ГОСУДАРСТВЕННОЕ АГЕНТСТВО ПО ВОПРОСАМ НАУКИ,
ИННОВАЦИЙ И ИНФОРМАТИЗАЦИИ УКРАИНЫ

НАУЧНО-ИССЛЕДОВАТЕЛЬСКИЙ ИНСТИТУТ
НИКОЛАЕВСКАЯ АСТРОНОМИЧЕСКАЯ ОБСЕРВАТОРИЯ

НИКОЛАЕВСКАЯ АСТРОНОМИЧЕСКАЯ ОБСЕРВАТОРИЯ

190 ЛЕТ

Материалы международной
научной конференции
“Астрономические исследования:
от ближнего космоса до Галактики”

26-29 сентября 2011 г.

Николаев
2011

УДК 520.1 + 52(093)
ББК 22.6г
Н 63

Ответственный редактор:
д-р физ.-мат. наук, проф. Г.И. Пинигин

Редколлегия:
канд. физ.-мат. наук Ж.А. Пожалова
канд. физ.-мат. наук А.В. Шульга
канд. физ.-мат. наук А.В. Иванцов

Н63 **Николаевская астрономическая обсерватория: 190 лет**. Материалы международной научной конференции "Астрономические исследования: от ближнего космоса до Галактики", 26-29 сентября 2011 г. – Николаев: Издательство Ирины Гудым, 2011. – 200 с., 92 илл., 23 табл.

ISBN 978-617-576-047-5

Книга содержит научные, методические и технические аспекты исследований околоземного пространства, астрометрии звезд и малых тел Солнечной системы, а также некоторые вопросы историко-астрономических исследований, которые были обсуждены на международной конференции "Астрономические исследования: от ближнего космоса до Галактики", посвященной 190-летнему юбилею Николаевской обсерватории. Конференция проходила 26-29 сентября 2011 г. в г. Николаеве, Украина.
Книга представляет интерес для специалистов астрономии, аспирантов и студентов соответствующих специальностей.

УДК 520.1 + 52(093)
ББК 22.6г

ISBN 978-617-576-047-5

Содержание

ПРЕДИСЛОВИЕ РЕДАКТОРА

В 2011 г. Николаевская астрономическая обсерватория отмечает свой 190-летний юбилей. Она прошла славный путь от Морской обсерватории Черноморского флота до Южного отделения знаменитой Пулковской обсерватории, а на пороге XXI века получила статус самостоятельного научного учреждения Украины. Одним из главных событий в рамках празднования нынешнего юбилея обсерватории стало проведение международной конференции "Астрономические исследования: от ближнего космоса до Галактики" (НАО190), которая проходила с 26 по 29 сентября 2011 г. в Николаеве (Украина) в Научно-исследовательском институте "Николаевская астрономическая обсерватория". Конференция состоялась при поддержке Государственного агентства по вопросам науки, инноваций и информатизации Украины, Украинской астрономической ассоциации, при содействии и помощи Облгосадминистрации и городской мэрии г. Николаева. В конференции приняли участие более 50 специалистов из 14 астрономических учреждений и обсерваторий Украины, России, Франции и Китая.

В настоящий сборник вошли обзорные статьи по направлениям научных исследований, проводимых в НАО в течение последних 20 лет, которые были представлены в докладах на конференции НАО190. Они включают изучение объектов ближнего космоса, результаты наблюдений малых тел Солнечной системы, создание каталогов положений звезд, использование информационных и виртуальных технологий в астрономии, астрономическое приборостроение. Широкое освещение получили вопросы международного сотрудничества, проводимого Николаевской обсерваторией в последние десятилетия с коллегами из Шанхайской астрономической обсерватории (Китайская Народная Республика), а также в рамках международного проекта по наземному сопровождению космического аппарата GAIA с астрономами из Франции, Турции и России. В ряде статей отражены историко-астрономические исследования, проводимые в НАО, в частности, о многолетней связи двух известных астрономических династий Струве и Кнорре на основе архивов Пулковской и Николаевской обсерваторий, архивов РАН и ВМФ, а также личных архивов потомков В.Я. Струве и К.Х. Кнорре.

Мемориальная часть книги посвящена высокоширотной научной экспедиции Николаевской обсерватории на остров Западный Шпицберген, которая работала в 1974-77 гг. В ней собраны воспоминания и дневниковые записи участников, которые раньше не публиковались.

Предлагаемый вниманию читателей сборник является логическим продолжением вышедшего в 1998 г. сборника “Николаевская астрономическая обсерватория. Звездный путь длиною в 175 лет”, в котором впервые за историю обсерватории были описаны различные стороны ее деятельности на протяжении 175 лет. Впоследствии эта тематика была расширена серией биобиблиографических сборников, посвященных директорам и выдающимся личностям в истории НАО, которая в настоящий момент насчитывает семь книг на четырех языках.

Мы надеемся, что данное издание будет интересным для читателей и займет достойное место среди книг, посвященных истории Николаевской астрономической обсерватории.

Г.И. Пинигин, директор НИИ НАО

The Maintenance of Optical Reference Frame and their Extension on Faint Magnitudes

G. Pinigin, N. Maigurova

Introduction

Reference frames in astronomy are usually defined by the positions of objects on the celestial sphere. The modern reference system is the International Celestial Reference System adopted by the IAU in August, 1997. Originally it was realized by the International Celestial Refence Frame (ICRF) [10] and extensions ICRF-ext1 [11], ICRF-ext2 [6] and ICRF2 were later issued. Last realization ICRF2 contain 3414 extragalactic radiosources most of which show submilliarcsecond accuracy in radio wavelengths. The space catalog Hipparcos was adopted as primary realization of the ICRS in optics. The link between the optical (Hipparcos Celestial Reference Frame – HCRF) and radio (ICRF) reference frames was realised in position within ± 0.6 mas at the mean epoch 1991.25 and in rotation within ± 0.25 mas per year [8]. There are two problems for ground-based astronomy:

1) By reason of the accuracy of the HCRF-ICRF link degrades over time due to the errors of proper motions, there is a need for verification and refinement of the two frames' link by different methods and telescopes;

2) The primary realization of the ICRS in optics – space catalog Hipparcos – was not good for direct application in positional astronomy by reason of its very small stars density for small fields of the CCD-astronomy. There was the problem of propagating Hipparcos Frame on fainter magnitudes.

Link between optical and radio reference frame

The underlying assumption is that the centers of emission of radio sources and the optical counterpart images are coincident at the accuracy level of the optical observations. A total of about 300 optical counterparts of the ICRF radio sources were observed mostly during 2000-2003 based on Joint Project (JP) between astronomical observatories from China, Turkey, Russia, and Ukraine (RI MAO) [1]. Observations were carried out with two telescopes equipped with CCD cameras: Russian-Turkish Telescope (RTT150), the fully automated Cassegrain telescope located at the TUBITAK National Observatory (TUG), Turkey, and the 1m telescope located at YAO, China. In addition, there are 8 fields around ERS (Extragalactic Radio Sources) obtained on RTT150 with CCD AP-47p of size 1024 × 1024 pixels (FoV = 4' × 4'), and 6 fields around ERS obtained on 2.16 m telescope of NAO with a CCD of size 2048 × 2048 pixels (FoV = 10.5' × 10.5'). The observations were made

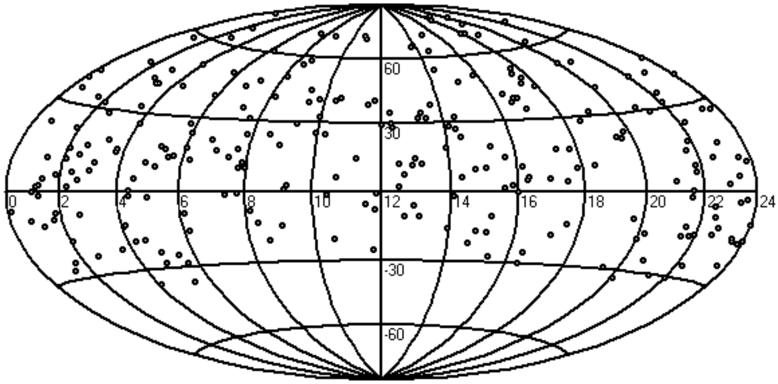

Figure 1. Distribution of the observed optical counterpart of ERS
in the JP over the celestial sphere

in declination range of (–40°) <= δ <= 80° and with uniform distribution over right ascension. Fig. 1 plots the final distribution of the observed ERS in the celestial sphere.

One of the main problem in astrometric reductions by reason their small fields of view is the absence of reference catalogues with precise positions and proper motions. In small CCD fields, one can not use such well-known catalogues with low star density as Hipparcos, TYCHO, or TYCHO2. The first reduction of our observational data was made with USNO catalogues (version USNO A2.0 and USNO B1.0) as reference catalogues. Results of the reduction with reference stars from USNO B1.0 catalogue show large systematic errors of about 200 mas in declination. Due to their low precision, the optical stellar positions from these catalogues can not be used to refine the link parameters between the radio and optical systems. The catalogs UCAC2, UCAC3 and 2MASS [4,16,17] are more accurate catalogues, which have made possible to partly re-process the available observational data.

The optical positions of the 126 ERS in the declination zone (-30°) <= δ <= 50° were measured with respect to the UCAC2 as reference catalogue and positions of 171 ERS in the declination zone (-40°) <= δ <= 80° were measured wit respect to the UCAC3 and 2MASS. The mean accuracies of the measured positions are 38 mas in right ascension and 35 mas in declination. A comparison between the measured optical positions referred to reference stars from UCAC2 catalog and the radio positions from the current ICRF has shown that the overall offsets (optical position minus radio position) are 3 and 14 mas in right ascension and declination, respectively. The formal internal errors of these mean offsets are 4 mas.

Comparative analysis of the results obtained with different catalogs are given in the tabl. 1. The data were calculated with using 113 common ERS.

Table 1

Optical-radio rotational parameters

Catalog	$\Delta\alpha\cos\delta$, mas	$\Delta\delta$, mas	N	Plate Solution		N stars
				σ_α	σ_δ	
UCAC2	-7 ± 4 (46)	13 ± 4 (42)	113	39	38	11
UCAC3	-9 ± 5 (48)	15 ± 4 (43)	113	57	57	16
2MASS	-8 ± 6 (68)	33 ± 7 (76)	113	87	88	33

Determination of Angles between Optical and Radio References Frames

The obtained values of differences were used for calculation of rotation angles between radio and optical systems of coordinates. Values of the angles between optical and radio reference frames were calculated by known formulas in accordance with available observations:

$$\Delta\alpha_{O\text{-}R}\cos\delta = \omega_x\sin\delta\cos\alpha + \omega_y\sin\delta\sin\alpha - \omega_z\cos\delta \quad (1)$$

$$\Delta\delta_{O\text{-}R} = -\omega_x\sin\alpha + \omega_y\cos\alpha$$

where: ($\Delta\alpha_{O\text{-}R} = \alpha_O - \alpha_R$) and ($\Delta\delta_{O\text{-}R} = \delta_O - \delta_R$) are ERS coordinate differences in optical and radio reference frames; ω_x, ω_y, ω_z – rotation angles about the x,y,z axes, respectively, where ω_x is a rotation around the axis (RA = 0^h, DEC = 0°), ω_y – around (RA = 6^h, DEC = 0°), ω_z – around DEC = 90° direction.

The two variants of the solution are given in tabl. 2. The first one was calculated from the differences (O - R), which had been obtained within the project (142 sources). The second one was calculated from the joint compiled data, both by the ours and optical positions, obtained by Brazilian astronomers [3].

The estimation of the link between optical and radio reference frames has shown that orientation angles are near zero within their accuracy about 5 mas.

The link accuracy becomes 3 mas when the observations are combined with other studies [2].

Table 2

Optical-radio rotational parameters, where: $\omega_{x,y,z}$ are rotation angles with their standard errors; σ_1 is error of unit weight

Source	ω_x (mas)	ω_y (mas)	ω_z (mas)	N
Joint Project, UCAC2	-0.2 ± 5.8	7.2 ± 5.5	7.0 ± 4.5	130
Joint Project, UCAC3	-0,1 ± 6,1	6.4 ± 5.8	-1,8 ± 3.5	171
Data from Assafin M., et al. 2003, UCAC2	-1.1 ± 3.6	1.3 ± 3.0	6.7 ± 2.4	172
Joint Project & data from Assafin M., et al. 2003, UCAC2	-0.4 ± 3.2	3.5 ± 2.8	6.8 ± 2.3	302

The increasing number of optical positions and accuracy of published positions, made by other astronomers, allows to improve the accuracy of determination of link parameters down to 4 mas. The error of the solution is defined by the accuracy of the reference optical catalogue.

The extension of the Hipparcos reference frame on faint magnitudes

As stated above direct use of high-precision cosmic Hipparcos and Tycho catalogs for determination of the positions of radio sources is impossible due to the low density of stars in these catalogs. Therefore the important task in this direction is to extend the HCRF system on faint stars. In addition, the proper motions of stars, that were determined with the help of spacecraft in a short period of observation, showed significant discrepancies with the ground proper motions determined using distant epochs. The remarkable event of modern astrometry was the creation of Tycho2 catalog (2539913 stars) – the result of the combination of positional data of the Tycho experiment and more than 140 ground-based catalogs of the 20th century for the determination of proper motions [7]. Using the Tycho2 catalog as a reference, such catalogs as UCAC3, CMC14, 2MASS, etc. expanded HCRF to 17 magnitude in the optical and infrared wavelengths on whole sky. The creation of high-level system of faint reference stars around ICRF extragalactic radio sources is also topical problem.

There are many papers devoted to the creation of such system of reference stars around astrometric ERS [5,9,15]. It should be noted such catalogs as ERLCAT, XC1, KMAC1. Their main idea is to give an opportunity to skip multi-step reductions from bright stars to faint stars in optical observations. For astrometric reductions of optical CCD-observations of extragalactic radio sources (ERS) the compiled catalogue of 21440 stars of 10-17 magnitude was obtained for 227 fields of size 30' - 40' in declination zone (-17°) to +89° with a center in ERS. This project is carried out within the frames of international cooperation between astronomers from Russia (Pulkovo, RAS), Romania and Ukraine [13]. Some differential catalogues of stars around ERS obtained from photographic and CCD-observations by different observatories were considered. The proper motion of 10795 stars up +50° in declination was chosen from UCAC2. Comparison of positions of stars was made with the UCAC2, CMC13 catalogues. The average external accuracy is about (0.05-0.15)" for majority of chosen fields of the compiled catalogue. The internal accuracy of positions on both coordinates is not worse 0.10". The average positions of stars in the compiled catalogue are given for stars with chosen from the UCAC proper motions on the epoch and the equinox of J2000.0, and for another one on the epoch of observation. The dependence of systematic differences (O-C) in right ascension and declination versus equatorial coordinate are shown in Fig. 2.

The usage of such high-sensitive light detectors as CCD in meridian instruments allowed us to carry out numerous observations of stars and other celestial objects at modern level of accuracy. The Axial Meridian Circle (AMC) of Nikolaev Observatory was put into operation in 1995. AMC is a modern robotic telescope having unique design features [12], which correspond to the best ones of meridian telescopes in the world and some parameters, such as weight and thermal deformations, even exceed them. Because of the unique design features, AMC was inscribed in a list of scientific objects that represents the National Heritage of Ukraine by the Decree #1709 issued by the Government of Ukraine on December 19, 2001. AMC design consists of a horizontal rotating telescope in the prime vertical and a motionless long-focal length autocollimator. CCD camera is installed in the telescope focal plane to measure the exact moment of the star passage through the meridian plane. The central optical unit, which consists of reflecting prism and glass limb, is attached to the telescope tube. The reflecting prism has two flat mirrors with 45° between them. Diagonal flat mirror reflects luminous flux from celestial bodies into the objective of telescope. Another flat mirror is installed perpendicularly to the rotation axis with accuracy of ± 20", providing a reflection of luminous flux from artificial marks back into the objective of autocollimator. A part of this luminous flux passes into the telescope through a small hole in

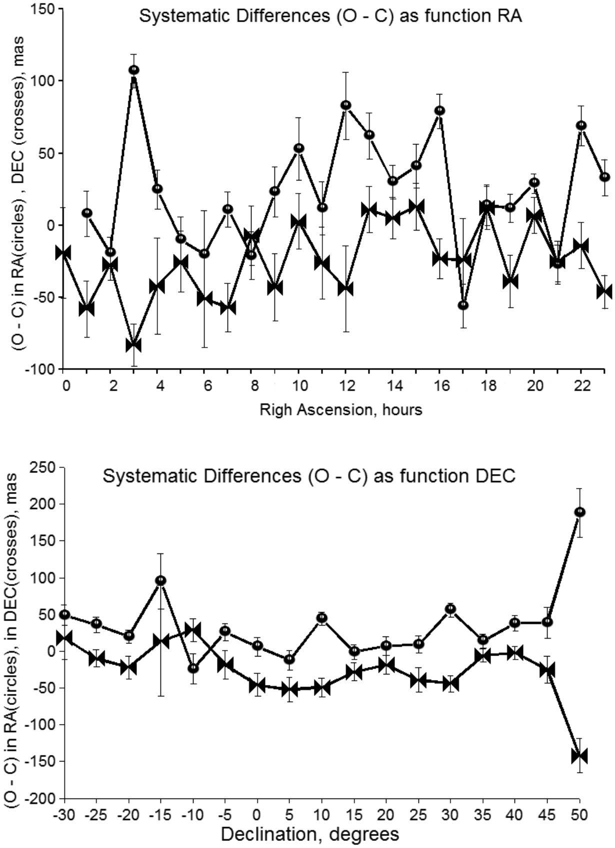

Figure 2. Dependence of systematic differences (O-C) in right ascension and declination versus equatorial coordinates (circles – right ascension, crosses - declination)

the center of the reflecting prism. Positions of the marks are measured in the telescope focal plane. It allows us to determine accurate positions of celestial bodies taking into consideration instrumental parameters. Systematic instrumental errors are from ± 0.02" to ± 0.03".

Observational campaigns with the Axial Meridian Circle (AMC) were also aimed on solution of these problems maintenance and extension of the ISRF/HIPPARCOS reference system to fainter objects.

In 1996-1998, regular observations of stars in fields around 188 extragalactic radio sources (ERS) were carried out to improve stellar positions and creation reference catalog for astrometric reductions of ERS. These observations in robotic mode using CCD cameras of telescope and autocollimator, photoelectric system for reading circle, setting system, control computer were the first ones in Ukraine. As the result, a catalogue of positions for 15000 of stars was compiled. The catalogue contains stars of 12 to 15 magnitude at epoch of J2000. Hipparcos and Tycho catalogues were used as input ones. USNO-A2.0 catalogue was used for recognition of stars.

In 2002-2005, the AMC was equipped with CCD camera made in the RI MAO on the basis of ISD017P chip made by Electron-Optronik, St Petersburg. Observations of stars in narrow equatorial zone from (-7.5°) to + 7° were carried out with the AMC to obtain positions of stars 10-15 magnitude and to compile a reference catalogue for reduction of geostationary satellite observations. As the result, a catalogue of positions for 11563 stars was compiled at right ascension zone of 17^h - 21^h. Accuracies of positions are 105 mas and 115 mas in right ascension (RA) and declination (Dec) correspondingly.

In 2003-2005, observations of stars in fields around ERS were carried out in ecliptical zone. As the result, a catalogue of positions for stars with accuracy better than 100 mas in 15 calibrated fields around the ERS was compiled.

In 2007, CCD camera S1C was installed at the AMC after reconstruction of enclosure and observations in ecliptical zone were continued. The program of observations was extended to 53 fields each with angular sizes of 7.5° x 1°. The fields are uniformly placed in right ascension in declination zone of ± 10° from ecliptic plane. As the result, a catalogue of positions and proper motions more than 140000 stars in the system of UCAC2 catalogue was obtained. Internal accuracy of catalogue positions are 40 mas to 125 mas for stars of 9.5 to 15 magnitude.

Despite the fact that the potential accuracy and limiting magnitude which are achieved by space astrometry cannot be compared with the ground-based astrometry, the role of ground-based astrometry consists in the edition of these observations in areas where “space” contribution is negligible or non-existent. The comparison of the “instant” (obtained with the help of space astrometry) and “ground” values of stars proper motions gives an additional information about the physical nature of studied objects, and allows to make a suggestion of presence or absence of invisible component. As a matter of fact, the high cost and limited terms of spacecrafts make it impossible to solve problems related to understanding the kinematics and dynamics of our Galaxy, which require numerous accurate determinations of the proper motions of stars and their parallaxes.

Since the 2008 year observations of stars with large proper motions have also started at axial meridian circle of Nikolaev observatory. Stars with large proper motions represent the specific interest for astronomers. Primarily it is due to the fact that these stars are relatively close to the Sun. This allows to use them for tasks such as determination of some parametes of our Galaxy model and refinement of Sun apex coordinates. A large percentage of stars with big proper motions are stars of low luminosity (white, red and brown dwarfs), which allows to use them for searching and studying of stars with unseen companions. Because of quick change of position of these stars on the background of more distant stars, they can also act as a lensing objects during the high-space experiments. Ground observations may help in the problem of prediction of these phenomena, their probability of occurrence and duration [14].

Nowadays, in the framework of fundamental research work "Refinement of the kinematic parameters of stars and stellar subsystems of the Galaxy based on CCD observations of selected zones" regular observations of stars with high proper motions are carried out using Nikolaev Axial meridian circle. The research work on this topic will be held during 2010-2012.

References

1. Aslan Z., Gumerov R., Jin W., Khamitov I., Maigurova N., Pinigin G., Protsyuk Y., Shulga A., Tang Z., Wang S. Results of Joint project on linking optical–radio reference frames // Kinematics and Physics of Celestial Bodies Suppl. Ser.– 2005. – № 5. – P. 333–337.

2. Aslan Z., Gumerov R., Jin W., Khamitov I., Maigurova N., Pinigin G., Tang Z., Wang S. Optical counterpart positions of extragalactic radio sources and connecting optical and radio reference frames // Astron. and Astrophys.,- 2010. - V. 510. - id. A10.

3. Assafin M., Zacharias N., Rafferty T.J., Zacharias M.I. Optical positions of ICRF sources using UCAC reference stars // Astron. J. – 2003. – V. 125. – P. 2728–2739.

4. Cutri et al. The IRSA 2MASS All-Sky Point Source Catalog, NASA/IPAC, 2003.

5. Fedorov P.N., Myznikov A.A. The catalogue of positions and proper motions of faint stars around the ICRF sources // Kinematics and Physics of Selectial Bodies. Suppl. Ser. – 2005. - N 5. - P. 333–337.

6. Fey A.L., Ma C., Arias E.F. et al., The Second Extension of the International Celestial Reference Frame: ICRF-EXT.1 // Astron. J. – 2004. – V. 127 – P. 3587-3608.

7. Hog E., Fabricius C., Makarov V.V., Urban S. The Tycho–2 Catalogue of the 2.5 million brighters stars // Astron. and Astrophys. – 2000. – V. 355 .– L 27- L30.

8. Kovalevsky J. Connection of the Hipparcos catalogue to the extragalactic reference frame // Hipparcos Venice’97, ESA, - 1997. – P. 11–12.
9. Lazorenko P., Babenko Yu., Karbovsky V., Buromsky M. The Kyiv Meridian Axial Circle catalogue of stars in fields with extragalactic radio sources //Astron. and Astrophys. - 2005. -V. 438. - P. 377–389.
10. Ma C., Arias E.F., Eubanks T.M., Fey A.L. The International celestial reference frame realized by VLBI // IERS Techical Note - 1997. - V. 23.- p. II - 3 - II-40.
11. Ma C. Extension of the ICRF// Proceedings of the 15th Workshop Meeting on European VLBI for Geodesy and Astrometry. Institut d'Estudis Espacials de Catalunya, Consejo Superior de Investigaciones Científicas, Barcelona, Spain, September 07-08, 2001. Edited by Dirk Behrend and Antonio Rius., p.187, 2001.
12. Pinigin G., Shulga O. Patent 35905A, on 16.04.2001.
13. Ryl’kov V., Dement’eva A., Narizhnaya N., Pinigin G., Maigurova N., Protsyuk Yu., Kleschenok V., Bocsa G., Popescu P. Reference stars compiled catalogue around extragalactic radio sourses. Reduction techniques and the first results // Kinematics and Physics of Celestial Bodies Suppl. Ser.– 2005. – № 5. – P. 328–332.
14. Salim S., Gould A. Nearby Microlensing Events – Identification of the Candidates for the Space Interferometry Mission. // Astrophys. J. - 2000. - V. 539. - P. 241-257.
15. de Vegt C., Genlich U. Precise optical positions of radio sources in the FK 4-system - Results from a pilot program // Astron. and Astrophys. - 1978. - V. 67. - P. 65-71.
16. Zacharias N., Urban S.E., Zacharias M.I., Wycoff G.L. The second US Naval Observatory CCD astrograph catalog (UCAC2) // Astron. J. - 2004. - V. 127. - P. 3043-3059.
17. Zacharias N., Finch, C.; Girard, T. et al. The Third US Naval Observatory CCD Astrograph Catalog (UCAC3) // Astron. J. - 2010. - V. 139. - P. 2184-2199.