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DEVELOPMENT OF JOINT PROJECT ON IMPROVEMENT OF LINKING BETWEEN OPTICAL AND RADIO REFERENCE COORDINATE SYSTEMS

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Results of performance of the Joint Project between observatories from China, Turkey, Russia and Ukraine on improvement of linking optical and radio reference systems are discussed. The program of supervision up to 300 extragalactic radio sources (ERS) is extended at the expense of increase of supervision in a southern hemisphere to -40^0 declinations. The optical counterparts of 73 ERS in northern sky and 37 ERS on southern are determined. As basic stars from catalogue AMC1B, received in 2000 on Nikolaev AMK was used, and a ladge part of stars from catalogue USNO-A2 was used. The analysis of differences O-R (optical – radio) on supervision on various telescopes shows satisfactory data on accuracy, about $\pm$40mas $\div$ $\pm$80mas. It is possible to explain some divergence by unsufficient accuracy of positions of intermediate basic stars. The necessity of creation for each field around ERS of the common catalogue of basic stars from the accessible catalogues of suitable accuracy and density expresses. The tentative estimation of angles of connection optical and radio of systems of coordinates on 60 ERS in a zone of declinations $+75^0 \div -40^0$ is executed: $\omega_x = -4 \pm 30$, $\omega_y = -4 \pm 29$, $\omega_{zy} = -13 \pm 26$ (s.e.) mas.

ПРО СТАН СПІЛЬНОГО ПРОЕКТУ ПО ПОЛІПШЕННЮ ЗВ'ЯЗКУ МІЖ ОПТИЧНОЮ І РАДІО ОПОРНИМИ СИСТЕМАМИ КООРДИНАТ

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Обговорюються результати виконання Спільного Проекту обсерваторій з Китаю, Туреччини, Росії й України по поліпшенню зв'язку оптичної і радіо опорних систем координат. Розширено програму спостережень до 300 позагалактичних радіоджерел (ПР) за рахунок збільшення спостережень у південній півсфері до –40^0 схілень. Визначено оптичні положення 73 ПР у північному небі і 37 ПР на

південному. Як опорні зірки використовувався каталог AMC1B, отриманий у 2000р. на миколаївському АМК, а при недостачі зірок АМК у площадках використовувався каталог USNO-A2. Аналіз разниць O-P (оптичні – радіо положення ПР) за спостереженнями на різних телескопах показує задовільні значення по точності, у межах ±40mas ÷ ±80mas. Деяку розбіжність можна пояснити недостатньою точністю положень проміжних опорних зірок. Висловлюється необхідність створення зведеного списку опорних зірок для кожної площадки навколо ПР з доступних каталогів придатної точності і щільності. Виконано попередню оцінку кутів зв'язку оптичної і радіо систем координат по 60 ПР у зоні схилень $+75^0 \div -40^0$: $\omega_x = -4 \pm 30$, $\omega_y = -4 \pm 29$, $\omega_{zy} = -13 \pm 26$ (s.e.) mas.

О СОСТОЯНИИ СОВМЕСТНОГО ПРОЕКТА ПО УЛУЧШЕНИЮ СВЯЗИ МЕЖДУ ОПТИЧЕСКОЙ И РАДИО ОПОРНИМИ СИСТЕМАМИ КООРДИНАТ

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Обсуждаются результаты выполнения Совместного Проекта обсерваторий из Китая, Турции, России и Украины по улучшению связи оптической и радио опорных систем координат. Расширена программа наблюдений до 300 внегалактических радиоисточников (ВР) за счет увеличения наблюдений в южной полусфере до -40^0 склонений. Определены оптические положения 73 ВР в северном небе и 37 ВР на южном. В качестве опорных звезд использовался каталог AMC1B, полученный в 2000г. на николаевском АМК, а при недостатке звезд АМК в площадках использовался каталог USNO-A2. Анализ разностей O-P (оптические – радио положения ВР) по наблюдениям на различных телескопах показывает удовлетворительные значения по точности, в пределах ±40mas ÷ ±80mas. Некоторое расхождение можно обьяснить недостаточной точностью положений промежуточных опорных звезд. Высказывается необходимость создания для каждой площадки вокруг ВР сводного списка опорных звезд из доступных каталогов подходящей точности и плотности. Выполнена предварительная оценка углов связи оптической и радио систем координат по 60 ВР в зоне склонений $+75° \div -40°$: $\omega_x = -4 \pm 30$, $\omega_y = -4 \pm 29$, $\omega_{zy} = -13 \pm 26$ (s.e.) mas.

INTRODUCTION.

· Proposed link programme could provide an intermediate system of reference stars in the Hipparcos Catalogue(HC) system made with AMT in fields around selected extragalactic radio sources (ERS). Collaborated CCD telescopes with available FOV and sensitivities should be guaranty a sufficient amount of intermediate reference stars for the determination of precise positions of faint ERS, as well as to cover a magnitude range between intermediate stars and ERS optical counterparts. This collaboration programme is elaborated on the level of joint research work in the field of optical/radio linking between observatories from China, Turkey, Russia and Ukraine /Tang et al.,2000; Pinigin et al., 2000/

. The primary task of proposed collaborated programme is an establishment of optical / radio linking with accuracy better than 5 mas globally. It will be appropriate for enhancing of current link accuracy. From the known equations it can be shown that for some available accuracy of ERS optical position and for enough number of ERS it is possible to have high accuracy of optical-radio

linking /Pinigin et al., 2000/. It can be shown that rotation parameters accuracy 5 mas will be reached by using of about 300 ERS with positional accuracy not worse than 20 mas.

PROGRAM AND INSTRUMENTATION

The collaborated program includes about 300 ERS for declination zone from $+75^{o}$ to -40^{o} .

Up today there are several collaborated CCD telescopes used in the program (Tabl.1):

· AMC – Axial meridian circle (180,2480) and Zone astrograph (160,2044) of the Nikolaev astronomical observatory (NAO) equipped by the similar CCD ISD017AP (1040x1160, 16 x 16 mkm);

· AST-8 astrograph (700,2819)) of the astronomical observatory of the Kharkov university (Ukraine) with the CCD ST-6 (375 x 241, 23 x 27 mkm, 1.″8 x 2.″1 / pix);

· A3T-22 astrograph (1500,11600) of the Engelghardt astronomical observatory of the Kazan university (Russia) installed in Turkey (TUG) for joint using. Right now it is equipped by the CCD ST-8 (1530 x 1020, 9 x 9 mkm, 0.″16 / pix);

1.56 meter astrograph (1560,15600) of the Shanghai Astronomical Observatory (China) with the CCD SONI (1024 x 1024, 16x16 mkm, 0.″25 / pix) and 1.0 meter reflector (1000,13000) with the CCD camera TI (1024 x 1024, 9x9 mkm, 0.″38 / pix, 6,5′×6,5′) from Yunnan Observatory / Maigurova et al., 2000; Tang et al.,2001 / (Table1).

Table 1.

COLLABORATED TELESCOPES USED IN PROGRAMME

Telescope φ	ÀÌ C (Nikolaev Ukraine), $+47^{0}$	ZA (Nikolaev Ukraine), $+47^{0}$	ÀZÒ-8 (Kharkov Ukraine), $+50^{0}$	1.0m telescop (Shanghai and Yunnan, China), $+25^{0}$	ÀZÒ-22 (Àntalia Turkey), $+36^{0}$
Type	refractor	refractor	reflector	reflector	reflector
D,F (mm)	180 2480	160 2044	700 2819	1000 13000	1500 11600
CCD	ISD017P 1040x1160 16 x 16 mkm 1. ″33/ pix 23′õ 26′	ISD017P 1040x1160 16 x 16 mkm 1.″6/ pix 28′õ 31′	ST-6 375 x 241 23 x 27 mkm 1.″8õ2.″1/ pix 8′õ 10.5′	TI 1024 õ 1024 9 x 9 mkm 0.″38/pix 6.5′x 6.5′	ST-8 1530 õ 1020 9 x 9 mkm 0.″28/pix 4′x 3′
Mode	drift scan	drift scan, stare	stare	stare	stare
Magnitude	$10^{m} \div 16^{m}$	$12^{m} \div 15^{m}$	$15^{m} \div 17^{m}$	$17^{m} \div 19^{m}$	$19^{m} \div 21^{m}$
Observation program	24 ERS selected stars around ERS	20 ERS	65 ERS	100 ERS	150 ERS
Data used in angles processing	catalogue AMC1B			38(N)+22(S) ERS	35(N)+15(S) ERS

3. REDUCTION AND RESULTS

3.1 AMC catalogue of reference stars:

The intermediate 4th version of AMC catalogue (AMC1B) was taken as the reference catalogue and is available on WWW address: http://www.mao.nikolaev.ua/arc/amc1b.zip. It contains about 15000 stars with internal catalogue accuracy on both coordinates with epoch 1997.09:

$\varepsilon_a \cos\delta = \pm 0''.07 \cdot (\sec Z)^{0.20} \cdot (mag - 7)^{0.43}$;

$\varepsilon_\delta = \pm 0''.09 \cdot (\sec Z)^{0.10} \cdot (mag - 7)^{0.31}$

This version AMC1B with good and stable internal accuracy was used as reference catalogue by previous evalution of comparison between optical and radio positions ERS. By the way for small fields of view (FOV) of CCD telescopes one can consider influences of all distortions as negligible and therefore it can adopt a linear model of reduction. However for more exact reduction with using of this catalogue showed marked differences between AMC1B and ICRF. It was shown about in detail in (Tang et all, 2001). By this reason, it was decided to use another catalogue as reference for correction of AMC1B.

3.2 Southern hemisphere observation in Yunnan observatory

The observations of 22 ERS in southern hemisphere and optical positions relative to UCAC1 were carried out (Tang et al,2002). The internal accuracy of comparison between optical and radio positions is of the order of 60mas and 45 mas in right ascension and declination, respectively. UCAC1 is on the ICRS and results of comparison with those of other authors was made. In common paper, determination of angles which shown satisfactory results for previous evaluation of available observation of Joint Project was made.

3.3. Northern and Southern hemisphere observation on the AZT-22 in Antalia

3.3.1 Southern hemisphere. The observations of 15 ERS in southern hemisphere and optical positions relative to USNOA2 were carried out in Antalia in accordance with Joint Project (Maigurova et al., 2000). The internal accuracy of comparison between optical and radio positions is of the order of 25mas and 24 mas in right ascension and declination, respectively.

3.3.2 Northern hemisphere. The observations of 35 ERS in northen hemisphere and optical positions relative to USNOA2 were carried out in Antalia. The internal accuracy of comparison between optical and radio positions is of the order of 27 mas and 41 mas in right ascension and declination, respectively. USNOA2 is not so exact catalogue as UCAC1 and its connection on the ICRS not so obviously.

4. DETERMINATION OF PREVIOUS ANGLES BETWEEN OPTICAL AND RADIO REFERENCE FRAMES

Using the real data of (O-R) data for observation with 1m telescope of Yunnan observatory and AZT-22 we can show the dependence of accuracy O-R on stellar magnitude (see Fig. 1 and Fig.2).

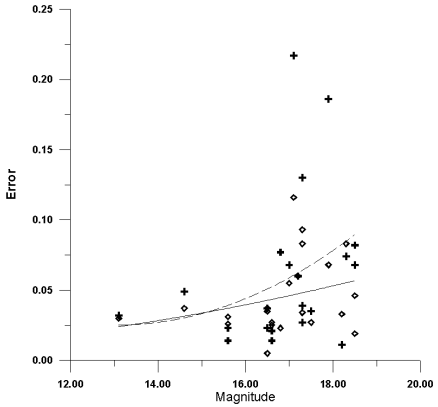

Fig1.Relationship between accuracy of $(O-R)_{\alpha}\cos\delta$ (+) and $(O-R)_{\delta}$ (∇) on mag. for 1-m telescope in Yunnan observatory.

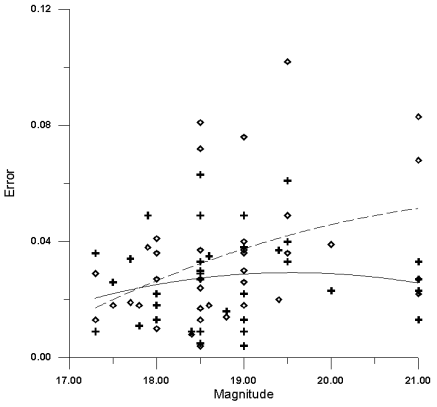

Fig2.Relationship between accuracy of $(O-R)_{\alpha}\cos\delta$ (+) and $(O-R)_{\delta}$ (∇) on mag for AST-22 in Antalia.

Value of angles between optical and radio systems of coordinates in accordance with the data of observations with A3T-22 in Turkey and 1-m telescope in China were also calculated.

Special conditions: it was determined in two equations a free terms for correction of differences between ICRF and USNO-A2. A values of these terms consisted $\Delta\alpha_0 = \pm 141$mas and $\Delta\delta_0 = \pm 158$mas. Our data in comparison with determinations of angles by other authors are given in Tabl. 2 (Stone, 1997; Stone et al., 1996; Kovalevsky, 1995; Zacharias et al., 1999).

Table 2

Source	ω_x (mas)	ω_y (mas)	ω_z (mas)	N	σ_1 (mas)	$\sigma_{(O-R)}$ mas
Hamburg(Ma+)1990	30±20	53±20	23±20	28	±86	
CAMC+Bord (1990)	32±18	10±19	13±18	20	66	±66
Kiev(T-Ad+)1992	0±30	70±30	20±20	251	365	
FASTT, (Stone)1994	–20±17	28±16	11±13	99	122	42
Jonston, et al., 1994	43±19	31±19	–29±18	43		
Kumkova, et al.,1995	38±18	22±16	–17±16	78		146
Zacharias, et al.,1999	–0.2±3.9	–5.4±3.9	–2.5±3.9	318	58	50
Joint Project, 2001 (China+ AZT22)	**–4 ± 30**	**–4 ± 29**	**–13 ± 26**	**60**	**178**	**40-35**

Note – The column N gives the numbers of ERS used in the solutions; σ_1 is the error of the unit weight; $\sigma_{(O-R)}$ is formal error of (O–R) differences in both coordinates and ω_x, ω_y, ω_z are the rotation angles with their formal standart errors (all in mas).

It is noted that our data in Tabl.2 are not so bad. We have possibility to

receive better accuracy results with the help of refinement of the linkage between UCAC1 (USNOA2, AMC1B) with ICRF and increasing of ERS number made by collaborated telescopes.

CONCLUSION

Expected accuracy will be better by using the collaborated telescopes for observation of ERS sufficient number and available positional accuracy of catalogue of intermediate reference stars on the level of not worse than 50 mas.

Determination of 300 optical / radio ERS differences with position accuracy of 20 mas permits to recive the rotation parameters with accuracy of 5 mas.

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