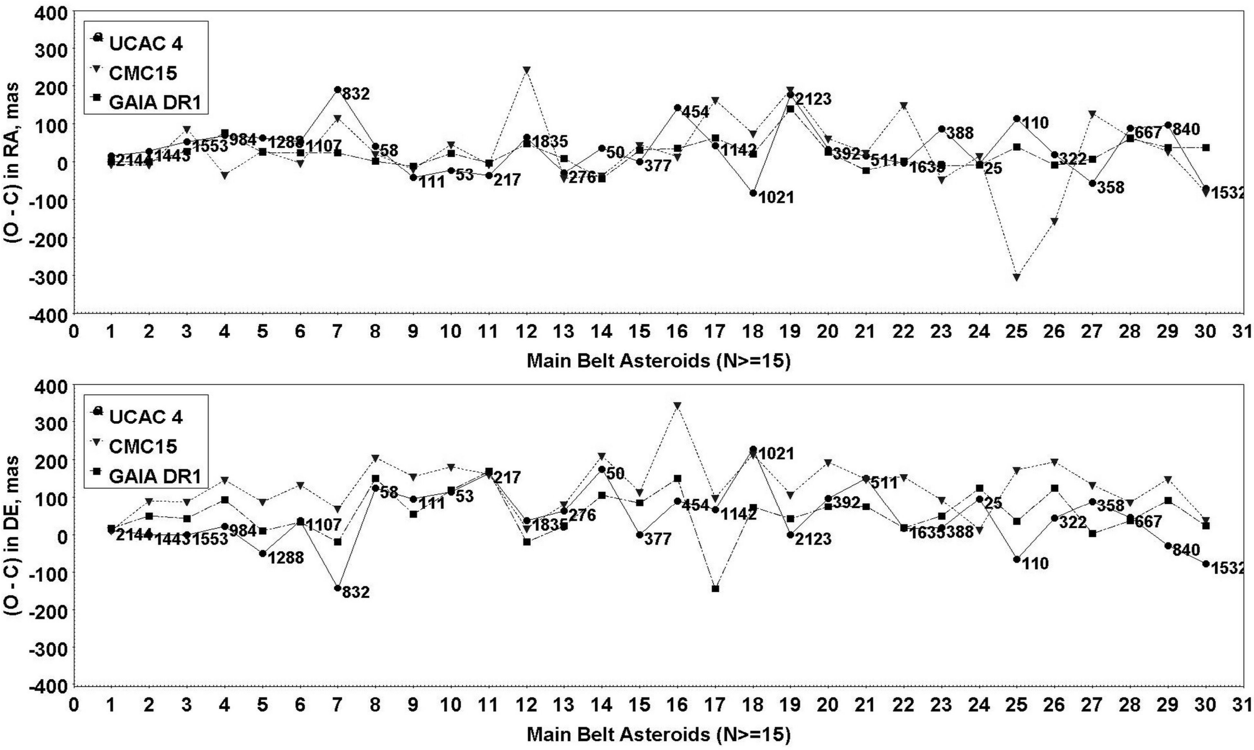

Figure 4: Residual differences (O – C) in right ascension (up) and declination (down) for asteroids with N>=15, calculated with different reference catalogs.

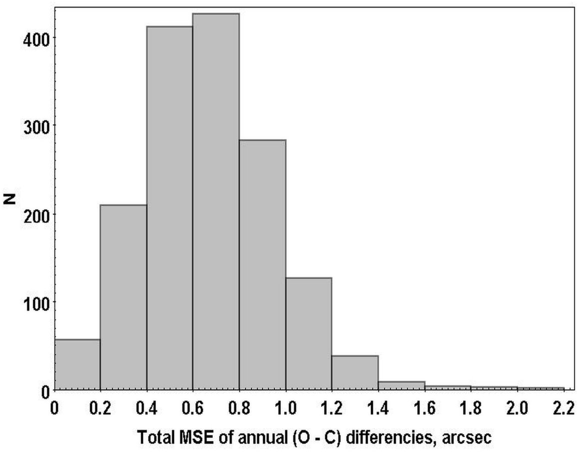

Figure 5: Distribution of total MSE of the mean annual residual differences (O – C) for the observatories with number of observations more than 100

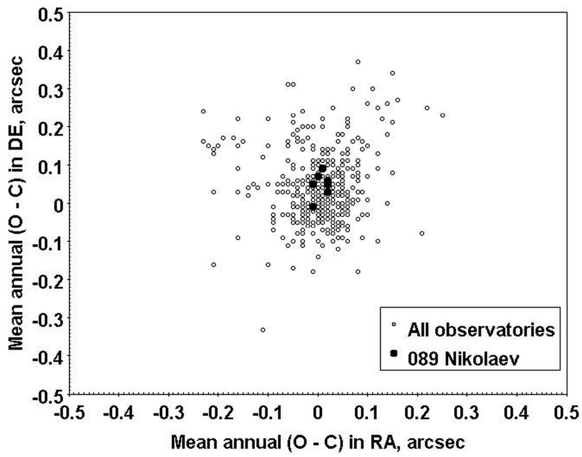

Figure 6: Mutual distribution of the mean annual (O – C) differences

The mutual distribution of the mean annual residual differences is shown in Fig. 5. Only 190 observatories with total MSE better than 0.5″ are presented in the figure. For these observatories, the mean values of the annual residual differences (O – C) are (-0.00 ± 0.08)″ and (0.04 ± 0.09)″. It can be seen from the Fig. 5 that (O – C) value in declination slightly differs from zero as for our data.

4. Conclusion

Topocentric equatorial coordinates referred to 3 modern astrometric catalogs were obtained for the array of asteroid observations at RI"MAO" during 2016. Results of astrometric reductions are shown that the use of the GAIA–DR1 catalog as reference one leads to a significant improvement in the position accuracy both for the random and for the systematic component. The positions obtained with the catalogs UCAC4 and CMC15 have practically the same accuracy in a random ratio, but in the system (O-C) in declination with usage CMC15 reference catalog, a significant non-zero difference have found.

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