Bull. Astron. Belgrade № 153 (l996), 85 – 88 **UDC 520.2.028**
Preliminary report

THE FLEXURE OF THE BELGRADE VERTICAL CIRCLE IN THE PERIOD 1976 – 1985

M. Mijatov, I. Pakvor and V. Sekulović

Astronomical Observatory, Volgina 7, 11050 Belgrade, Yugoslavia

(Received: February 15, 1996)

SUMMARY: A review of the results of determinations of the Belgrade Vertical Circle's flexure in the period 1976 – 1985 is given. The flexures were obtained with the aid of the collimators horizontally mounted in E-W direction. From the comparison of the positions of the observed stars with those in catalogues FK4 and FK5, it was shown that the residual flexure of this instrument is of the same order as in the majority of other vertical circles. It is proposed that, besides using collimators for flexure determinations, observations of selected fundamental stars are also to be used for such determinations.

1. INTRODUCTION

The flexure of meridian instruments - the effect wich can cause significant systematic errors in zenith distances determinations - represents one of the main problems at the determination of absolute declinations of stars. Therefore, special care has to be dedicated to this problem at elaborating absolute catalogue of declinations. Because of a very complex variation of this effect, wich can occur at very short intervals, it is desirable to use the flexure obtained during the same observation night. This is not always possible because of considerable random and systematic errors. This effect is specially prominent with vertical circles.

On the basis of previous examinations of this effect in a number of meridian instruments it was found that it can have three main aspects: mechanical flexure - which is the consequence of gravitation effect on the tube, especially on objective and micrometer; thermal flexure - temperature effect on the tube; and apparent flexure due to the tube refraction.

After the successful reconstruction of Belgrade Vertical Circle (BVC) which was carried out in 1974 (Usanov at al., 1978) regular determinations of star declinations by absolute method were started in 1976. These determinations were accompanied by regular flexure measurments during each observation night. In 1983 regular observations with BVC of outer planets of the Solar system were started.These observations were accompanied by flexure determinations too, but with rather reduced frequency, depending on the planets visibility.

In this paper, the flexure determinations of BVC in the period 1976 – 1985, obtained on the base of measurements carried out with horizontally mounted collimators in E-W direction, are shown as well as the results of their comparison with the corresponding data obtained independently by comparison of star observations with FK4 and FK5 positions. These comparisons can answer the question of how real the measured flexures are in the mentioned period.

2. THE RESULTS OF FLEXURE MEASUREMENTS

The flexure measurements in the period 1976–1985 can be divided into three groups for the two above mentioned intervals.

a. The first BVC flexure measurements were carried out during the five year period (1976 – 1980) of star observations. The purpose of these observations was to work out first absolute catalogue of declinations with this instrument (BCAD). The total number of horizontal flexure component determinations was 263. The Bessel method was used for these determinations.

The preliminary results of these measurements are given in Mijatov and Bozhichkovich (1982). More detailed results are given in Mijatov and Trajkovska (1989). The following was found: mechanical flexure $b'_0 = +0.''69$, thermal flexure $+0.''04$ per 1^oC; the maximum variation during the night approx. $0.''5$; seasonal variation during autumn $0.''5$; dependence on the observer and quality of the measurement, in both cases approx. $0.''3$.

b. Dj. Bozhichkovich carried out 157 measurements of horizontal flexure component during absolute observations of 214 FK4 stars (declination zone $-30^o - +90^o$) in 1983 – 1985. The value of the flexure in the whole period was small (mean value $b = +0.''20 \pm 0.''03$) , quite stable and practically independent of the temperature (Bozhichkovich, 1991).

c. V. Trajkovska made observations of the outer planets of the Solar system beginning in 1983. During these observations flexure measurements were also carried out. The values of the flexure were small, which is in harmony with the paragraph b. These values have therefore not been applied in the treatment.

As it can be seen the measured flexure in the two different periods (1976 – 1980 and 1983 – 1985) had different values and different characteristics.

3. ANALYSIS

On the base of the analysis of measured flexure values in the 1976 – 1980 period (Mijatov and Trajkovska, 1989), in the treatment of BCAD stars the following relation was used for flexure b determination during the observed period:

$$b = +0.''69 + 0.''04(t - 12.9) + \Delta_1 + \Delta_2 + \Delta_3. \quad (1)$$

where

$+0.''69$ - measured mechanical flexure b'_o ;

t - temperature;

$0.''04(t - 12.9)$- measured thermal flexure;

Δ_1 - dependence on the difference between observers;

Δ_2 - dependence on the measurement quality estimation of the individual values b;

Δ_3 - tube refraction and other possible effects which are causing diurnal variation of the value b.

Temperature t was measured inside the pavilion during observation of each star.

The correction Δ_1 is the result of the existence of a significant systematic difference of flexure measurements betwen observers who eccomplished about 90% of all measurements. This difference is $MB - B = -0.''26$. Notation MB means that two observers executed the measurements: M. Mijatov (M) carried out collimator and tube settings, as well as corresponding micrometer readings; Dj. Bozhichkovich (B) conducted circle and level readings. These two observers carried out flexure measurements on those nights when they observed stars jointly. During star observations M. Mijatov observed star transits and read the ocular micrometer whilst Dj. Bozhichkovich performed circle and level readings. Notation B means that Dj. Bozhichkovich carried out observations and all the measurements alone. When other observers, which happened only in 1976, made the measurements then $\Delta_1 = 0$ was adopted.

For the correction Δ_2 , the values from Table 1 have been used. The quality estimations of the measurements are as follows: bad, satisfactory, good and very good. These estimations are determined on the base of instrument and collimators behavior during each series of flexure measurements.

Table 1. The quality estimations of the measurements.

QUAL. EST.	$\Delta_2['']$
Bad	+0.14
Satisfactory	+0.05
Good	−0.12
Very good	−0.18

The correction Δ_3 was obtained from the relation:

$$\Delta_3 = -0.''26 + 0.''22T - 0.''03T^2. \quad (2)$$

where T is the time after the end of the evening twilight (the moment of sunset $+0.5h$) Value Δ_3 is positive if $1h < T < 5h$.

The difference MB-B, values in Table 1 and relation (2) are taken from Mijatov and Trajkovska (1989).

The flexure obtained by relation (1) can be considered as measured flexure for two different systems which differ by Δ_1. As $z = z' - b \sin z$ (z is calculated zenith distance while z' represents calculated zenith distance without flexure), the difference of zenith distances of two observers which depends only on Δ_1 is : $z_{MB} - z_B = +0''.18$; $(\overline{sinz} \approx 0.7)$.

In the introduction to BCAD (Mijatov et al, 1991) the corresponding mean systematic difference between two observers is $z_{MB} - z_B = +0''.24$ for all zones of observed zenith distances. This means that the mean systematic difference in the case of non application of Δ_1 would be only $z_{MB} - z_B = +0''.06$. Also zonal systematic differences would be reduced. This shows that the mean flexure system obtained from the measurements of two observers, without Δ_1, is more real. It is necessary to state that the application of Δ_1 in the relation (1) did not affect the zenith distances determinations because Δ_1 was eliminated by the application of zonal zenith distances corrections for differences between observers.

The values of the corrections Δ_2 and Δ_3, for the seasons and for the whole period, are given in Table 2. These data are taken from Mijatov *et al.* (1992).

Table 2. Seasonal values of the corrections Δ_2 and Δ_3

CORRECTIONS	Spring	Summer	Autumn	Winter
Δ_2 [$''$]	0.00	0.00	-0.06	-0.02
Δ_3 [$''$]	$+0.04$	$+0.03$	-0.16	$+0.02$

As seen from Table 2 both corrections, partcularly Δ_3 have greater values in autumn. Therefore, the significant seasonal variation of measured flexure in this period can partly be explained by the existence of these two effects.

By the comparison of BCAD with FK5 (Mijatov et al, 1992) it was shown that the mean systematic error of used flexure is $\Delta b = +0.''14$. The significant seasonal errors of applied flexure of $+0.''25$, $+0.''04$, $+0.''92$ and $-0.''50$ respectively for spring, summer, autumn and winter season do exist. As evident the applied flexure values from relation (1) are most accurate in the summer. Applied values in autumn and winter are distinctly inaccurate.

If in relation (1) we put the following values: $b_0' = +0.''69$, mean temperature effect $-0.''02$, $\Delta_1 = 0$, Δ_2 and Δ_3 from Table 2, and add the mean systematic error $\Delta b = +0.''14$, we will obtain mean real flexure $b = +0.''49$ for the whole five-year period. This value comprises real mechanical flexure b_0 and the whole real effect of other factors. The conception real is taken conditionally considering that real data are those wich are obtained from star observations.

If we take into consideration seasonal flexure values from relation (1) and obtained seasonal corrections to these values from the comparisons with FK5, the following approximate mean flexure values are obtained: $+0.''60$, $+1.''00$, $-0.''30$ and $+0.''60$ respectively for spring, summer, autumn and winter. As seen, real flexure has significant irregularity in autumn in relation with other seasons. Also the summer value is increased relative to the two others.

On the base of parameter Δ_3 in the autumn, given in Table 2, which corresponds to the mean value $T \approx 7h$ in relation (2), the following can be concluded: the instrument's behavior and observation conditions in the second part of the night are not sufficiently examined. This can be the cause of the above mentioned autumn irregularity, too. On the basis of mean seasonal values of real flexure and the conclusion that, in the autumn, serious irregularity exists, it can be supposed that real mechanical flexure b_0 is close to the measured mechanical flexure b_0'. In that case the whole real effect of other factors is approx. $-0''.2$.

Considering the reality of thermal flexure existence in measured values, the mean seasonal values of the real flexure show that such effect does not exist. Even if it exists it is completely repressed by other significant effects.

Because the thermal flexure, as an important effect, probably does not exist, the real mechanical flexure represents the basic part of the flexure in all seasons except in autumn. In this season "additional flexure", which is the result of different influences, in the first place of tube refraction, is greater than $1''$.

Therefore, the application of measured flexure in $1976-1980$ period did not eliminate the real flexure. In autumn the significant uneliminated flexure remained.

The accuracy verification of Dj. Bozhichkovich's own flexure measurements from $1983-1985$, whose characteristics are given in Chapter 2, paragraph b, was effected by comparison of his absolute observations of 212 FK4 stars with the FK4 catalogue (Bozhichkovich, 1991.). Besides others, an analysis using the temperature inside the pavilion and without application of measured flexure was carried out. Bozhichkovich obtained for mechanical flexure $b_0 = -0''.69 \pm 0''.07$ and for thermal flexure $+0''.34(t-10.5)$.

As evident the measured data are uncertain and their application, as stated also by the author, produces significant "residual" flexure. It is also important to stress that real mechanical flexure b_0 in the period $1983-1985$ is distinctly different from the one obtained in the period $1976-1980$.

4. CONCLUSION

The general conclusion which can be drawn on the base of this analysis is that the application of measured flexure, obtained at BVC by horizontal collimators in $1976-1985$, did not allow the elimination of this influence from observed zenith distances. Therefore, the so called residual flexure, as is the case with the majority of vertical circles, remained. In contrast to this, data obtained for flexure from star observations, can be considered as real.

Since the measured flexures do not give reliable values whereas data obtained from star observations do, the flexure of BVC in the future has to be determined not only by means of the collimators but also from observations of fundamental stars.

On the basis of such measurements it is necessary to make further examinations of the reality of the flexure obtained with the aid of horizontal collimators.

Acknowledgements – This work is a part of the project "Astrometrical, Astrodynamical and Astrophysical Researches", supported by Ministry of Science and Technology of Serbia.

REFERENCES

Bozhichkovich, Dj.: 1991, Astrophysics and Space Science, Kluwer Academic Publishers, Dordrecht, Boston, London, 177, 277.

Mijatov, M. and Bozhichkovich, Dj.: 1982, *Bull. Obs. Astron. Belgrade*, **132**, 3.

Mijatov, M., Pakvor, I., Trajkovska, V. and Sekulović, V.: 1992, *Bull. Obs. Astron. Belgrade*, **145**, 125.

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

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

Usanov, D. S., Teleki, G. and Mijatov, M.: 1978, Novye idei v astrometrii (Trudy 20. Astron. Konf.), Ed. Nauka, Leningrad, 158.

САВИЈАЊЕ БЕОГРАДСКОГ ВЕРТИКАЛНОГ КРУГА У ПЕРИОДУ 1976 – 1985

М. Мијатов, И. Паквор и В. Секуловић

Астрономска опсерваторија, Волгина 7, 11050 Београд, Југославија

УДК 520.2.028
Претходно саопштење

У овом раду је дат преглед резултата одређивања савијања Београдског вертикалног круга у току 1976 – 1985 године која су добијена из мерења помоћу хоризонтално постављених колиматора у правцу E-W. Из упоређивања резултата посматраних звезда са положајима у каталозима FK4 и FK5 показано је да и код овог инструмента, као и код већине других вертикалних кругова, постоји неелиминисано савијање. Предлаже се да, поред одређивања савијања помоћу колиматора, убудуће се ова одређивања врше и из посматрања изабраних фундаменталних звезда.