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ASTROMETRICAL OBSERVATIONS OF THE SELECTED WDS STARS

The results of binary observations at RI «MAO» in 2013–2016 are presented. Astrometric reduction of frames to the equatorial coordinates of components of binary and multiple systems at the time of observation has been done. The combination of the CCD received data with other Strasbourg base catalogs has enabled to determine new proper motions of stars observed. Parameters of mutual component configuration (position angle and separation) have been measured for 214 double stars. Analysis of measurement results has been carried out. The measurement results have been added to the WDS database.

Keywords: CCD observations, astronomical databases, visual binaries, and proper motions.

Astrometric observations of visual binary stars (visual binaries) are the main source of information about the positions. Based on these observations equatorial coordinates, brightness estimate, mutual angular distance, and position angle of relative orientation of binary system components are obtained. These data as they arrive are used to build a visible orbit arc of the fainter companion with respect to the brighter primary. If the observations last for a long time (decades or longer), it is possible to trace a complete revolution of the companion around the primary. The visual binaries are quite bright objects, as for 90% of known stars the apparent magnitude of the primary is up to 15^m while that of the companion reaches 17^m. The angular distance between the components for 60% of the systems exceeds 4", which makes possible to observe them using small ground-based telescopes. Currently, there are several catalogs of double and multiple systems. The most complete one is the Washington Double Star Catalog (WDS) [1]. This catalog of binary stars is currently maintained by U.S. Naval Observatory (USNO). The catalog contains positions, magnitudes, proper motions, and spectral classes of 138,234 pairs of double and multiple stars (as of September 2016). The catalog includes information on both the binary and multiple star systems. For each component of such systems there is a separate record in the catalog.

TDSC (Tycho Double Star Catalogue) [2] is based on combination of Hipparcos observations and WDS catalog. It contains 103,259 records with information on 66 219 components of 32 631 double and multiple systems.

CCDM (Catalog of Components of Double and Multiple Stars) [3] includes 105,838 records for 49,325 binary and multiple star systems with information about coordinates, magnitudes, spectral class, and proper motions of each component. It should be noted that despite the fact that the above mentioned catalogs contain tens or even hundreds thousands of objects, ORB6 (Sixth Catalog of Orbits of Visual Binary Stars) [4] that comprises systems for which orbital elements have been obtained numbers only 2558 systems (as of April 2016).

OBSERVATIONS

The regular observations of binary and multiple stars at RI «MAO» have been carried out since 2013. Two telescopes equipped with CCD

camera are used for the observations. This research deals with processing of observation data received in 2013—2016. In 2013—2014, the observations were made using *Mobitel* KT-50 and AMC (axial meridian circle) telescopes. After a failure of AMC's camera, the observations are made on KT-50 telescope only. In the future, after replacement of the camera the binary star observations are expected to be resumed on AMC. The telescope parameters are given in Table below.

The observation program was based on WDS catalog with options provided by the telescopes taken into account, using the following criteria for the object selection:

- Declination — more than −20°;
- Magnitude of each component — up to 17^m for KT-50 observations, 14.5^m — for AMC observations;
- Angle distance between the components — over 4—6" that for our images corresponds to 2—3 FWHM (Full Width at Half Maximum). Exposure at equator is 102 s for AMC and 85 s for KT-50 telescope, which provides a field of view of 25.6' × 22.9' and 21.2' × 42.5', respectively.

RESULTS OF MEASUREMENTS

The obtained observations are processed in two stages.

Firstly, standard astrometric reductions are made using *Astrometrica* [5]. As a result, array of positions of all stars covered by the frame field of view as equatorial coordinates (right ascension and declination) at the time of observation, as well as the orientation of the frame in the equatorial coordinate system used for the next stage of processing have been obtained. The reference catalogs used for he astrometric reductions are UCAC2 and UCAC4.

As a result of the astrometric reductions of CCD frames a catalog of positions and proper motions of all the objects in the frame field of view together with program star has been obtained. To identify all WDS catalog objects that could be located in the frame of view, a cross-identification of obtained catalog arrays with WDS catalog is carried out using TOPCAT (Tool for Operations on Catalogues And Tables) software. Totally, 1038 binary and multiple stars from WDS catalog have been found, with 98 of them obtained by the AMC telescope.

Diagram of distribution of component magnitudes (Fig. 1) shows that the KT-50 observations enable measurements of the binary systems having a companion magnitude of, at least, 17.5^m. The average number of observations of each star using the AMC telescope is 4, whereas for the KT-50 telescope it amounts to 7.5. The position error of the catalog stars ranges within (20—60) mas for the KT-50 observations of $(10—17.5)^m$ stars and within (50—80) mas for the AMC observations of $(8—13.5)^m$ stars. The extrinsic accuracy of positions resulting from the comparison with other catalogs is estimated as less than 100 mas. The positions of stars from USNOA2.0 catalog were taken as the first epoch of positions for calculating new proper motions of the components. The average difference between the epochs of observations for the Northern hemisphere in this case is about 60 years. This enables to get accuracy of the proper motions of about 5 mas/year.

For individual binaries the proper motions were calculated by solving a system of linear equations by the method of least squares using a lin-

Parameters of RI «MAO» Telescopes

	AMC	KT-50
Type of telescope	Meridian circle	Maxutov telescope
Parameters of optical system	D = 180 mm, F = 2500 mm	D = 500 mm, F = 3000 mm
Camera	S1C	Alta U9000
Matrix	1040 × 1160 pix	3056 × 3056 pix
Pixel	16 μm, square	12 μm, square
Scanning mode	drift scan	
Angle scale	1.32"/pix	0.83"/pix
Filter	V	OC-14

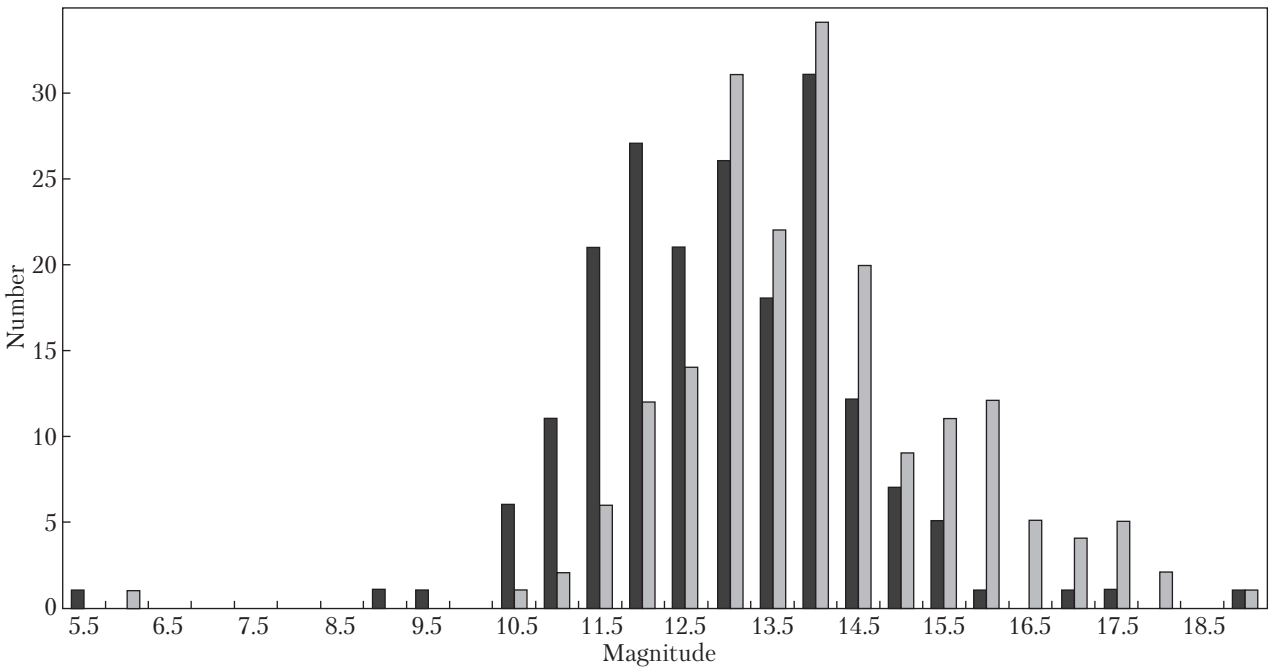

Fig. 1. Magnitude distribution of the primaries (*black*) and the companions (*gray*) of binaries measured

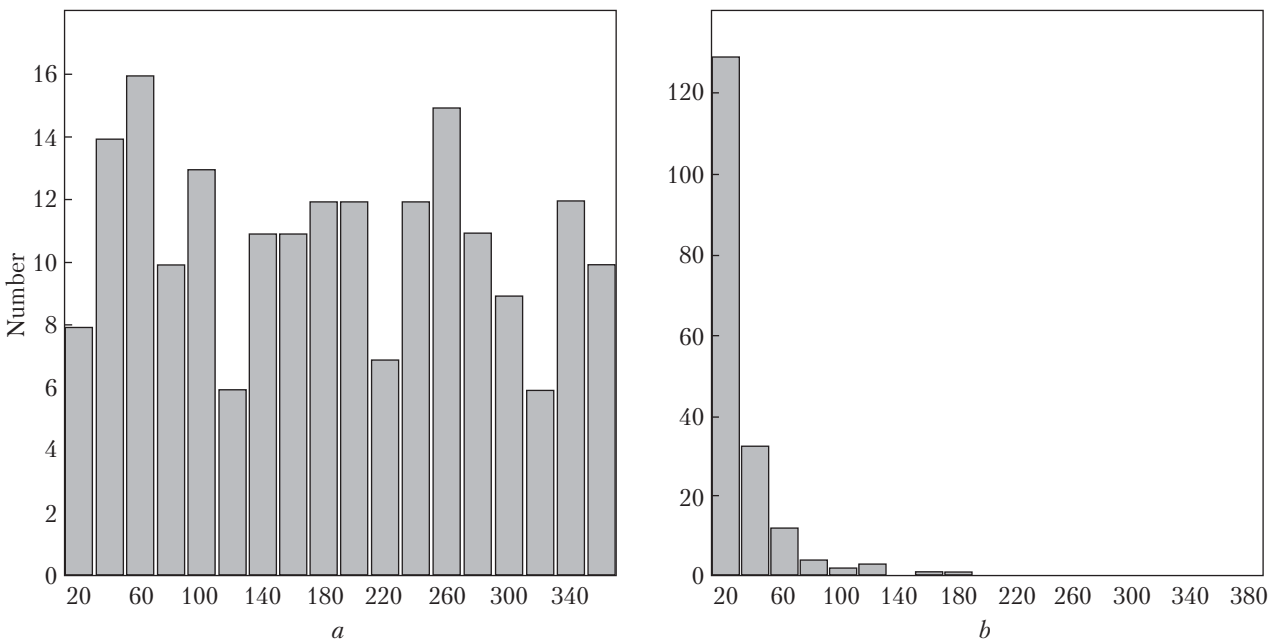

Fig. 2. Diagram of position angle (*a*) and angular distance (*b*) distribution of binaries measured

ear model of star motion. To this end, data from several modern catalogs are used, which enables improving the accuracy of calculations of proper motions up to 2 mas/year. More detailed results of analysis of the proper motions obtained are given in [6].

Secondly, the parameters characterizing the relative position of the components are measured. As AMC matrix deteriorated the companions were missing in many frames or had a very low *signal/noise* ratio. Therefore, only the images obtained by KT-50 telescope were selected for measurements. Totally, about 2,000 frames of 214 binary and multiple systems from WDS catalog have been measured.

The measurements were made using REDUC software [7]. It should be noted that to calculate the position angle and the angular distance REDUC uses the rectangular coordinates of the image center and orientation of measured frame in the equatorial coordinate system instead of equatorial coordinates of measured stars. As a rule, from 5 to 10 frames with a high quality of image are used to measure the selected series of successive observations. The average number of frames in the series of observations for each star was 9. The parameters of mutual configuration for 214 WDS catalog systems have been measured. The resulting array of measurements contains position angle, angular distance between the components and standard deviation (SD), difference in brightness between the components, the observation date, and the number of observations of each object. Fig. 2 shows the distribution of measured systems by position angles and angular distances. The major part of measured systems (84%) has an angular distance ranging from 6 to 40". Analysis of the measurement results has showed that the error of parameters depends on angular distance between the components [8]. As can be seen, the measurement accuracy deteriorates when angular distance is less than 10". The mean standard error of position angle is ±0.2°, that of angular distance is 0.06". The obtained parameters for 194 binary and multiple systems have been included in the WDS database, which accounts for about 20% of all observations available for these 194 stars.

CONCLUSIONS

In 2013—2016, an array of positions for the stars constituting binary and multiple systems was obtained as a result of CCD observations using the telescopes at RI «MAO». For 214 WDS pairs the position angles and angular distances have been measured with a standard error of ±0.2° and 0.06", respectively. The measurement results for 194 binaries have been published in JDSO and added to WDS base.

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АСТРОМЕТРИЧНІ СПОСТЕРЕЖЕННЯ ОБРАНИХ ЗІР КАТАЛОГУ WDS

Наведені результати спостережень подвійних зір, що спостерігалися в НДІ «МАО» протягом 2013—2016 років. Виконана астрометрична редукція отриманих кадрів до отримання екваторіальних координат компонентів подвійних і кратних систем на момент спостереження. Комбінація отриманих ПЗЗ-положень з іншими каталогами Страсбурзької бази дали можливість визначити нові значення власних рухів зірок, що спостерігались. Для 214 подвійних систем були виміряні параметри взаємної конфігурації компонентів (позиційний кут і кутова відстань). Проведено аналіз результатів вимірювань. Результати вимірювань додані в базу каталогу WDS.

Ключові слова: ПЗЗ-спостереження, астрономічні бази даних, візуально-подвійні зорі, власні рухи.

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АСТРОМЕТРИЧЕСКИЕ НАБЛЮДЕНИЯ ИЗБРАННЫХ ЗВЕЗД КАТАЛОГА WDS

Представлены результаты наблюдений двойных звезд, наблюдавшихся в НИИ «НАО» на протяжении 2013—2016 годов. Выполнена астрометрическая редукция полученных кадров до получения экваториальных координат компонентов двойных и кратных систем на момент наблюдения. Комбинация полученных ПЗС-положений с другими каталогами Страсбургской базы позволили определить новые значения собственных движений наблюдавшихся звезд. Для 214 двойных систем были измерены параметры взаимной конфигурации компонентов (позиционный угол и угловое расстояние). Приведен анализ результатов измерений. Результаты измерений включены в базу каталога WDS.

Ключевые слова: ПЗС-наблюдения, астрономические базы данных, визуально-двойные звезды, собственные движения.