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Preliminary report

SYSTEMATIC ERRORS OF $\Delta\delta_\alpha, \Delta\delta_\delta, \Delta\delta_m$ TYPE OF THE BELGRADE ABSOLUTE DECLINATION CATALOGUE

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SUMMARY: In this paper are presented the systematic differences $\Delta\delta_\alpha$, $\Delta\delta_\delta$ and $\Delta\delta_m$ of the Belgrade Absolute Declination Catalogue (BCAD) with respect to the fundamental catalogues FK4, FK5 and GC. It is found that prominent changes in $\Delta\delta_\delta$ occur within the zones of 2° in declination, that $\Delta\delta_\alpha$ possesses changes of a seasonal character particularly emphasized during autumn and winter and that the magnitude dependence $\Delta\delta_m$ is not negligible. The present systematic differences appear as a consequence of the systematic-error influences not estimated here.These systematic errors are due to the inadequately determined circle corrections, flexure, refraction and to an insufficient fading of stellar brightness.

1.INTRODUCTION

After a detailed reconstruction of the Belgrade Vertical Circle (BVC) which took place in late 1974 (Usanov et al., 1978), observations for the Catalogue of 307 Bright Stars between declinations +65° and +90° (BCAD) were performed with this instrument during 1976 – 1980 (Mijatov et al., 1991).The comparisons with the fundamental catalogues FK4 and FK5 presented in the introduction to the Catalogue show that BCAD contains significant systematic differences of $\Delta\delta_\alpha$ and $\Delta\delta_\delta$ type.

In the present paper the differences $\Delta\delta_\alpha$, $\Delta\delta_\delta$ and $\Delta\delta_m$ are considered with respect to the fundamental catalogues FK4, FK5 and GC.The systematic difference $\Delta\delta_0$ cannot be determined because there were no observations in the equatorial zone, hence this constant affects the value of $\Delta\delta_\delta$. The systematic difference $\Delta\delta_{SP}$ is not determined because of a small number of stars existing for a majority of spectral types.

2. DIFFERENCES $\Delta\delta$

All BCAD stars were observed in both culminations since the geographic latitude of the instrument ($\varphi \approx +44°48'$) enabled it.The declinations δ_{BCAD} are derived by the absolute method.They are functions of the mean values of declinations δ_1 and δ_2 obtained by observing in the upper and lower culminations, their random errors ε_1 and ε_2 and the number of observations n_1 and n_2, i.e. $\delta_{BCAD} = f(\delta_1, \delta_2, \varepsilon_1, \varepsilon_2, n_1, n_2)$.

The differences $\Delta\delta = \delta_{BCAD} - \delta_{FC}$ between BCAD and the fundamental catalogues are deter-

mined from the data about the stars common with FK4, FK5 and GC by reducing δ_{BCAD} to the epochs of the fundamental catalogues.For this purpose the corresponding systems of the precession constants and the proper motions of fundamental-catalogue stars are used.

The general data for the differences $\Delta\delta$ are presented in Table 1 where $\Delta\delta$ is the mean value of $\overline{\Delta\delta}$ differences, $\varepsilon_{\Delta\delta}$ – random error of a single difference and n – number of differences.

Table 1. Values $\overline{\Delta\delta}$, $\varepsilon_{\Delta\delta}$ and n

	FK4	*FK5*	*GC*
$\overline{\Delta\delta}$	$-0''.01 \pm 0''.03$	$+0''.05 \pm 0''.02$	$+0''.16 \pm 0''.03$
$\varepsilon_{\Delta\delta}$	$\pm 0''.28$	$\pm 0''.25$	$\pm 0''.53$
n	110	236	307

An insight can be gained about the internal distribution of $\Delta\delta$ differences grouping them within certain intervals. So, about 48% of all $\Delta\delta$ differences for the case of FK4 and above 55% for that of FK5 fall within the interval $|0''.2|$ and about 95% within $|0\,\mathrm{sec}\,5|$ for the both catalogues.For the case of GC about 47% of all differences are within $|0''.3|$ and about 80% within $|0''.6|$.

The relationship between individual $\Delta\delta$ and the systematic differences $\Delta\delta_\alpha$, $\Delta\delta_\delta$ and $\Delta\delta_m$ is given by

$$\Delta\delta = \Delta\delta_\delta + \Delta\delta_\alpha + \Delta\delta_m + \nu \qquad (1)$$

where ν contains the differences of the systematic influences, that are not calculated, and those of the random errors.The order of the systematic differences on the right-hand side of (1) is given according to the priority of their elimination from $\Delta\delta$.

3. SYSTEMATIC DIFFERENCES $\Delta\delta_\delta$

The analysis of the mean values $\overline{\Delta\delta}$ for various zone widths indicates the existence of a prominent, and to a certain degree, periodic change of these values within 2° zones in declination.Bearing this in mind and in order to emphasize the periodicity, we decide to use zone widths of 1° regardless the fact that in some zones the number of the $\Delta\delta$ differences becomes then small.

In Fig. 1 the systematic differences $\Delta\delta_\delta$ obtained by averaging $\Delta\delta$ on every degree of declination are presented for the cases of FK4, FK5 and GC.

As can be seen from Fig. 1, there are very prominent changes of $\Delta\delta_\delta$ between two neighbouring zones.The changes are somewhat more prominent with in the zones +65° – +70° and +80° – +90°, but it should be borne in mind that the number of $\Delta\delta$ differences is somewhat smaller than in the zone +70° – +80° due to the nonuniformity of star distribution in δ.Therefore, the random errors in $\Delta\delta$ are more prominent. These statements are valid for the comparisons with all the three fundamental catalogues.

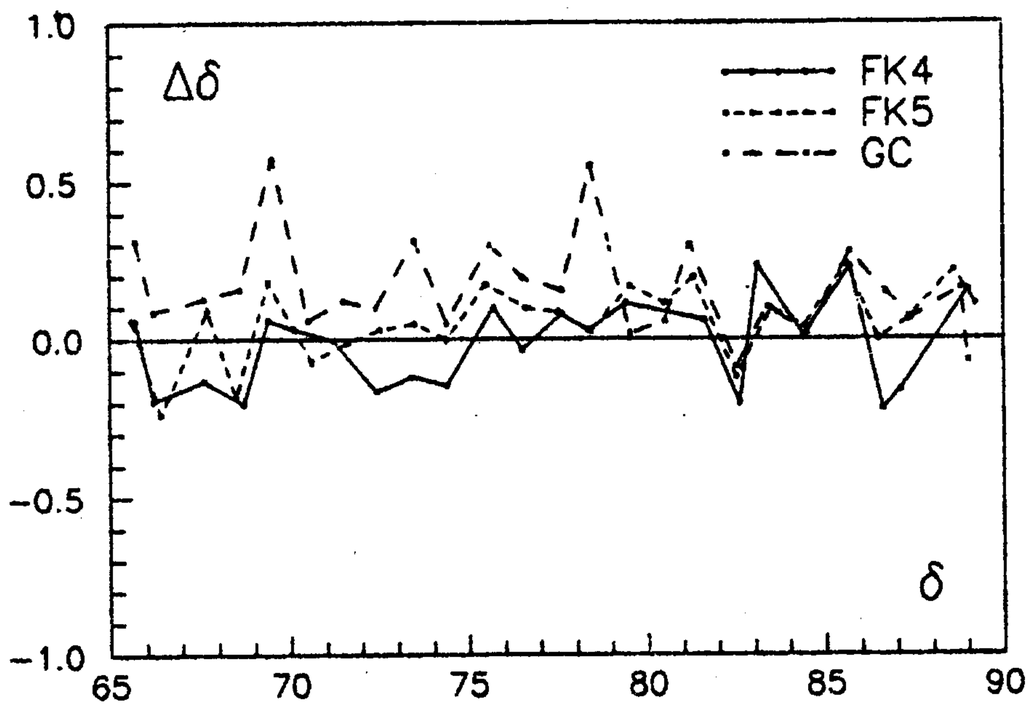

Fig. 1. Curves $\Delta\delta_\delta$ in 1° zones of declination

It should be stressed that, in almost all the cases, the $\overline{\Delta\delta}$ values are higher in the zones beginning with odd declinations (65° – 66°, 67° – 68°, ...) than in the neighbouring ones beginning with even declinations (66° – 67°, 68° – 69°, ...).The mean differences obtained from $\overline{\Delta\delta}$ for the neighbouring zones beginning with odd declinations, i. e. with even ones, are $+0''.18$ $+0''.13$ and $+0''.09$ for FK4, FK5 and GC, respectively. Although these differences decrease with the total number of $\Delta\delta$ differences increasing, a systematic difference within 2° declination zones may be considered.If the situation with FK5 is taken representative the influence gives systematic errors exceeding $0''.1$.

The circle corrections examinations for some meridian instruments produced by "ASKANIA" demonstrated the presence of a 2° periodicity for these instruments that is due to the shortcomings in the graduating machines.This effect was firstly established from star observations with the Meridian Circle of the Belgian Royal Observatory (Becq and Melchior, 1957).

The 2° periodicity was also established for the Belgrade Meridian Circle (BMC), by applying the spectral analysis to the corrections on every $0^{\circ}.5$ (Trajkovska, 1981; Jovanović and Bozhichkovich, 1987) by applying the spectral analysis.However, this periodicity is not clearly seen when $2'$ circle corrections are used in the spectral analysis for this instrument (Dejaiffe, 1973).In the case of BVC, also produced by "ASKANIA", approximately at the same time as BMC, such periodicity was not found by applying the spectral analysis method on the circle corrections made on every $10'$ (Jovanović and Bozhichkovich, 1987).

If a realistic hypothesis that the 2° periodicity of the circle graduation is also present for BVC, then its circle corrections have their systematic errors of determination, hence the prominent $\Delta\delta_\delta$ changes in

the declination zones of 2° are just due to these errors. This hypothesis can be confirmed or negated in additional examinations.

In order to eliminate this influence as much as possible, as well as that of random errors, and in this way to demonstrate the presence of other effects producing the differences $\Delta\delta_\delta$, we carry out a smoothing of $\overline{\Delta\delta}$ grouped within 2° declination zones.The smoothed curves for the cases of FK4, FK5 and GC are presented in Fig. 2.

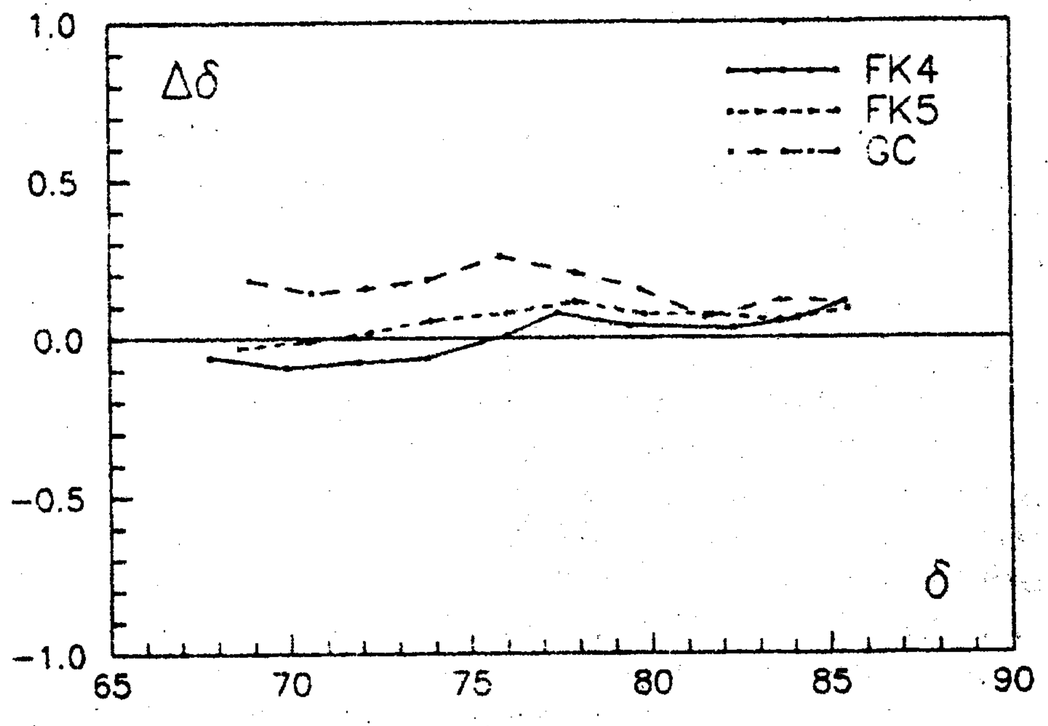

Fig. 2. Smoothed curves $\Delta\delta_\delta$ in 2° zones of declination

The curves for the cases of FK4 and FK5 are approximately linear and they have an increasing trend in $\Delta\delta_\delta$ whose total variation is about 0″.15. Certainly, this variation is due to the influences of flexure and refraction that are not calculated because their effect is approximately linear due to relatively small variations in z.

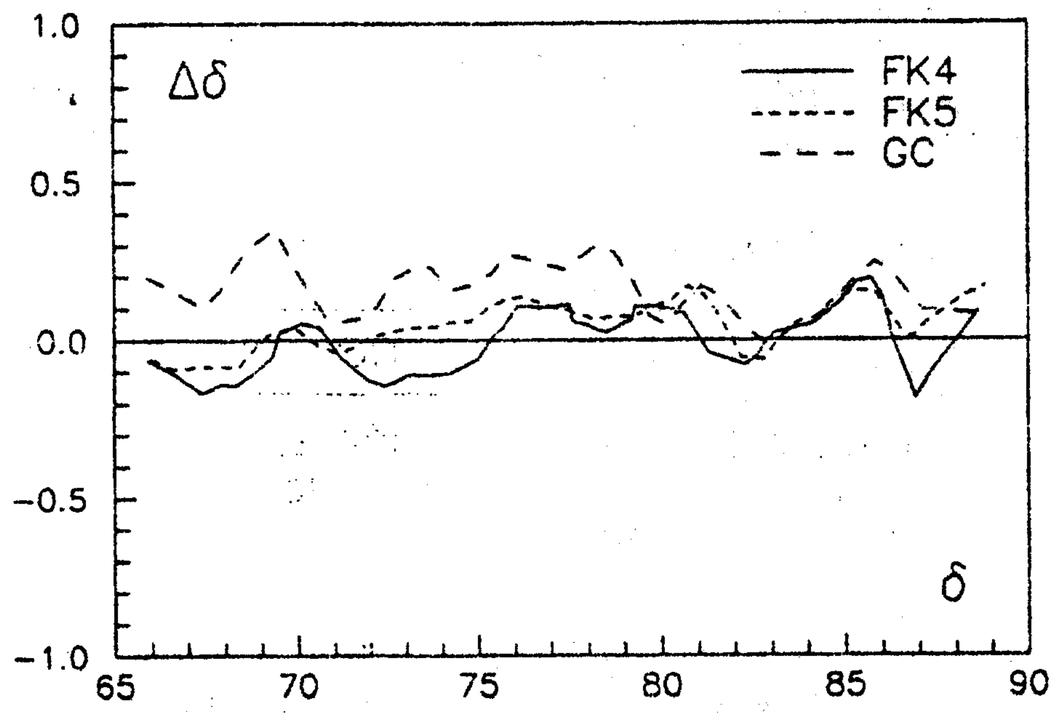

Fig. 3. Curves of systematic differences $\Delta\delta_\delta$

Thus the main sources of $\Delta\delta_\delta$ type systematic errors in BCAD are, probably, at the first place the systematic errors of the circle corrections determination and then the influences of BVC flexure and refraction not being evaluated.

In order to preserve all found systematic influences as much as possible a smoothing of the $\Delta\delta_\delta$ values in 0°.5 declination zones for the case FK4, FK5 and GC are carried out. These values are presented in Fig. 3 and they may be (approximatively) treated as the curves of the systematic differences $\Delta\delta_\delta$.

4. SYSTEMATIC DIFFERENCES $\Delta\delta_\alpha$

The systematic differences $\Delta\delta_\alpha$ primarily arise due to the changes of the observational conditions with time-daily and seasonal.Therefore, it should be considered in which right ascension zones the existence at $\Delta\delta_\alpha$ due to the daily and seasonal changes can be expected.

In Table 2 presented are the observational seasons for the upper and lower culminations in 4^h right ascension zones.The seasons are denoted as: 1 – winter, 2 – spring, 3 – summer and 4 – autumn.The seasons, when the number of observations within a zone and for a given culmination prevails, are underlined.

Table 2. Observational seasons in right ascension and culmination

	0^h-4^h	4^h-8^h	8^h-12^h	12^h-16^h	16^h-20^h	20^h-24^h
Upper Cul.	3,4	4,1	1,2	2,3	2,3,4	3,4
Lower Cul.	1,2	2,3,4	3,4	3,4,1	4,1	1,2,4

Above all the effect of daily variations can be expected in those right ascension zones where the observations were performed in the same season in both culminations.These are the zones: $4^h - 8^h$, $12^h - 16^h$, $16^h - 20^h$ and $20^h - 24^h$.

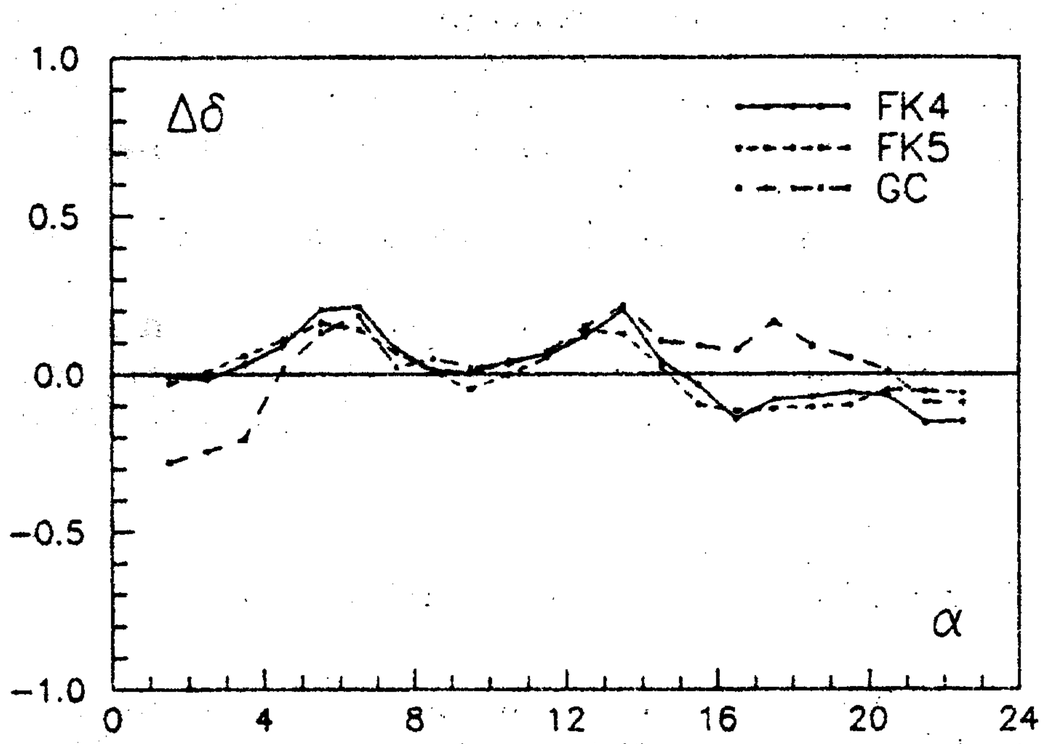

Fig. 4. Smoothed curves $\Delta\delta_\alpha$ in 1^h zones of right ascension

The seasonal variations effect can be expected in those right ascension zones where the observations in the autumn and winter periods prevail no matter which culmination is studied and these are the zones $4^h - 8^h$, $12^h - 16^h$ and $16^h - 20^h$. Namely, it has

been found that the seasonal variations in flexure (not calculated in the treatment of BCAD) are especially prominent in the autumn period (Mijatov and Trajkovska, 1989) and that the declination values obtained from winter observations (at temperatures about zero) are significantly different from the other ones.

In Fig. 4 are presented the smoothed curves of the $\Delta\delta_\alpha$ values for FK4, FK5 and GC obtained by averaging the $\Delta\delta$ differences over right ascension zones of 1^h previously made free of the mean $\Delta\delta_\delta$ values in declination zones of 1°.

According to Fig. 4, in the zones $4^h - 8^h$, $12^h - 16^h$, $16^h - 20^h$ and $20^h - 24^h$ the $\Delta\delta_\alpha$ values are higher, as expected, and they are due to both daily and seasonal variations concerning the autumn and winter observational conditions.

In the zones $0^h - 4^h$ and $8^h - 12^h$ where the observations causing daily variations are absent the $\Delta\delta_\alpha$ variations are small.In these zones the observations were largely performed during the seasons favourable for observing from both instrumental and observational view point, such as spring and summer.

The different signs of the $\Delta\delta_\alpha$ values for the zones $4^h - 8^h$ and $16^h - 20^h$ correspond to the culminations at which the observations were performed in winter.This fact indicates that the sources of the seasonal variations are those influences of a seasonal character not treated in the calculations, but most strongly affecting the zenith distance determination. These are the flexure and the refraction.

From the abovesaid it follows that the systematic differences $\Delta\delta_\alpha$ are mainly due to the flexure influences (daily and seasonal) and refraction influence (seasonal) not calculated in the treatment of BCAD.

All these considerations are made for $\Delta\delta_\alpha$ for the cases of FK4 and FK5 since the $\Delta\delta_\alpha$ type systematic errors for these catalogues are small.Therefore, the systematic differences $\Delta\delta_\alpha$ with respect to FK4 and FK5 can be largely considered as systematic errors of BCAD.

In addition to the procedure applied here, the systematic differences $\Delta\delta_\alpha$ can also be determined by expanding in a trigonometric series in α.In our case it is possible to achieve a good agreement with the curves from Fig. 4 by expanding in a series up to 3α.

5. SYSTEMATIC DIFFERENCES $\Delta\delta_m$

The systematic differences $\Delta\delta_m$ are determined by using the least-square method from the expressions

$$a_0 + (m - m_0)a_1 = \Delta\delta - \Delta\delta_\delta - \Delta\delta_\alpha \qquad (2)$$

where: m– star magnitude, m_0 – mean magnitude obtained from all stars, $\Delta\delta = \delta_{BCAD} - \delta_{FC}$ and $\Delta\delta_\delta$ and $\Delta\delta_\alpha$ are the corresponding systematic differences used for Figs. 1 and 4.

Table 3 contains the values of the coefficients a_0 and a_1 with their errors, m_0 and the standard deviation σ for FK4, FK5 and GC.

Table 3. Parameters of magnitude dependence

	a_0	a_1	m_0	σ
FK4	$0''.000 \pm 0''.018$	$-0''.026 \pm 0''.019$	5.27	$\pm 0''.19$
FK5	$0''.000 \pm 0''.013$	$-0''.019 \pm 0''.015$	5.90	$\pm 0''.20$
GC	$0''.000 \pm 0''.026$	$-0''.035 \pm 0''.029$	5.89	$\pm 0''.46$

The coefficient a_1 defining the dependence of $\Delta\delta$ on the magnitude is significant with respect to all the three catalogues.The agreement of the a_1 values for FK4, FK5 and GC shows its reality.

The cause to $\Delta\delta_m$ existence is, most likely, the application of an inadequate system for fading the star brightness.BVC used to have an original system for fading the star brightness, but because of its influence on the instrument's equilibrium that system had to be removed.The nets for fading the star brightness, made afterwards of densely interwoven silk threads lying on cardboard cariers, dimensions comparable to those of the telescope's dew cap, have not been able to fade the star brightness efficiently.

6. ν VALUES

The ν values are obtained according to (1) by eliminating the systematic differences $\Delta\delta_\delta$, $\Delta\delta_\alpha$ and $\Delta\delta_m$ from the differences $\Delta\delta$.

Let us consider now to what degree the data characterising the sets $\Delta\delta$ are improved by eliminating these systematic differences.

The general data for the ν values corresponding to the data from Table 1 concerning $\Delta\delta$ are presented in Table 4.

Table 4. Values $\overline{\nu}$, ε_ν and n

	FK4	*FK5*	*GC*
$\overline{\nu}$	$0''.00 \pm 0''.02$	$0''.00 \pm 0''.01$	$0''.00 \pm 0''.03$
ε_ν	$\pm 0''.19$	$\pm 0''.20$	$\pm 0''.46$
n	110	236	307

As can be seen from Table 4, the mean systematic differences $\overline{\Delta\delta}$ between BCAD and the fundamental catalogues are eliminated completely.The random errors $\varepsilon_{\Delta\delta}$ are reduced by about 30% for the case of FK4, by about 20% for that of FK5 and for GC by about 13%.

The rate of the ν values within the interval $|0''.2|$ has grown with respect to $\Delta\delta$ from 48% to 68% for the case of FK4 and from 55% to 71% for that of FK5.In the case of GC this rate has grown

within $|0''.3|$ from 47% to 61%.All the ν values for the cases of FK4 and FK5 are within $|0''.5|$.

The number of the ν values within the intervals of $|0''.1|$ for the cases of FK4 and FK5 and within the intervals of $|0''.3|$ for that of GC satisfies the Gaussian normal distribution that is not the case with the $\Delta\delta$ differences.

All abovesaid points out that the ν values are practically affected solely by the random errors of the declinations determination in BCAD and the fundamental catalogues.

7. CONCLUSION

In spite of the presence of the systematic errors of the types $\Delta\delta_\alpha$, $\Delta\delta_\delta$ and $\Delta\delta_m$, by which it is affected, the BCAD Catalogue can satisfy the requirements of modern fundamental astrometry as an absolute catalogue.By applying the obtained systematic differences $\Delta\delta_\alpha$, $\Delta\delta_\delta$ and $\Delta\delta_m$ with respect to the fundamental catalogues FK4, FK5 and GC it is possible to reduce the BCAD Catalogue, if necessary, to the systems of these fundamental catalogues.

Special analyses are required in order to discover the causes for the 2°-periodicity existencein $\Delta\delta_\delta$ and those of the refraction and flexure influences for $\Delta\delta_\alpha$ and $\Delta\delta_\delta$ that have not been calculated.

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REFERENCES

Becq, G., Melchior, P. J.: 1957, *Comm. Obs. R. de Belgique*, 117.

Dejaiffe, R.: 1973, *Publ. Dept. Astron. Belgrade*, **4**, 40.

Jovanović, B., Bozhichkovich, D.: 1987, *Bull. Obs. Astron. Belgrade*, **137**, 41.

Mijatov, M., Teleki, G., Bozhichkovich, D., Trajkovska, V.: 1991, *Bull. Obs. Astron. Belgrade*, **143**, 1.

Mijatov, M., Trajkovska, V.: 1989, *Bull. Obs. Astron. Belgrade*, **140**, 37.

Trajkovska, V.: 1981, *Publ. Astron. Obs. Sarajevo*, **1**, 85.

Usanov, D. S., Teleki, G., Mijatov M.: 1978, *Novye idei v astrometrii* (Trudy 20 - j Astrometricheskoj Konferentsii SSSR), ed. Nauka, Leningrad, 158.

СИСТЕМАТСКЕ ГРЕШКЕ ТИПА $\Delta\delta_\alpha$, $\Delta\delta_\delta$, $\Delta\delta_m$ БЕОГРАДСКОГ КАТАЛОГА АПСОЛУТНИХ ДЕКЛИНАЦИЈА

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Претходно саопштење

У овом раду су приказане систематске разлике $\Delta\delta_\alpha$, $\Delta\delta_\delta$ и $\Delta\delta_m$ Београдског каталога апсолутних деклинација (БКАД) у односу на фундаменталне каталоге ФК4, ФК5 и ГК.

Констатовано је да $\Delta\delta_\delta$ има изразите промене у оквиру зона од 2° по деклинацији, да $\Delta\delta_\alpha$ има промене сезонског карактера нарочито изражених у јесењем и зимском периоду и да зависност од магнитуде $\Delta\delta_m$ није занемарљива.