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INSTRUMENT SYSTEM OF THE BELGRADE MERIDIAN CIRCLE

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SUMMARY: Investigation has been executed of the systematic difference „FK4 system minus instrument system" of the Belgrade meridian circle. The data, used in the present analysis, were acquired during two periods – 1973/75 and 1977/78 – by the observation of Küstner series, with a total of about 1000 transits. The data processing was accomplished in two stages. The first stage consisted in the instrument parameters being calculated by the method of least squares. In the second stage (O – C) deviations in both coordinates have been determined. The instrument system is presented in the form $\Delta\alpha_\delta \cos\delta$ and $\Delta\delta_\delta$. Thus it was established that the instrument systems at both clamps were close to each other and that the mean instrument system kept steady over several years.

1. INTRODUCTION

The deduction of the „instrument system" of the Belgrade meridian circle Askania, 190/2578 mm in both coordinates has proceeded on the basis of data, acquired by observations of the, so called, Küstner series (Küstner, 1900). These series comprise, as a rule, all the declinations accessible to observation with a particular instrument. The data, provided by the observation of such series, constitute an exellent means of getting insight into the instrumental features, but also into those of the observer and the totality of conditions of observation (Zverev, 1950).

Underlying the deduction and the analysis of the „instrument system" of the Belgrade meridian circle, of which account is given in the present paper, are observations of the Küstner series, carried out during two periods – June 1973 to July 1975, and March 1977 to March 1978. The stars have been observed at both CE and CW clamps. These series turned out to be unevenly distributed in time, a result of the observation of NPZT stars having been given priority (Sadžakov, 1982).

The observation of a Küstner series took two hours at the most, whereby both of the coordinates have been observed simultaneously. A total of 30 series has been observed, the average number of stars in one series being 28 for the first period and 34 for the second. The declinations of the observed stars ranged from -25^{o} to $+80^{o}.5$ at the upper, and from $+65^{o}$ to $+80^{o}.5$ at the lower transits. The number of stars in the zone $+10^{o}$ to $+60^{o}$ declination is somewhat higher than that in the rest of the meridian arc observed. The stars above $+80^{o}$ declination have also been observed, yet in the second period only, their number being, anyhow, very low.

The time of transit of a star over meridian has been determined by the formula:

$$T = \bar{T} + c_o \sec\delta \mp a \cos\varphi \sec\delta + \frac{\omega}{2} \sec\delta$$

where T – registered time of transit, c_o – collimation, determined with a pair of collimators, a – diurnal aberation, $\frac{\omega}{2}$ – the sum of the contact width and the lost motion.

The reduction of the declinations implied, first of all, the callculation of the circle reading according to the formula:

$$M = \bar{M} + mr + \Delta\lambda + \rho + k tg\delta$$

where $\bar{M}$ – mean value of four microscope – micrometer readings, m – reading of the eyepiece–micrometer, r – the value of the micrometer revolution, $\Delta\lambda$ – correction to the circle division, ρ – refraction, calculated according to Pulkovo Tables, $k tg\delta$ – correction for the curvature of the parallel. Thereafter the quantities $(M-\delta)$ and $(M+\delta)$ were calculated, whereby the former relates to the CE and the latter to the CW clamps. These are the „equator points" – a term to be taken coditionally, for no correction, due to the tube flexure, has been applied to them.

2. PROCESSING OF KÜSTNER SERIES BY THE METHOD OF LEAST SQUARES.

The observations of the Küstner series were processed in two stages: the first stage consisted in the determination of the instrument parameters (Section 2.1. and 2.2.), while the second implied the calculation of the star position deviations and their being arranged according to the declination (Sections 3. and 4.). Here we present the formulae used in the calculation of the instrument parameters.

Bessel formula, otherwise very handy for the reduction of relative observations, supplies three parameters: (u+m), n and c, for the deduction of the right ascension system of the instrument. Again, the parameter M_o (equator point) or the parameter M_z (zenith point) are used in the derivation of the declination system of the instrument.

The determination of the instrument parameters by the method of least squares proved suitable to a high degree. Besides, it is in harmony with the principle of homogeneity as defined by Khomik (1975). In this, I am anticipated by at least three authors: Bykov (1977) at the Tashkent observatory, and Izvekov, Izvekova (1965) at the Pulkovo observatory.

2.1. Right ascension system and the formation of equations of deviation.

Bessel formula, furnishing the observed right ascension can be written in the form:

$$\alpha' = T + (u + m) + n\, tg\delta.$$

Denoting the difference of the catalogue right ascension α and the observed right ascension α' by $\Delta\alpha$ we obtain:

$$-\Delta\alpha = -(\alpha - T) + (u + m) + n tg\delta.$$

where $(\alpha - T)$ is a known quantity. The latter equation should, in principle, enclose the terms which account for the variations of the parameters (u + m) and n. However, a preliminary investigation disclosed that the linear variation in time of (u + m) was the only one deserving attention. This variation will be expressed by the term $\tau(\alpha - \alpha_o)$, where α_o is some apriori given right ascension. It is, besides, necessary for all the deviations to be reduced to the equator. Thus we have:

$$-\Delta\alpha\cos\delta = -(\alpha - T)\cos\delta + (u + m)\cos\delta + n \sin\delta + \tau(\alpha - \alpha_o)\cos\delta \quad (1)$$

Under the first variant the instrument parameters and the deviations $\Delta\alpha$ have been determined by the formula (1). However, it appeared necessary to correct the collimation c in the equations (1). Accordingly, we had to resolve – under the second variant – the equations

$$-\Delta\alpha\cos\delta = -(\alpha - T)\cos\delta + \Delta c + (u + m)\cos\delta + n \sin\delta + \tau(\alpha - \alpha_o)\cos\delta \quad (2)$$

The unknowns could be well separated from each other thanks to the Küstner series covering a very long arc of the meridian. This implied great weights of the coefficients, i.e. their values were trusworthy. It should be noted, however, that the lower transits (their number is, anyhow, very small), on account of the deviations in them being too great, are omitted from our calculations, i.e. only upper transits have been dealt with. This, also, must have contributed to the accuracy.

2.2. Declination system of the meridian circle and formation of the equations of deviations.

In denoting by $\Delta\delta$ the difference of the declination δ, taken from the fundamental catalogue and the observed declination δ', the equation of deviation assume the form:

CE: $\Delta\delta = -(M - \delta) + M_o$
CW: $-\Delta\delta = -(M + \delta) + M_o$

where $(M - \delta)$ and $(M + \delta)$ are known quantities.

Küstner series, being extended over a very long arc of the meridian, allow good determination of the flexure. Hence, the above equations can be expanded by the two first Fourier terms: a cos z and b sin z, the former standing for the horizontal and the latter for the vertical flexure components (measurable with the collimators). Preliminary testings proved that the variation in time $\tau'(\alpha - \alpha_o)$ of the equator point was considerable, so that it had to be taken into account. Accordingly, the equations of conditions assume the form:

$$\pm \Delta\delta = -(M \mp \delta) + M_o + a \cos z + b \sin z + \tau'(\alpha - \alpha_o) \quad (3)$$

where the circle reading M does not enclose the correction for the flexure.

In the preliminary deduction of the instrument system the horizontal flexure component was the only one determined, i.e. the vertical component was disregarded. We proceeded in this way for two reasons: due to the specific distribution of stars on our programme it proved difficult to separate the M_o values from those of a; second, the a values were found greatly changeable from one series to the next. Moreover, the a values had to be turned down in a considerable number of series on account of their large errors. However, the results obtained clearly indicated the presence of some influence, proportional to cos z, or to some related function, symetrical relative to the zenith. This was the reson why, besides the first variant, involving the solution of the equations (3), an additional variant:

$$\pm \Delta\delta = -(M \mp \delta) + M_o + b \sin z + \kappa \sec^2 z + r'(\alpha - \alpha_o) \quad (4)$$

has been applied.

As evident, in the second variant the assumption is made of the effect of the anomalous refraction being expressible by a term with $\sec^2 z$ (Teleki, 1967).

3. RIGHT ASCENSION SYSTEM OF THE MERIDIAN CIRCLE

The deduction of the right-ascension system has been accomplished in two stages. First, the set of normal equations (1) and (2) has been resolved and the values of the instrument parameters calculated and discussed. Thereupon, the deviations have been determined and grouped according to five degree zones. The instrument system has been deduced upon smoothing these deviations. In order to acquire the picture of the instrument system as best as possible, the deviations in the first period (1973/1975) have separately been treated from those in the second period (1977/78), as have been the deviations associated with CE and those in the CW positions.

The instrument parameters have been determined by the equation (1) in the first and by the equation (2) in the second variant, the method of least squares being used with both variants. The only difference cosisted in that, under the second variant, the collimation error has also been determined.

It should be indicated that T has been chosen such, that the differences $(\alpha - T)$ was always positive and less than 60^s. The final results have not, thereby, been affected, but the quantity (u + m) underwent arbitrary changes from one series to the next.

As for the weight unit error, it is larger under the first variant, amounting there, on the average, to $\pm 0\overset{s}{.}0258$, while its value in the second variant attains $\pm 0\overset{s}{.}0240$.

3.1. Analysis of the parameters c and n

It has been indicated above that the parameter (u + m) assumed, on account of the way of its determination, arbitrary values fromone series to another. Investigation of the behavour of the parameters c and n appeared, therefore, all the more interesting, as there have been no mechanical interferences with the instrument over long time intervals.

On solving the set of normal equations, the correction to the collimation has been derived. Its mean value for the first period (1973/75) is $-0.^s026$. Its value for the second period is $-0^s.106$.

The difference between the collimation obtained from the astronomical observations and the one resulting from the collimator readings, as well considerable scattering of $\Delta\alpha \cos\delta$ at lower transits, made us suspect that the collimation value, used in the reduction of observations, had not been a correct one. To clarify the matter we first checked the signs and the micrometer middle wire reading. Thereafter the dead motion and the contact width have been put under scrutiny. These two parameters have, anyhow, been controlled during both periods of observation, at intervals judged appropriate. It was found, however, that the reduction have been performed with correct values of the parameters. The question of the origin of the inconsitencies referred to above remains, therefore, unanswered.

The possibility of this difference originating from the pivot irregularities has also been considered. But the joint effect, produced by the pivots–balancing system on the observation results, even thought it can be considerable, cannot amount to 0ˢ.1 (Mijatov et al. 1975) – the value we obtained for the correction to the collimation for the period 1977/78.

The correction to the collimation, resulting from the observation of the Küstner series could not, at least for the time being, be accounted for. Special, supplemental, observations are obviously necessary for an adequate explanation to be provided. But one can surmise, in view of the collimation being variable with the zenith distance (Pil'nik, 1957) and being different at CE and CW clamps (Pil'nik, 1960), that our instrument is subjected to the same effects. On the other hand, it is quite conceivable that there can be a difference between the collimation, as furnished by the collimator readings, i.e. with the instrument occupying a horizontal position, and the one, resulting from the observation of stars at zenith distances varying from about 75° to 0°. Still other origins of this discrepancy must also be reckoned with.

As for the changes in the collimation value in the course of a year, it could be established by applying the Abbe's criterion (Linik, 1958), that none existed over the period 1973/75, while in the period 1977/78 we had $p < 0.05$. The values of c, assumed dependent on the temperature, have also been investigated by applying the same criterion. Such a dependence could not, however, be confirmed.

The values of the parameter n display an increasing trend during the first 20 series, especially during 1975, so that no special criterion is even needed for the systematics to be brought out. Subsequent to the 20th series the instrument's azimuth and the inclination have been adjusted so as to diminish the amount of n.

3.2. Derivation of the right ascension system

Following the determination of (u + m) and n under the first variant, and Δc, (u + m) and n under the second, the deviations $\Delta\alpha \cos\delta$ in each one of the observational series have been calculated. The arc of the meridian, comprised between −22°.5 and 117°.5 declination, has been divided into five degree zones. Further, the values of $\Delta\alpha \cos\delta$ have been arranged according to declination. A small number of stars from −22°.5 to −24° declination have been included in the zone −22°.5 to −17°.5 declination. The data from the first period have separately been treated from those in the second period. Likewise, the CE data have separately been treated from the CW data.

Next, the mean values of the relevant deviations have been deduced. This was followed by deducing the systematic runs of E_a, E_b, W_a and W_b, whereby the use has been made of Abbe's criterion. The notation a relates to the period 1973/75 and the notation b to the period 1977/78. the systematic run of the quantities $S_a = E_a + W_a$, $S_b = E_b + W_b$, $S_E = E_a + E_b$ and $S_W = W_a + W_b$ have also been derived.

Thus could be found that the mean values of the deviations by zones, as derived under the first variant, exhibit a systematic run for the cases W_a, W_b, S_b, S_E and S_W. No systematic runs have been established for any of the quantities under the second varinat.

The mean right ascension systems are illustrated graphically. The Graphs 1 and 2 reproduce the results under

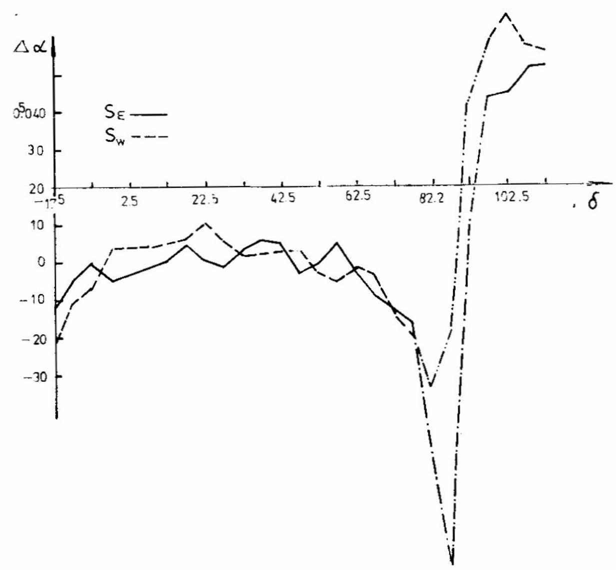

Fig. 1. Mean right ascension systems at clamp E (marked S_E) and at clamp W (marked S_W) for both (1973–75 and 1977–78) periods of observation – first version.

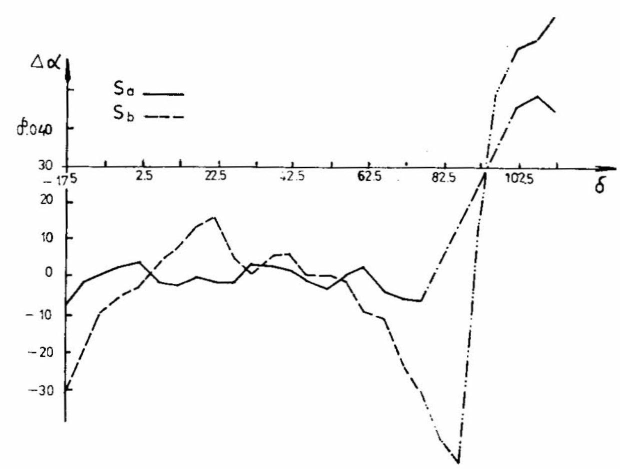

Fig. 2. Mean right ascension system for the periods 1973–75 (marked S_a) and 1977–78 (marked S_b) – first version.

the first variant. The Graphs 3 and 4 represent the results under the second variant. The Graph 5 reproduced the mean right ascension system from both periods. Very few stars have been observed in the zone + 80° to +90° declination, alike at upper and the lower transits. The results, relating to this zone, are marked differently in the graph.

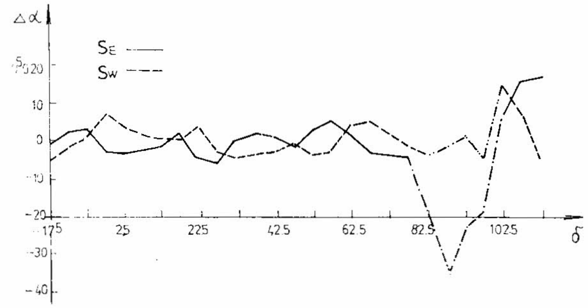

Fig. 3. Mean right ascension systems at clamp E (marked S_E) and at clamp W (marked S_W) for both (1973–75 and 1977–78) periods – second version.

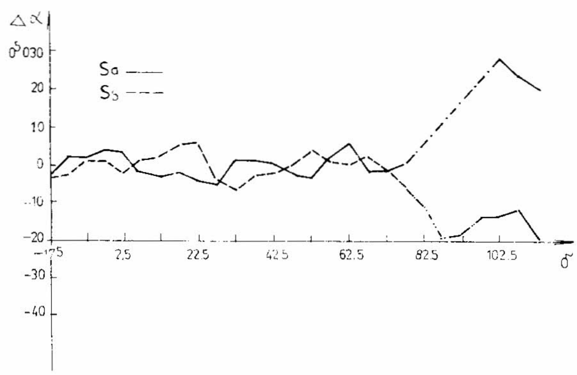

Fig. 4. Mean right ascension system for the period 1973–75 (marked S_a) and the period 1977–78 (marked S_b) – second version.

The graphs display a far closed accordance of the right ascension system in the second variant, except for the lower transits. These latter were therefore ignored in the subsequent treating. Why the lower transits differ so sharply from the upper ones cannot, at least for the time being, be adequately answered. Besides graphic presentation, the coefficients of correlation have been calculated. The objective pursued was the finding out of the numerically expressed measure of accordance of the CE and CW systems for both periods, as well as the degree of accordance of the mean systems for both periods. The results are shown in Table I.

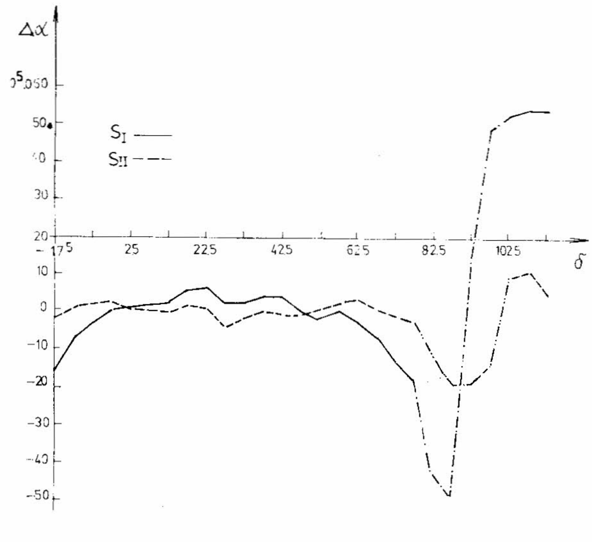

Fig. 5. Mean right ascension system according to the first version (marked S_I) and the second version (marked S_{II}).

Table I. Correlation coefficients between particular right ascension systems at various clamp positions in both periods of observation.

	I variant	II variant
	R_I	R_{II}
E_a/W_a	0.01 ± 0.22	– 0.22 ± 0.21
E_b/W_b	+0.88 ± 0.05	– 0.02 ± 0.22
E_a/E_b	+0.46 ± 0.18	+ 0.27 ± 0.21
W_a/W_b	+0.45 ± 0.18	– 0.08 ± 0.22
S_a/S_b	+0.57 ± 0.15	– 0.26 ± 0.21
S_E/S_W	+0.73 ± 0.10	– 0.39 ± 0.19
S_I/S_{II}	R = + 0.26 ± 0.21	

The closest accordance is found with the E_b and W_b curves under the first variant, i.e. with the uncorrected collimation. As has already been indicated, this correction for the second period amounts to – 1ˢ.106 on the average.

The correlation in the second variant, in which the corrected collimation is operated with, is practically nonexistent. The systematic run in declination, as evident from the graph, is insignificant for the upper transits – a result that was to be expected. The coefficient of correlation has been calculated for the upper transits only.

As evident, the mean right ascension system under the first variant, after (u + m), n and the variation in time (in as much as the latter existed) have been found, exhibits a variation in declination. Expecially prononouced is the difference between the northern stars at upper transit and those same stars at lower transit. Nearly identical curve has been obtained in the preliminary examination of the right ascension system, whereby the procedure consisted in determining first the values of n for each one of the series observed and thereafter representing the system in the form Δ (u + m) variation in declination.

In contrast to the first variant, the run in declination as obtained in the second variant -- in which account is taken, among other things, of the correction to the collimation deduced from the observations -- is virtually zero for all the zones up to + 80° declination. However, a slight systematic difference can be discerned in the zone beyond + 80°, but it must be remarked that there far fewer stars have been observed than in the rest of the zones.

The deviations under the second variant are small (hardly above the errors of observation), being confined between – 0ˢ007 and + 0ˢ008. The picture is completed by the following facts: The CE and CW systems under both variants are similar; the variations of the parameters c and n are slight. This cannot but be taken as evidence of the Belgrade meridian circle being of satisfactory quality. There still remain, as open questions, the correction to the collimation (or the quantity behaving like it), and the difference between the right ascension system resulting from the upper transits and the one associated with the lower transits.

4. DECLINATION SYSTEM OF THE MERIDIAN CIRCLE

The declination system has been deduced in analogous way to that applied with the right ascension system. First the instrument parameters have been calculated and the deviations arranged according to the five degree zones. The means have been calculated separately for the CE and CW clamps, as have the means corresponding to the first and the second periods.

Küstner series have been processed according to two variants: underlying the first variant is the equation (3); underlying the second variant is the equation (4). Thereafter the attempt is made to remove the effect of refraction on the observation. The adequacy of this approach of ours remains to be confirmed since no reference to any analogous treatment could be found in the literature. The occasion will present itself at the definite deduction of the declinations system.

The mean error of the weight unit is ± 0".406 for the first variant. Under the second variant it amount to ±0."417.

4.1. Discussion of the parameters a, b and κ

As our results indicate, the equator point M_0 assumes different values, exhibiting far greater changes than those found with a, b and κ. These changes are, sometimes, even jumplike. An adjustment of the microscope–micrometer alone is sufficient to provoke appreciable changes in its value. A conclusive discussion of the M_0 variation for several nights, of those depending on the temperature in particular, appears therefore impossible–at least in the present case.

It seems that the horizontal flexure component, held usually as the mean component of the declination system, is the parameter which lends itself to good determination from the astronomical observations. This flexure component in our meridian circle attains considerable values, mostly above 2 seconds of arc.

The examination of the flexure b variations from one night to another, as well as that of the temperature dependent variations, did not furnish any indication of them bearing a systematic character. It was ineresting to compare the values of this flexure component deduced from the astronomical observations and those provided with the aid of collimators. Unfortunately, this kind of flexure measurements are available for only 12 last observing nights (1977/78). Thus could be established that the flexure values, resulting from the astronomical observations, amounting to about 2".4, were about twice the values provided by the collimator readings, which attained 1".4.

We are unable to offer definite interpretation of this discrepancy (the same applies to the collimation). In this, one should, possibly, proceed from the fact that the instrument tube is placed horizontally at measuring the flexure with the collimators. On the other hand, this same tube is inclined during observation.

This should be connected with the fact that the instrument's objective is fixed at the tube end at three equidistant points. Thus, the objective is – at the same clamp – differently supported for its south, than for its north zenith distances. The situation is reversed after the clamp is changed.

Absolute value of the parameter a ranges from 0" to 3". However, this value does not seem to be particularly well determined. Yet, it turned out that the declination system is improved by introducing the term acos z. This system is also improved by introducing the term $\kappa \sec^2 z$ in place of acos z, but somewhat less. But the lesser weight unit error, and the lesser deviations of the mean system, resulting from introducing the term acos z, suggest that this term is to preferred.

Simultaneous determination of the parameters M_0, a and κ has also been tried. However, due to their being difficult of mutual separation, the results obtained were very poor.

It could be established by employing the Abbe's criterion that *a* was not experiencing systematic variations from one night to the next, nor is there any systematic variation with temperature.

4.2. Derivation of the declination system

On calculating the parameters M_0 a, b and τ' under the first, and M_0, b, κ and τ' the second wariant, deviations have been found and arranged according to groups and zones, in analogy to what has been done in treating the right ascensions.

Next, the variation has been examined for each of the groups, i.e. E'_a, E'_b, W'_a, W'_b as well as for the mean systems S'_a, S'_b, S'_E, S'_W. The examination has been performed by using the Abbe's criterion.

Thus it turned out hat E'_b and S'_b were exhibiting systematic variation under the first variant. Under the second variant systematic variation in declination has been stated in E'_b, S'_a, S'_E and S'_W.

The results of the declination system determination are illustrated graphically. The graphs 6 and 7 reproduce the results obtained under the first variant and the graphs 8 and 9 those obtained under the second variant.

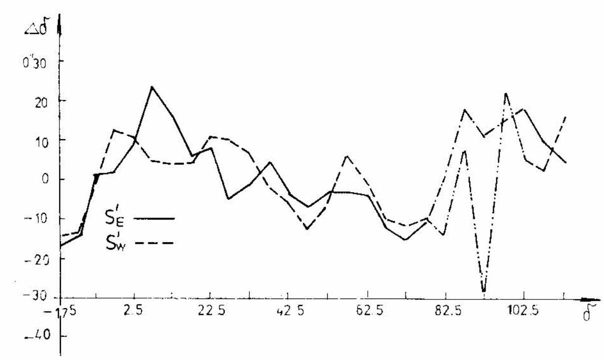

Fig. 6. Mean declination systems at clamp E (marked S'_E) and at clamp W (marked S'_W) for both (1973–75 and 1977–78) periods of observation – first version.

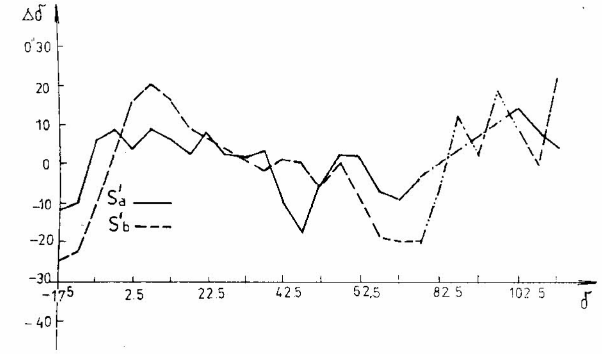

Fig. 7. Mean declination system for the periods 1973–75 (marked S'_a) and 1977–78 (marked S'_b) – first version.

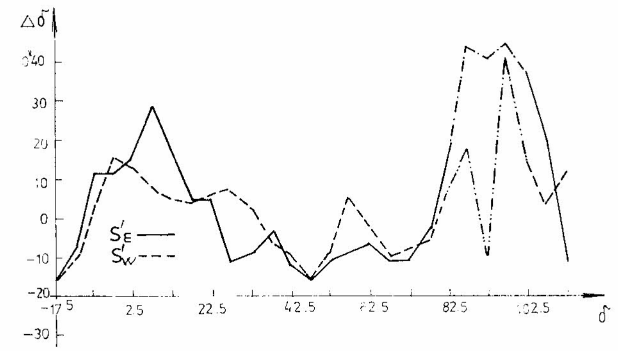

Fig. 8. Mean declination systems at clamp E (marked S'_E) and at clamp W (marked S'_W) for both (1973–75 and 1977–78) periods of observation – second version.

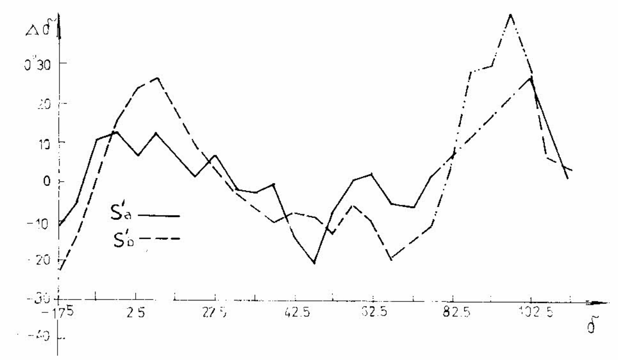

Fig. 9. Mean declination system for the period 1973–75 (marked S'_a) and the period 1977–78 (marked S'_b) – second version.

The graph 10 illustrates the mean declination system, i.e. the results of the first and the second variants are compared.

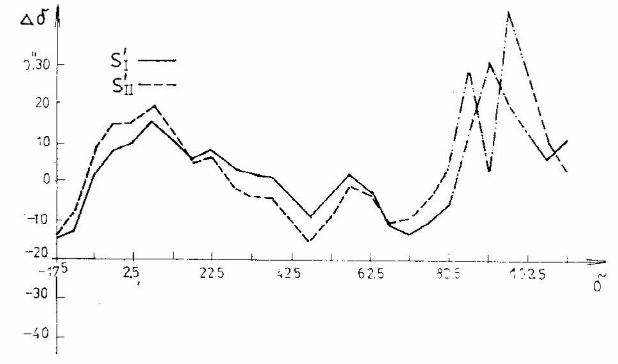

Fig. 10. Mean declination system according to the first version (marked S'_I) and the second version (marked S'_{II}).

The CE and CW systems, as well as those resulting from the first and the second periods, exhibit a clear similarity. It is also evident that the mean system exhibits certain run in declination which persits, in spite of the terms with cos z or $\sec^2 z$ having been applied to.

The similarity of the declination systems at both clamps and in both periods of observation, as well as the absence of the variation in time along with the instrument system being confined between $-0''.25$ and $+0''.29$ all this tends to suggest that our meridian instrument is furnishing satisfactory results concerning declinations as well.

Here too, in analogy to what has been done with the right ascension system, the coefficients of correlation have been determined for particular cases. These coefficients are summarized in Table II.

Table II. Correlation coefficients between particular declination systems at various clamp positions in both periods of observation

	I variant	II variant
	R_I	R_{II}
E'_a/W'_a	0.28 ± 0.19	0.47 ± 0.16
E'_b/W'_b	0.64 ± 0.12	0.45 ± 0.17
E'_a/E'_b	0.67 ± 0.12	0.78 ± 0.08
W'_a/W'_b	0.19 ± 0.20	0.32 ± 0.19
S'_a/S'_b	0.62 ± 0.13	0.79 ± 0.08
S'_E/S'_W	0.66 ± 0.12	0.68 ± 0.11
S'_I/S'_{II}	$R = 0.86 \pm 0.05$	

The accordance of the E'_b and W'_b systems is closer for the first variant. In all other instances the accordance is found closer with the second variant.

Significant values of the correlation coefficients in both variants, in connection with the value resulting from the comparison of the two variants, are an indication of a systematic variation with declination, not removed by the introduction in the equation of condition of either the term acosz or the term $\kappa \sec^2 z$.

5. CONCLUSIONS

The discussion of the instrument parameters and the instrument system leads to the following conclusions:

1. The presentation of the instrument system in the form of $\Delta\alpha_\delta \cos\delta$ and $\Delta\delta_\delta$ provides a more complete picture of the instrument than it was possible by its presentation by way of runs of individual parameters n, (u + m) and M_o. This is particularly true of the right ascension system, keeping in mind that the run of the parameter n does not affect the transits of the equatorial stars.
2. The method of least squares proved convenient as it allowed the parameters to be deduced in various combinations, whereupon the most appropriate solutations could be decided upon.
3. Close similarity is stated of the right ascension system for both clamps. Moreover, the instrument system did not undergo appreciable changes over longer periods. On applying the correction Δc, the instrument system was virtually reduced to null.
   Concerning the lower transits, there appear such deviations which evade being accounted for without additional observations and investigations. The difference between the collimation errors as deduced from the observations and those resulting from the collimators reading are still to be inquired into. It is likely that underlying this difference is the variability of the collimation error with the zenith distance, although other origins cannot be ruled out.
4. The declination system at both clamps also display similarity. No significant changes over several years are found. The results point to the existence of the vertical component in the instrument flexure as being real. Here, too, a difference between the flexure, measured with the collimators and the one resulting from the astronomical observations has been stated, possibly a consequence of the objective displacement in its supports.
5. The investigations have demonstrated that the Belgrade meridian circle is capable of yielding reliable results. The instrument system is not pronounced and its changes over several years are slight. Attention should be paid in the forthcoming observations to the parameter determination, particularly so if observations are made over extended declination zones.

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ANALYSIS OF SOME CHARACTERISTICS OF THE LEVELS OF THE BELGRADE VERTICAL CIRCLE

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SUMMARY: On the basis of laboratory examinations of the levels of the Belgrade Vertical Circle, executed in the period 1963 to 1981, mean division values, as well as their dependence on time, air temperature and bubble length, are derived. The formulae (4) and (5) are proposed for use in the reduction of astronomical observations. The level division values, as derived by laboratory measurements, proved to fit in the regular astronomical observations made with our Vertical Circle.

1. ORGANIZATION OF LABORATORY INVESTIGATIONS

Account is given in the present paper of the results of investigation of two levels of the Belgrade Large Verical Circle (Askania, N° 80118), with which the inclination of the LVC vertical axis is being determined. The objective of the investigation performed was the determination of the level division values to be applied in the reduction of the astronomical observations carried out with this instrument. The level investigation started in 1963, as noted in Tables I and II. The lower level (L) on the instrument has been examined 63 times, while the number of investigations of the upper level (U) amounts to 48. The method employed at first was that of Vassiley, but alter on we passed to the Wanach method. The measurements have, overwhemingly, been executed in a special box (thus. in an insulated medium), whereby several investigators have taken part. A minor part of examinations has been performed in the Geodetic –Geophysical Laboratory of the Hungarian Academy of Sciences (Sopron, Hungary) with various level triers, under various conditions, including artificial heating. Yet, these additional examinations failed to affect, to any appreciable degree, the results originally derived at our observatory.

The examinations have been carried out at various temperatures: they ranged from – 3°.5 C up to + 27°.0 C with the L level and from – 3°.6 C up to + 27°.0 for the U level. The L level bubble lenghts have been varied from 16.2 to 30.0 divisions and those of the U level from 16.7 to 30.0 divisions. In effecting these investigations we benefited from earlier experiences of Teleki and Grujić (1982).

Two level triers have been used in these examinations: „Askania" (N° 630348) as long as Wanach method was applied, and the level trier „Bamberg" (N° 630348) since our switching to the Vassilev method. In the reduction of our measurements the values of the level trier divisions, as furnished by the expressions below, have been used, respectively:

$$p\,(\text{Askania}) = 0''.99983 + 0''.00013\,(t_i - 13^\circ.8)$$
$$p\,(\text{Bamberg}) = 0''.99302 + 0''.00006\,(t_i - 14^\circ.7)$$

As evident, the level trier division values are subject to the temperature t_i effects. The level trier divided circle was moved by one division in the examinations under the Vanach method, while the motion from 2 to 3 divisions has been applied with the Vassilev method. The positions of the level bubble ends have been read up at 1.5 to 2 minutes intervals. The air temperature changes during any one of the sets of measurements did not exceed 0°.2 C.

2. ANALYSIS OF MEASUREMENTS MADE IN THE PERIOD 1963 to 1981

The level division values obtained (Tables I and II) have been submited to analysis with respect to three factors: temperature, bubble length and time. The aim we thereby had in view was the establishing of the best possible relation for the calculation of the division values. Three forms of such relation were alternatively adopted:

$$\lambda_i = \lambda_{01} + \alpha_1 (T_i - T_o) + \beta_1 (t_i - t_o) + \gamma_1 (l_i - l_o) \quad (1)$$

$$\lambda_i = \lambda_{02} + \alpha_2 (T_i - T_o) + \beta_2 (t_i - t_o) + \gamma_2 (l_i - l_o) + \delta (t_i - t_o)^2 + \xi (l_i - l_o)^2 \quad (2)$$

$$\lambda_i = \lambda_{03} \exp [\alpha_3 (T_i - T_o) + \beta_3 (t_i - t_o) + \gamma_3 (l_i - l_o)] \quad (3)$$

Table I. Results of the L level investigation in the period 1963–1981.

N°	Date in fractions of year	Observers	Method	t	lm	Mean division value	Quality mark	Locality of measurement
1	1963.57	MM	Va	25°.6C	20.7p	1".1810		Students' pavilion
2	.58	MM	Va	25.4	20.4	1.1669		Students' pavilion
3	.64	SS	Va	17.6	20.0	1.1084		Main building
4	.64	SS	Va	17.8	26.0	1.1082		Main building
5	1964.07	MM	Va	−0.5	25.5	1.0319		Geodetic pavilion
6	.08	SS	Va	−3.5	21.1	1.0746		Geodetic pavilion
7	1963.74	GT	Vn	18.7	20.0	1.1073	3	Sopron
8	.74	GA	Vn	18.5	20.0	1.1288	3	"
9	.74	GT	Vn	19.0	25.0	1.1317	1	"
10	.74	GA	Vn	19.0	25.0	1.1454	1	"
11	.75	GT	Vn	17.4	30.0	1.1207	1	"
12	.75	GA	Vn	17.5	30.0	1.0953	1	"
13	.75	photograph.	Vn	15.0	20.0	1.0908	3	"
14	.75	"	Vn	15.0	25.0	1.0760	3	"
15	.75	photograph.	Vn	15.0	30.0	1.0554	1	Sopron
16	1964.76	GT	Vn	18.0	25.0	1.1228	2	Sopron (with heating)
17	.76	GA	Vn	18.0	25.0	1.1214	1	"
18	.76	GT	Vn	18.0	25.0	1.1141	1	"
19	.76	GA	Vn	18.0	25.0	1.1212	1	Sopron (with heating)
20	.79	MM	Vn	17.1	22.1	1.1090	2	Levels' box
21	.79	SS	Vn	15.9	22.8	1.1167	2	"
22	1965.95	MM	Vn	15.1	23.7	1.1295	2	"
23	.95	SS	Vn	15.5	23.6	1.1882	4	"
24	.96	SS	Vn	15.7	23.1	1.0412	3	"
25	.96	MM	Vn	16.0	23.1	1.1475	3	"
26	.96	MM	Vn	15.1	24.0	1.1213	2	"
27	.96	SS	Vn	15.5	23.5	1.1029	4	"
28	.99	MM	Vn	15.6	22.4	1.1181	2	"
29	.99	SS	Vn	15.9	22.3	1.1229	3	"
30	1966.01	MM	Vn	12.8	22.9	1.0798	3	"
31	.01	SS	Vn	13.6	22.8	1.1295	3	"
32	.11	MM	Vn	15.4	23.0	1.1915	3	"
33	.11	SS	Vn	16.1	23.0	1.0289	1	"
34	.15	MM	Vn	16.9	21.2	1.1800	2	"
35	.15	SS	Vn	17.1	21.2	0.9960	1	"
36	.82	SS	Vn	17.4	23.2	1.1537	1	"
37	.82	MM	Vn	17.0	23.3	1.1302	2	"
38	.83	SS	Vn	16.2	23.4	1.0811	2	"
39	1967.89	MM	Vn	13.5	23.8	1.1419	1	"
40	.89	SS	Vn	12.6	24.3	1.1651	1	"
41	1968.78	MM	Vn	12.9	22.5	1.1122	3	"
42	.78	BK	Vn	13.1	22.4	1.1463	2	"
43	1976.16	MM	Vn	4.6	21.6	1.0010	4	"
44	.16	MM	Vn	4.8	21.7	0.9820	2	"
45	.19	GT	Vn	2.0	23.2	0.9923	1	"
46	1981.07	DB	Vn	2.5	18.6	0.9106	2	"
47	.09	MM	Vn	3.6	21.4	1.0217	1	"
48	.09	DB	Vn	3.4	22.0	0.9750	2	"
49	.09	MM	Vn	2.8	22.0	0.9420	1	"
50	.09	MM	Vn	12.1	20.9	0.9807	1	"
51	.09	DB	Vn	12.3	20.9	0.9671	1	"
52	.11	MM	Vn	10.1	20.3	0.9476	1	"
53	.11	VT	Vn	10.8	20.2	0.9528	1	"
54	.11	VT	Vn	12.4	17.4	0.9464	1	"
55	.11	MM	Vn	12.7	17.2	0.9458	2	"
56	.12	DB	Vn	11.7	17.8	0.9644	2	"
57	.12	MM	Vn	14.4	16.2	0.9330	2	"
58	.13	VT	Vn	1.6	18.3	0.9493	2	"
59	.13	MM	Vn	2.2	18.2	0.9330	2	"
60	.13	VT	Vn	2.6	18.0	0.9167	3	"
61	.13	DB	Vn	2.7	18.2	0.9251	2	"
62	.15	VT	Vn	2.3	20.1	0.9191	2	"
63	1981.15	MM	Vn	3.7	19.9	0.9175	1	Levels' box

Table II. Results of the U level investigation in the period 1963–1981. For notations see explanation in Table 1

N°	Date in fractions of year	Observers	Method	t_i	l_m	Mean division value	Quality mark	Locality of measurement
1	1963.67	MM	Va	26°.2 C	19.4p	1".1024		Students' pavilion
2	.67	MM	Va	20.0	25.1	1.1274		Students'pavilion
3	.73	SS	Va	17.8	20.0	1.0825		Main building
4	.73	SS	Va	17.8	26.6	1.0891		Main building
5	1964.04	SS	Va	−2.6	20.3	1.0280		Geodetic pavilion
6	.04	MM	Va	−3.6	25.4	1.0465		Geodetic pavilion
7	1963.75	GA	Vn	13.8	20.0	1.0862	3	Sopron
8	.75	GT	Vn	18.7	25.0	1.0856	1	"
9	.75	GA	Vn	18.8	25.0	1.0880	1	"
10	.76	GA	Vn	17.8	30.0	1.0831	3	"
11	.76	GT	Vn	17.8	30.0	1.0807	1	"
12	.76	GT	Vn	18.0	20.0	1.1189	3	"
13	.76	photograph.	Vn	18.0	20.0	1.0289	1	"
14	.76	"	Vn	18.0	25.0	1.0583	2	"
15	.76	photograph.	Vn	18.0	30.0	1.0172	1	Sopron
16	1964.81	MM	Vn	14.7	23.1	1.1200	2	Levels' box
17	.81	SS	Vn	15.0	23.1	1.1156	1	"
18	.81	MM	Vn	14.9	22.3	1.0855	1	"
19	.81	SS	Vn	15.4	22.2	1.0756	1	"
20	1966.13	MM	Vn	18.0	24.0	1.1216	2	"
21	.13	SS	Vn	17.7	24.4	1.1202	1	"
22	.84	SS	Vn	14.0	23.0	1.0899	1	"
23	.84	MM	Vn	14.0	23.1	1.1225	1	"
24	1967.86	MM	Vn	14.2	24.1	1.1307	2	"
25	.86	SS	Vn	13.9	24.2	1.1266	2	"
26	1968.90	MM	Vn	15.0	22.3	1.1472	2	"
27	.91	BK	Vn	14.2	22.9	1.1232	2	"
28	1976.16	MM	Vn	3.8	22.2	0.8329	2	"
29	.16	MM	Vn	4.1	22.4	0.9062	1	"
30	.17	GT	Vn	2.1	21.9	0.8922	2	"
31	1981.09	MM	Vn	3.0	21.2	1.0006	4	"
32	.09	DB	Vn	3.2	21.5	0.9725	1	"
33	.09	MM	Vn	3.2	21.3	0.9645	1	"
34	.09	MM	Vn	10.2	22.0	0.9905	1	"
35	.09	DB	Vn	11.2	21.7	0.9941	1	"
36	.11	VT	Vn	11.5	20.3	0.9629	1	"
37	.11	MM	Vn	11.4	20.4	0.9773	2	"
38	.11	VT	Vn	11.5	17.0	0.9516	2	"
39	.11	MM	Vn	12.2	16.7	0.9591	2	"
40	.12	DB	Vn	13.5	17.7	0.9604	2	"
41	.12	MM	Vn	14.0	17.2	0.9762	2	"
42	.13	VT	Vn	2.4	17.1	0.9545	3	"
43	.13	MM	Vn	2.7	17.0	0.9458	2	"
44	.13	VT	Vn	1.6	17.5	0.9257	2	"
45	.13	DB	Vn	2.5	17.3	0.9364	1	"
46	.15	DB	Vn	2.9	17.8	0.9199	2	"
47	.15	VT	Vn	2.8	20.1	0.9135	2	"
48	1981.15	MM	Vn	3.0	20.1	0.9365	1	Levels' box

Labels of the Tables I and II:

Observers: MM – M. Mijatov, SS – S. Sadžakov, GT – G. Teleki, GA – G. Alpar, BK – B. Kubičela, DB – Dj. Bozhichkovich, VT – V. Trajkovska.
Method: Va – Vassilev, Vn – Wanach
Quality marks: 1 – very good, 2 – good, 3 – fair, 4 – bad (these marks are provided by the Wanach scale and relate solely to this method).

where:

λ_i – division value (in seconds of arc), resulting from the i-th measurement

λ_{ok} – most probable division value (in seconds of arc) at T_o, t_o and l_o defined by:

$$T_o = \frac{\Sigma T_i}{n}, \quad t_o = \frac{\Sigma t_i}{n}, \quad l_o = \frac{\Sigma l_i}{n};$$

k = 1, 2 or 3 are indices in expressions (1), (2) and (3)

n – number of measurements

T_i – time of the i-th measurements (in fractions of year)

t_i – temperature with the i-th measurement

l_i – level bubble length with the i-th measurement (in fractions of the level division)

α_k – time coefficient

β_k – temperature coefficient

γ_k – bubble length coefficient

δ and ξ – coefficients with the second order terms.

No quadratic term in T appears in (2), for the preliminary graphic illustration of the division values as a function of time disclosed an umistakable linear dependence.

The solution of 63 equations relating to the level L and of 48 equations pertaining to the level U by the least square method furnished the most probable mean division values of both levels valid for $t' = +12^\circ.0$ C, l'_o = 22.0 divisions and T'_o = 1970.0 (these are rounded up figures of t_o, l_o and T_o), the coefficients as well as the determination errors. The results are summarized in Table III.

undergoes changes, a consequence, in all probability, of the non–adequate inlay of the ampulla in the level body (see, for instance, Tarczy–Hornoch's paper, 1959). This feature of our levels should, therefore, be pursued in the future also.

An special analysis has been performed of the (O–C) residuals of the division values as a function of temperature and the bubble length. Thus it was found that the temperature effects scattering with higher temperatures was conspicuously lesser than the one stated with the low temperature. This is, in our view, a result of decreasing, with higher temperatures, of both the surface tension and the viscosity (Sadžakov, Mijatov, 1968). The behaviour of the (O–C) values dependent on the bubble length, is typified by higher scattering with the growing bubble length. This might be an indication of the existence of some other effects, not accounted for in the present analysis.

Normal distribution test of the (O–C) deviations did not yield any reliable results, due to the low number of intervals and low frequences within these intervals.

Since no significant differences could be stated between the forms (1), (2) and (3), we adopted, for practical resons, the linear form for the calculation of the division values of both levels. Accordingly, we propose, for the effective use, the following expressions:

$$\lambda_L = 1''.0615 - 0.0083\,(T - 1970.0) + 0.0029\,(t - 12^\circ.0) + 0.0007\,(l - 22.0) \quad (4)$$

$$\lambda_U = 1''.0408 - 0.0063\,(T - 1970.0) + 0.0037\,(t - 12^\circ.0) - 0.0004\,(l - 22.0) \quad (5)$$

Table III. Results of analysis of the totality of level examinations in the period 1963–1981. λ_{ok}, α_k, β_k, γ_k, δ, ξ, k correspond to the expressions (1) – (3); r – the correlation coefficient; ϵ_{reg} is the mean regresion error; ϵ_{res} – mean error of residuals

Level	k	λ_{ok}	α_k	β_k	γ_k	δ	ξ	r	ϵ_{reg}	ϵ_{res}
	1	1''.0615	−0''.0083	0''.0029	0''.0007			0.89	0.12	0.002
L	2	1.0700	−0.0068	0.0036	0.0050	0''.00002	−0''.0013	0.91	0.08	0.001
	3	1.0580	−0.0080	0.0027	0.0008			0.90	0.11	0.001
	1	1''.0408	−0''.0063	0''.0037	−0''.0004			0.85	0.08	0.002
U	2	1.0567	−0.0063	0.0033	0.0010	−0''.0001	−0''.0008	0.87	0.05	0.002
	3	1.0378	−0.0062	0.0037	−0.0004			0.85	0.07	0.002

High correlation can be noted in all three cases. The errors, relating to both levels, are of the same order of magnitude in all three cases considered. The time coefficients α_k, by their assuming considerably values, as well as the „ageing" of the levels (at least in the period 1963 to 1981), produce the diminishing of the division values ($\alpha_k < 0$). The character of the level „ageing"

3. THE ANALYSIS OF MEASUREMENTS MADE IN 1981.

During 1981 the opportunity presented itself of carrying out a greater number of level examinations, following the conclusion of works on an absolute catalogue of declinations of bright stars in the zone +65° to +90°

Table IV. Results of analysis of the laboratory level examinations performed in 1981. Notations the same as in Table 3.

Level	k	λ_{ok}	β_k	γ_k	δ	ξ	r	ϵ_{reg}	ϵ_{res}
	1	0.″9850	0.″0025	0.″0094			0.64	0.003	0.0005
L	2	0.9881	−0.0048	0.0221	−0.″0007	0.″0029	0.67	0.002	0.0005
	3	0.9852	0.0026	0.0098			0.64	0.003	0.0006
	1	0.″9914	0.″0027	0.″0066			0.72	0.003	0.0003
U	2	1.0142	0.0071	0.0404	0.″0006	0.″0058	0.86	0.002	0.0002
	3	0.9916	0.0029	0.0069			0.72	0.003	0.0004

Table V. Results of analysis of the laboratory level examinations performed in the period 1963–1981, omitting the level bubble lengths above 24.0 divisions. Notations as in Table 3.

Level	k	λ_{ok}	α_k	β_k	γ_k	δ	ξ	r	ϵ_{reg}	ϵ_{res}
	1	1.″0713	−0.″0075	0.″0029	0.″0100			0.92	0.11	0.001
L	2	1.0647	0.0070	0.0036	0.0135	0.″0001	0.″0008	0.92	0.07	0.002
	3	1.0682	0.0072	0.0027	0.0099			0.92	0.10	0.001
	1	1.″0470	−0.″0052	0.″0048	0.″0051			0.86	0.06	0.002
U	2	1.0488	0.0056	0.0043	0.0137	−0.″0001	0.″0022	0.87	0.04	0.002
	3	1.0433	−0.0051	0.0049	0.0046			0.85	0.06	0.002

declination. We, therefore, analysed separately, 18 sets of measurements effected in 1981. The expressions used were of the form (1), (2) and (3), the condition being $\alpha_k = 0$. The results of these calculations are presented in Table IV.

The deviations (O–C) of these measurements are by a whole order of magnitude lesser than those resulting from the totality of measurements.

The differences between the mean division values obtained from the totality of measurements and the corresponding values provided in 1981, are given by both linear and quadratic forms:

For L level: – 0.″016 and + 0.″006
For U level: – 0.″021 and – 0.″028

We assumed the differences of results to be due to the fact that the examinations in 1981 were carried out with the bubble lenght ranging from 16 to 22 divisions, while those covering the whole of the period were executed with the bubble lengths between 16 to 30 divisions (mostly above 22 divisions).

4. PROCESSING OF MEASUREMENTS MADE IN 1963 TO 1981 WITH THE BUBBLE LENGTHS FROM 16 TO 24 DIVISIONS

In view of the above asumption those measurements were taken apart from the whole of the material, which were performed with the bubble lengths between 16 and 24 divisions, i.e. the bubble lengths used in almost all the astronomical observations with the LVC.

The same kind of analysis, as the one previously described, was accomplished here, too. The results obtained are listed in Table V.

The linear dependence furnishes:

$$\lambda_L = 1.''0713 - 0.0075\,(T - 1970.0) + 0.0029\,(t - 12.^\circ0) + 0.0100\,(l - 22.0) \quad (4')$$

$$\lambda_U = 1.''0470 - 0.0052\,(T - 1970.0) + 0.0048\,(t - 12.^\circ0) + 0.0051\,(l - 22.0) \quad (5')$$

On comparing the values of β and γ, contained in Table V, and those comprised by Table IV, it becomes evident that there exists a good accordance between them. The difference, referred to in Section 3 is a consequence of the considerable divergence of γ values in Tables III and V. It follows that the level division values are greatly affected by larger bubble lengths and this fact should be given full consideration in the future. Similarly, the finding, stated in Section (3), about the scattering (O–C) being larger with growing bubble lengths, must be taken into account.

There arose the question of whether to use, in the reductions of observations with LVC, the expressions (4) and (5), or else, (4') and (5'). However, we found that the accuracy of the declination determination remained practically the same irrespective of what group of equations was used. That is why we propose the use of the expressions (4) and (5), obtained from the totality of laboratory measurements, considering the fact that there have been, with some of the observations, bubble lengths above 24 divisions.

Care must be taken in the future observations that the bubble length is not above 24 divisions.

5. COMPARISON OF THE RESULTS AND CONCLUSIONS

In the second stage of our study we used the LVC observational data for verifying the reality of the mean division values of both levels, obtained by the laboratory examinations. To this end 37 nights were picked up, with different temperatures and bubble lengths, the condition being, however, that no less than 10 stars have been observed. Mean inclination for each individual night has been applied, derived separately from readings of both U and L levels. As the number of the observed stars on individual nights was different, corresponding weights have been attached to each particular observation.

In the analysis of this material we proceeded from the formulae of Bozhichkovich (1978), wherein the dependencies on temperature t_i and the bubble length l_i are combined:

$$\frac{i''_U - i''_L}{\frac{i_U - i_L}{2}} = (\Delta\lambda_L - \Delta\lambda_U) + (\beta_L - \beta_U)(t_i - t_o) + (\gamma_L - \gamma_U)(l_i - l_o) \quad (6)$$

$$\frac{i_U - i_L}{i_U + i_L} \cdot k'' = (\lambda_{oL} - \lambda_{oU}) + (\beta_L - \beta_U)(t_i - t_o) + (\gamma_L - \gamma_U)(l_i - l_o) \quad (7)$$

where:

i_U and i_L denote the measured inclinations by the upper and lower levels, expressed in divisions;

i''_U and i''_L – measured inclinations by the upper and lower levels, expressed in seconds of arc;

$\Delta\lambda_U$ and $\Delta\lambda_L$ – corrections to the level divisions in seconds of arc;

λ_{oU} and λ_{oL} – most probable mean division value of the upper and lower levels in seconds of arc;

β_U and β_L – temperature coefficients

γ_U and γ_L – bubble lengths coefficients;

k'' – constant (in seconds of arc), obtained by the expressions (4) and (5) as the sum of the division values of the upper and lcwer levels, corresponding to the mean temperature $t_o = +10.0C$ and the mean bubble length $l_o = 22.0$ divisions, reduced to the mean moment 1978.0.

In applying these realtions to the observational material we obtained by the method of least squares, weights being attached (number of stars), the following values:

Table VI. Results of analyses according to equations (6) and (7)

	Values by the equation (6)	Values by the equation (7)
$\lambda_{oL} - \lambda_{oU}$	–	0.0116
$\Delta\lambda_L - \Delta\lambda_U$	−0.1436	–
$\beta_L - \beta_U$	0.0008	0.0009
$\gamma_L - \gamma_U$	0.0113	0.0226
r	0.28	0.17
$\epsilon_{reg.}$	0.15	0.70
$\epsilon_{res.}$	0.005	0.07

Under the second variant the quadratic terms, depending on temperature and the bubble length, with the coefficients $\delta_L - \delta_U$ and $\xi_L - \xi_U$, have been added in (6) and (7). The results are presented in Table VII.

Table VII. Results of analysis according to eqs. (6) and (7) extended by the second order terms

	Values by the equation (6) (quadratic term included)	Values by the equation (7) (quadratic term included)
$\lambda_{oL} - \lambda_{oU}$	–	0.0294
$\Delta\lambda_L - \Delta\lambda_U$	−0.1457	–
$\beta_L - \beta_U$	0.006	0.0066
$\gamma_L - \gamma_U$	0.0118	0.0206
$\delta_L - \delta_U$	−0.0001	−0.0000
$\xi_L - \xi_U$	0.0015	−0.0053
r	0.30	0.20
$\epsilon_{reg.}$	0.09	0.45
$\epsilon_{res.}$	0.005	0.06

In the reduction of our observations the following level division values have been used: $\lambda_L = 0''.992$ and $\lambda_U = 0''.876$, whose difference $\lambda_L - \lambda_U = 0''.116$. Now, let us see what one is getting by performing the analysis with the eqs. (6) and (7). By introducing the relation

$$\lambda_L + \Delta\lambda_L = \lambda_{oL}$$
$$\lambda_U + \Delta\lambda_U = \lambda_{oU}$$

for the same T, t and l, using thereby the data from Table VI, we have

$$\lambda_L - \lambda_U = (\lambda_{oL} - \Delta\lambda_L) - (\lambda_{oU} - \Delta\lambda_U) =$$
$$= (\lambda_{oL} - \lambda_{oU}) - (\Delta\lambda_L - \Delta\lambda_U) = 0.''155$$

whereas from Table VII

$$\lambda_L - \lambda_U = 0.''175$$

Thus, the algorithm based on (6) and (7), though approximate one, yields rather accordant results.

By reducing the values from Tables VI and VII to 1976.0 i.e. to the instant for which the values λ_L and λ_U are deduced, the difference $\lambda_L - \lambda_U$ amounts to $0.''154$ if (1) is used and to $0.''156$ if (2) is used. These values can be considered as being comparable with $\lambda_L - \lambda_U = 0.''116$.

On the other hand, from the laboratory measurements (reduced to 1976.0) taken together, we obtain

$$\lambda_{oL} - \lambda_{oU} = 0.''015 \qquad \text{for the form (1)}$$

$$\lambda_{oL} - \lambda_{oU} = 0.''016 \qquad \text{for the form (2)}$$

i.e. the values which are in fair harmony with those in Tables VI and VII ($0.''012$ and $0.''029$).

On inspecting other data too in Tables VI and VII one may well conclude that the observational data of the LVC confirm the reality of the mean level division values as obtained by the laboratory method.

We are induced to state on the present occasion too that no substantial difference whatever is found between the results furnished by (1) and (2). Therefore, the linear form (1) should be accepted in future work, a suggestion that was put foreward in Section 2.

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INVESTIGATION OF THE DIVIDED CIRCLE OF THE BELGRADE LARGE VERTICAL CIRCLE

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SUMMARY: Corrections for 1080 diameters at 10' spacing of the 2' divided circle of the Belgrade Large Vertical Circle are determined according to Nikolić's method. All the diameter corrections are within ± 1".5 limits, the accuracy being ±0.11. The values of the corrections are tabulated and illustrated graphically.

1. INTRODUCTION

In the period 1976–1980 observations, by absolute method, have been carried out with the Large Vertical Circle (LVC) of the Belgrade Observatory. These observations are aimed at elaborating a catalogue of absolute declinations of 308 bright stars in the zone $+65^{\circ}$ to $+90^{\circ}$ declination (Teleki et al., 1981). Certain preparatory works were thereby necessitated, one of them being the circle investigation. The method used was that of Nikolić (1965). The method has been given preference for its efficiency. The investigation was executed in the period February 8 – March 12, 1980.

The first ever investigation of the LVC division errors has been performed in 1964 at 4° according to both Nikolić's and Bruns' methods (Nikolić, 1968a), Fig. 2.

All the measurements comprised by the present investigation are made visually, five microscope pairs having been mounted for the purpose. Three of these microscope pairs are LVC's „own" ones and other two have been borowed from the neighbouring Large Meridian Circle (LMC). The LMC microscopes had to be fastened on the LVC by means of a special supporting construction, whereby the general stability of the measuring system was preserved. Let it be noted that only two microscope pairs, 90° apart, are used in the regular astronomical observations with the LVC.

2. METHOD APPLIED

In spite of its high efficiency the Nikolić method is little known; up to now it has nowhere, outside Yugoslavia, been actually applied. We shall, therefore, expose it in more details, in particular one of its versions which, even the author did not insist on, although it appeared to us as most suitable.

The implementation of the Nikolić's method involves k microscope pairs, whereby k = 3 is a minimum, k = 5 being the actual number of pairs used in our investigation. Higher accuracy is attained with microscope pairs distributed at different angles θ_i (Fig. 1.). For the programme to be fulfilled in respect to the desired number of determined corrections and their weight, it is necessary to have determined the quantity $W = 180^{\circ}/mn$, where m – the number of measuring series comprised by a programme and n – the number of circle displacements in a series, i.e. the number of readings of all microscopes at rotating the circle in one sense. As usual, the readings of diameters are executed at both direct and inverse circle displacements.

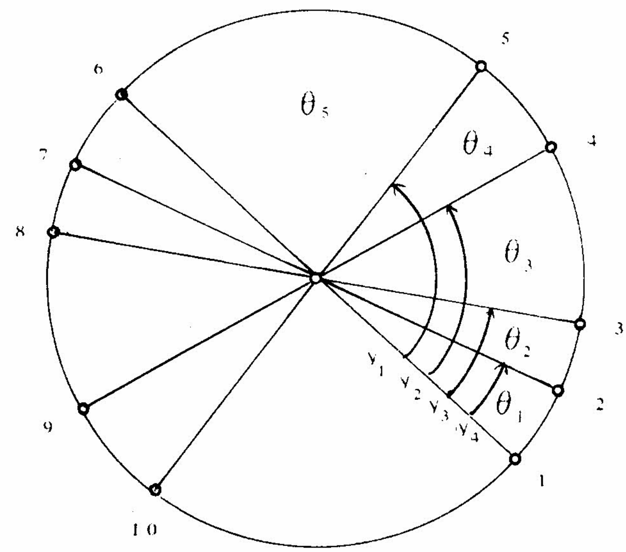

Fig. 1. Arrangement of microscope pairs in conformity with Nikolić's method.

The microscopes can be installed in such a way that the relation $Y_i/W = Q_i+L_i$ $(i = 1,2,..\ k-1)$, where Y_i – angles between the prime and the rest of microscope pairs (Fig. 1) complies with one of the following contingencies:

a. Q_i – integers, divisible by k, $L_i = 0$. Each of the required corrections is obtained k times in one programme.

b. Q_i – integers. The remainders L_i are evenly distributed over the interval W. The required corrections are determined but once in a given programme. (We were met by this case four times).

c. Q_i – integers. The remainders L_i are unevenly distributed over the interval W. The number of determinations of individual corrections is different.

Nikolić (1968a, 1968b), in his investigation of the LVC and LMC circles at 4^o spacing, whereby the second circle was. supplementary, investigated at $0^o.5$ spacing, applied the version a.. We. as above indicated, applied the version b. in our determination of the 10' corrections of LVC circle diameters. We opted for the version b. because it seems as most convenient for detailed investigation of circles whose microscopes are read visually. Repeating the entire programmes enables the desired accuracy to be attained with all the required diameter corrections. Care should thereby be taken that any subsequent programme is started from the prime diameter in the first series of the first programme, increased by one L_i.

The measuring procedure unrolls in the following way: A particular diameter is first proclaimed reference diameter and brought under the prime microscop-micrometer. All of the microscop-micrometers are read. Next. the circle is rotated by the angle $180^o/n$, the microscopes being read again. Upon completing the n-th microscope reading, the circle is rotated in the inverse sense and the same readings are performed once more. This accomplished, the measurements under one series are completed. By adding the value W to the position of the initial diameter, the position of the initial diameter for the second series of measurements is obtained ect.

The basic treatment of the measuring results proceeds as follows: First. the means are formed of the readings of the same diameter obtained at both direct and reverse circle rotation. Denote by the mean values obtained x_{ji} (j = 1,2.., n – the ordinal number of measurement in the series, i = 1,2., k – the ordinal number of the microscope pair with which the particular diameter has been measured). Let x_{ji} be expressed by

$$x_{ji} = X_{ji} + F_{ji} \qquad (1)$$

where X_{ji} is unknown, exact, value of the mean reading x_{ji} of the diameter and $F_{ji} = f_{ji} + \epsilon_{ji}$, the measuring error in x_{ji} consisting of the looked for error f_{ji} of the measured diameter and of ϵ_{ji} – measuring error in that diameter. The mean value of the readings by k microscope pairs is:

$$\frac{1}{k}\sum_i x_{ji} = \frac{1}{k}\sum_i X_{ji} + \frac{1}{k}\sum_i F_{ji} \qquad (2)$$

Form the differences $B_{ji} = (2) - (1)$:

$$B_{ji} = \frac{1}{k}\sum_i X_{ji} - X_{ji} + \frac{1}{k}\sum_i F_{ji} - F_{ji}$$

or

$$B_{ji} = C_{ji} + \frac{1}{k}\sum_i F_{ji} - F_{ji} \qquad (3)$$

By summing (3) according to j and forming the means we have

$$B_i = C_i + \frac{1}{kn}\sum_j\sum_i F_{ji} - \frac{1}{n}\sum_j F_{ji} \qquad (4)$$

where

$$C_i = \frac{1}{n}\sum_j C_{ji}$$

Having regard to the nature of the quantities concerned there will be, for the same i, $C_i = C_{ji}$.

Thus, the difference of the relations (3) and (4) gives:

$$E_{ji} = -F_{ji} + \frac{1}{k}\sum_i F_{ji} + \frac{1}{n}\sum_j F_{ji} - \frac{1}{kn}\sum_j\sum_i F_{ji} \qquad (5)$$

In the b. version any one of m measuring series under some of p programmes will furnish nk values of E_{ji}. In other words, any of p programmes will supply knm=N values in the form E_{ji}, i.e. there will be one value E_{ji} for any one of the diameters investigated. Their mean value E for any of the investigated diameters, according to (5) will be:

$$E = -F + \frac{1}{kp}\sum F + \frac{1}{n}\sum F - \frac{1}{kpn}\sum F \qquad (6)$$

For the sake of clarity we omitted subscripts from this relation (four subscripts with each F), as well as the manyfold symbols Σ. Otherwise, close attention should be paid to these notations in the actual treating.

As evident, the quantities E with any of the of N investigated diameters consist of: – F – the required mean measured correction to the given diameter. The term $(1/pk)\Sigma F$ contains the measured errors of the *non–uniformly* distributed diameters of the investigated circle. The value of this term is determined by successive approximations (iterative procedure). All the values of this term lied within ± 0."30, but treated as accidental quantities, they amounted on the average to ± 0."11. The last term in (6) $(1/kpn)\Sigma F$ contains the measured errors of a large number of *uniformly* distributed diameters, its value being, accordingly, unconsequential and negiligible. The term $(1/n)\Sigma F$ contains mainly the errors of *n uniformly* distributed diameters. On account of the short period division errors, the value of this term. if the values of *n* are relatively small, while being small, is not necessarily negligible. However, this term cannot be determined from the above measurements alone and its values emerge, in some respect, as the systematic errors introduced by Nikolić's method as such. This neglecting should be taken care of when evaluating the accuracy degree of the errors obtained. With the more up to date circle division reading, as for instance the photographic and photoelectric reading, which afford measurements to proceed considerably faster, *n* can attain considerably greater values. By this very fact this error is becoming insignificant. With the measuring procedure suggested by Bozhichkovich (1981), which provides for the uniformly rotating circle and the photoelectrical registering of the division positions, the term under consideration would contain the errors of *all* the diameters, for all the diameters would have been read *k* times within one series. In that case the last two terms in (6), in addition to being trivial, would have been eliminated. All the necessary measurements would be executed by one or two series (depending on the accuracy aspired at) within about three hours.

As above indicated, the term $(1/pk)\Sigma F$ in (6) can be determined by successive approximations. In the first step we take, instead of the unknown values of F, the corresponding values E, thus

$$\begin{aligned} E_1 &= E + \frac{1}{pk} \Sigma E \\ E_2 &= E + \frac{1}{pk} \Sigma E_1 \\ &\dots\dots\dots\dots \\ E_i &= E + \frac{1}{pk} \Sigma E_{i-1} \end{aligned} \qquad (7)$$

The operation is repeated until the term $(1/pk)\Sigma E_i$ has become practically constant, i.e. until $E_i \approx E_{i-1}$. This is usually arrived at by the second or third approximation.

In addition to the procedure just cited, of settling the question of the term $(1/pk)\Sigma F$, the following one has also been applied. The values of E (6), are miltiplied by $k/k-1$. Denoting by E_o the result obtained, there will be $E_o = (k/k-1)E$. Thus

$$E_o = -F + \frac{1}{p(k-1)} \Sigma F + \frac{1}{n} \Sigma F - \frac{1}{pn(k-1)} \Sigma F \qquad (8)$$

The successive approximations proceed as above:

$$\begin{aligned} E_1 &= E_o + \frac{1}{p(k-1)} \Sigma E_o \\ E_2 &= E_o + \frac{1}{p(k-1)} \Sigma E_1 \\ &\dots\dots\dots\dots \\ E_i &= E_o + \frac{1}{p(k-1)} \Sigma E_{i-1} \end{aligned} \qquad (9)$$

This procedure seems to be more correct if one keeps in mind the way of calculating E, the expressions (1) through (6) as well as the quantities appearing in the terms (6). Moreover, it supplies the final results somewhat faster. Following the third approximation the differences between the results, yielded by the two procedures, were reduced to ±0.015, i.e. the final E were practically equal.

In consideration of all above stated, the accuracy of visual measurements inclusive, the quantities expressed by (7) or (9) can even with E_1 be taken as the true corrections to the given circle diameter.

How close is the approximation of errors, derived in the manner just indicated, can be estimated by using the expression, deducible from (9), considering all the quantities in it as being independent. Thus we have

$$\epsilon_E^2 = \left(1 + \frac{1}{p(k-1)}\right) \epsilon_o^2 \qquad (10)$$

By identical procedure the error ϵ_{E_o} in (8) is also determined. It is thereby assumed that we have removed completely all errors in the nonuniformly distributed diameters, appearing in the term $(1/p(k-1))\Sigma F$, and that the measuring errors in them were the only remaining. Therefore

$$\epsilon_{E_o}^2 = \left(\frac{1}{p} + \frac{1}{p(k-1)} + \frac{1}{pn} + \frac{1}{pn(k-1)}\right) \epsilon_x^2 + \left(\frac{1}{n} + \frac{1}{pn(k-1)}\right) e^2 \qquad (11)$$

Here, by ϵ_x (previously by ϵ_{ji}) the measuring error of one diameter. The determination (evaluation) of ϵ_x is usually accomplished through measurements of the same diameters in both senses of circle motion within one series. The last term appears as a result of the neflectings, related to earlier, conditioned by the method applied. By e are denoted the true accidental errors in the circle lines positions, characteristic of workmanship quality of individual circles. Since we are dealing with the sums of errors of the uniformly distributed diameters, we can assume their systematic errors as mutually cancelled, except for the shortperiodic ones, whose effect should be taken into account at accuracy estimating. The errors e can otherwise be estimated by differences of corrections in neighbouring diameters.

3. CIRCLE INVESTIGATION

Correction determination of 1080 circle diameters (10' spacing) by Nikolić's method involved the mounting of k=5 visual micrometer pairs with the following angular spacing in reference to the prime microscope pair: $Y_1 = 17°20'$, $Y_2 = 36°20'$, $Y_3 = 85°10'$ and $Y_4 = 120°20'$. The measurements implied p = 4 programmes each comprising m = 12 series. Accordingly, 48 series in all, were produced. Any individual series involved n = 18 circle positions, at each 10° distance at the direct and as many at the retrograde circle rotating. The starting diameter was the one defined by the 130°0' division line, the instrument's tube occupying thereby a horizontal position. Since we had W = 50', the starting diameter in the second series was the one at 130°50' marking. The starting diameter in the remaing three programmes were those at 13°10', 130°20' and 130°30'. Unfortunately, we were denied the possibility of producing the fifth programme, which should have started at 130°40' marking due to our obligation of returning two microscope pairs borrowed from the LMC.

A half of the measurements (two programmes) was carried out by Dj. Bozhichkovich and the other half was executed jointly by two observers: Dj. Bozhichkovich and M. Mijatov. In those instances where two observers were at work, the former observer read off the first five microscopes and the latter the reamaining opposite five. Accordingly, the measurement of one diameter is constituted by the mean of readings by both observers. The measurements, loudly pronounced, were recorded on a magnetoscope tape, to be later, usually the next day, replayed and transcribed in the observer's notebook.

The measurements were produced in the afternoon and evening hours in the closed pavilion, mostly by cloudy or reiny weather. Most often, two series of measurements daily were realized. The measurements of the first series were performed usually by one observer and those in the second series by both observers.

The average series of measurements took about 2^h30^m if executed by one observer and 1^h45^m if performed jointly by both observers It took about 102 hours in all to accomplish the entire examination. The air temperature inside pavilion ranged from 0.5°C to 7.0°C, the average being 3.6°C. The maximum temperature variation during a series amounted to 1°C, its average being 0.3°C. The temperature circumstances, prevailing at our examinations, may therefore be termed as rather stable. The temperature inside instrument was not measured. As a precaution measure, the circle illumination was turned on 15 minutes before starting the examinations. When two measuring series in the same evening were produced, the circle illumination between the first and the second series was not interferred with.

As only diameters at 10'spacing were measured, the interpolation had to be performed for the go–between diameterers with 2' spacing. In order to reduce the effect of the accidental errors in the directly investigated diameters, on those interpolated ones, one diameter is understood as a mean of three consequtive division lines. The division lines 8', 10' and 2' were set upon. In placing the desired diameter under the prime microscope pair, care has been taken to get the 10' line as close to the microscope index as possible, in order to achieve the readings on all the microscopes to be approximately equal. In view of low eccentricity (about 5") of the LVC circle, this presented no difficulty. Hence, we even could dispense with the micrometer runs.

4. THE CORRECTIONS DEDUCED AND THEIR ACCURACY

The forming of reading means and their cheking for gross errors was performed in the observer's notebooks The diameter readings were transferred on punched cards for the processing on the WANG 2200B computer of the Belgrade Observatory.

Following three successive approximations, corrections were derived of 1080 diameters. These corrections are presented in Table 1. These corrections appear with three decimal places as a result of our computer failing to round up the figures. The above corrections are also illustrated in Fig. 3. As evident, the LVC circle diameter corrections lie all within ± 1".5 boundaries.

By means of the above corrections we computed:

$$\left(\frac{\Sigma E^2}{1079}\right)^{\frac{1}{2}} = \pm 0.50; \quad \left(\frac{\Sigma (E_i - E_{i+1})^2}{1079}\right)^{\frac{1}{2}} = \pm 0.25 ;$$

$$\frac{\Sigma |E|}{1080} = 0.40; \quad \frac{\Sigma |E_i - E_{i+1}|}{1080} = 0.20$$

Table 1. Corrections for 1080 diameters at 10′ spacing of the 2′ divided circle of the Belgrade LVC.

0°	−0".214	0".135	0".243	−0".390	0".355	−0".206
1	0.384	0.444	0.343	0.213	0.021	0.293
2	0.200	−0.135	−0.003	−0.342	−0.019	−0.061
3	−0.092	0.011	−0.159	−0.228	−0.050	−0.230
4	−0.117	0.114	0.027	−0.276	−0.100	0.050
5	−0.226	−0.439	−0.263	−0.147	−0.189	−0.206
6	−0.299	−0.546	−0.113	−0.315	−0.257	−0.712
7	−0.442	−0.684	−0.756	−0.476	−0.696	−0.394
8	−0.814	−0.747	−0.794	−0.791	−0.636	−0.985
9	−1.019	−0.814	−0.538	−0.748	−0.998	−0.575
10	−0.537	−0.822	−0.896	−0.671	−1.050	−0.838
11	−0.856	−0.950	−0.859	−0.904	−1.003	−0.717
12	−0.887	−0.821	−0.942	−1.017	−0.671	−0.675
13	−0.940	−0.851	−1.225	−0.865	−0.937	−1.010
14	−0.915	−0.819	−0.642	−0.965	−0.444	−0.832
15	−0.741	−0.411	−0.495	−0.599	−0.698	−0.181
16	−0.325	−0.850	−0.750	−0.837	−0.903	−0.644
17	−0.571	−0.448	−0.786	−0.806	−1.067	−0.869
18	−0.504	−0.623	−0.402	−0.369	−0.538	−0.316
19	−0.005	−0.540	−0.375	−0.352	−0.248	−0.216
20	−0.743	−0.735	−0.588	−0.169	0.157	0.098
21	0.224	−0.081	0.081	0.006	0.220	0.071
22	0.097	0.165	−0.195	−0.369	−0.175	−0.089
23	0.090	0.076	−0.546	0.192	−0.280	−0.215
24	−0.111	−0.399	−0.082	−0.229	0.013	−0.073
25	−0.361	−0.588	−0.053	−0.476	−0.502	−0.941
26	−0.141	−0.069	−0.086	0.347	−0.353	−0.300
27	−0.231	0.154	−0.266	−0.552	−0.167	−0.226
28	−0.405	−0.386	−0.335	−0.017	0.108	−0.112
29	0.046	0.026	0.015	0.116	−0.204	−0.005
30	−0.113	−0.350	−0.175	−0.442	−0.358	−0.792
31	−0.526	0.032	−0.466	−0.383	−0.398	−0.408
32	−0.167	−0.094	−0.376	−0.202	0.125	0.029
33	−0.083	0.074	0.346	−0.165	−0.113	−0.018
34	−0.367	−0.367	−0.101	−0.293	−0.217	−0.555
35	−0.253	−0.187	−0.236	−0.171	−0.217	−0.428
36	−0.584	−0.847	−0.586	−0.999	−0.884	−0.959
37	−0.643	−0.639	−0.667	−0.576	−0.886	−0.666
38	−0.027	0.448	0.635	0.072	0.672	0.356
39	0.016	0.207	0.034	0.356	−0.045	−0.033
40	0.047	0.078	−0.041	0.243	0.371	0.180
41	−0.129	0.008	−0.060	0.352	0.074	0.075
42	0.190	−0.616	−0.104	−0.191	−0.187	−0.257
43	−0.051	−0.352	−0.262	−0.374	−0.215	−0.455
44	−0.482	−0.293	−0.457	0.061	−0.444	−0.320
45	−0.377	0.085	−0.213	−0.211	−0.105	−0.016
46	−0.155	−0.573	−0.351	−0.546	−0.614	−0.019
47	−0.275	−0.140	−0.399	−0.379	−0.123	−0.405
48	−0.275	−0.461	0.148	−0.127	−0.296	−0.303
49	−0.039	−0.098	−0.265	−0.098	−0.078	−0.392
50	−0.248	−0.569	−0.384	−0.156	−0.332	−0.313
51	−0.396	−0.531	−0.528	−0.537	−0.211	−0.279
52	−0.234	−0.364	−0.324	−0.211	−0.307	−0.669
53	−0.489	−0.413	−0.298	−0.296	−0.363	−0.289
54	−0.176	−0.312	0.172	−0.135	−0.280	−0.181
55	−0.145	0.007	−0.216	−0.479	−0.176	−0.086
56	−0.569	−0.931	−0.630	−0.492	−0.570	−0.544
57	−0.388	−0.182	−0.389	−0.489	−0.490	−0.473
58	−0.594	−1.162	−0.880	−0.878	−1.384	−0.842
59	−1.441	−1.090	−1.107	−1.015	−0.911	−0.969
60	−0.742	−0.429	−0.605	−0.671	−0.502	−0.671
61	−0.641	−0.666	−0.304	−0.579	−0.443	−0.741
62	−0.491	−0.410	−0.343	−0.188	−0.491	−0.247
63	−0.754	−0.430	−0.434	−0.774	−0.709	−0.764

Table 1 (continued)

64°	−0".586	−0".297	−0".507	−0".127	−0".445	−0".778
65	−0.534	−0.083	−0.444	−0.884	−0.399	−0.475
66	−0.750	−0.593	−0.288	−0.638	−0.191	−0.592
67	−0.452	−0.632	−0.260	−0.136	0.049	−0.452
68	−0.346	−0.236	−0.285	−0.371	−0.145	−0.217
69	−0.319	−0.288	−0.451	−0.208	−0.162	−0.591
70	−0.178	0.024	−0.194	−0.169	−0.257	−0.025
71	−0.587	−0.275	−0.463	−0.378	−0.395	−0.447
72	−0.281	−0.415	−0.003	−0.194	−0.279	−0.004
73	−0.084	−0.297	−0.096	−0.351	−0.461	−0.233
74	−0.437	−0.191	−0.141	−0.249	−0.191	−0.343
75	−0.026	−0.050	−0.528	−0.305	−0.441	0.210
76	−0.326	−0.269	−0.337	−0.037	−0.048	−0.148
77	−0.058	−0.361	0.122	−0.146	−0.063	−0.065
78	0.046	0.191	0.313	−0.038	0.120	−0.119
79	0.153	−0.056	0.138	0.176	0.226	−0.141
80	0.530	0.260	0.705	0.333	0.195	0.224
81	0.162	0.222	0.054	0.302	−0.004	0.100
82	−0.044	0.003	0.002	−0.050	−0.049	0.157
83	0.014	−0.068	−0.254	−0.160	0.207	−0.285
84	0.004	−0.369	−0.496	−0.565	−0.626	−0.692
85	−0.327	−0.517	−0.415	−0.446	−0.259	−0.301
86	−0.577	−0.543	−0.341	−0.511	−0.083	−0.204
87	−0.518	−0.336	−0.103	−0.528	−0.417	0.006
88	−0.066	0.190	−0.406	−0.133	0.082	0.108
89	0.192	−0.074	−0.266	−0.009	−0.310	−0.021
90	0.056	−0.429	−0.294	−0.097	−0.690	−0.369
91	−0.327	−0.438	−0.256	−0.397	−0.278	−0.517
92	−0.415	0.125	−0.008	0.266	−0.301	−0.066
93	0.134	0.576	0.320	0.125	0.151	0.278
94	0.497	0.759	0.406	0.430	0.389	0.798
95	0.524	0.665	0.352	0.541	0.802	0.518
96	0.289	0.030	−0.142	−0.024	−0.249	−0.154
97	−0.147	−0.058	−0.028	0.196	0.086	−0.021
98	0.017	0.263	0.322	−0.050	−0.105	0.165
99	0.053	0.243	0.125	−0.147	0.389	0.218
100	0.202	−0.030	0.159	−0.145	−0.308	0.389
101	0.076	0.003	0.018	−0.062	−0.214	−0.133
102	−0.554	−0.542	−0.354	−0.391	−0.477	−0.804
103	−0.366	−0.629	−0.475	0.167	0.413	0.473
104	0.207	−0.320	−0.552	−0.639	−0.295	−0.015
105	0.151	−0.189	−0.044	0.393	0.455	0.413
106	0.591	1.005	1.021	1.019	1.312	1.075
107	0.962	0.840	1.185	1.261	1.084	0.752
108	0.635	0.831	0.879	0.814	0.831	1.042
109	1.091	0.930	0.764	0.786	1.069	0.997
110	0.633	0.538	0.532	0.645	0.695	0.840
111	0.546	0.625	0.703	0.841	0.505	0.432
112	0.584	0.847	1.153	1.177	0.943	0.882
113	1.343	0.849	0.929	0.948	1.187	0.914
114	0.886	0.993	0.991	1.138	0.855	1.175
115	1.103	1.049	1.270	1.106	0.871	0.858
116	0.861	1.092	1.205	1.128	1.265	1.211
117	1.213	0.876	0.945	0.932	1.102	1.239
118	0.951	1.158	0.738	0.588	0.571	1.205
119	1.130	1.063	0.754	0.656	0.894	0.718
120	0.631	0.614	0.849	0.632	1.123	0.861
121	1.196	1.027	0.893	1.379	1.072	1.022
122	1.014	1.149	0.861	1.226	1.116	1.046
123	1.025	1.348	1.307	1.263	1.022	1.454
124	1.186	0.472	0.605	0.684	0.446	0.830
125	0.770	0.453	0.636	0.492	0.712	0.631
126	0.467	0.591	0.531	0.542	0.444	0.560
127	0.237	0.577	0.730	0.357	0.514	0.220

Table 1 (continued)

128°	0.″489	0.″135	-0.″008	0.″464	0.″382	0.″385
129	0.409	0.340	0.174	0.460	0.327	0.350
130	0.121	0.303	0.381	0.758	0.344	0.136
131	0.400	0.238	0.412	0.165	0.295	0.345
132	0.129	0.394	0.207	0.237	0.308	0.309
133	0.063	0.094	0.096	0.167	0.228	0.121
134	0.043	0.087	0.346	0.153	0.500	0.256
135	0.048	0.040	-0.043	0.197	-0.261	-0.168
136	0.237	0.466	-0.146	0.328	0.363	0.456
137	0.072	0.181	0.193	0.513	0.595	0.466
138	0.319	0.076	0.241	0.465	0.244	-0.023
139	0.201	0.668	0.555	0.191	0.391	0.378
140	0.354	0.402	0.168	0.297	-0.164	0.317
141	0.464	0.081	0.447	-0.082	0.283	0.253
142	0.125	0.147	0.145	-0.162	-0.020	-0.125
143	0.078	-0.318	0.115	-0.064	-0.133	0.127
144	-0.179	0.344	-0.034	0.058	0.046	-0.000
145	0.148	-0.180	-0.040	0.207	-0.282	-0.145
146	0.215	0.307	0.004	0.150	-0.120	0.243
147	-0.019	0.037	-0.025	0.221	0.119	0.183
148	0.094	0.336	0.439	0.474	0.261	-0.054
149	0.084	0.031	0.386	0.085	0.136	0.239
150	0.404	0.711	0.176	0.305	0.617	0.117
151	0.403	0.375	0.374	0.340	0.337	0.342
152	0.394	0.823	0.439	0.684	0.581	0.575
153	0.589	0.487	0.814	0.543	0.255	0.359
154	0.582	0.444	0.220	0.449	0.507	0.217
155	0.025	0.255	0.426	0.306	0.218	0.206
156	0.240	0.636	0.296	0.595	0.304	0.209
157	0.342	0.168	0.364	0.314	0.200	0.155
158	0.390	0.179	-0.045	0.295	0.376	0.323
159	0.255	0.021	0.391	0.138	0.346	0.545
160	0.124	0.572	0.267	0.354	0.398	0.385
161	0.153	0.321	-0.119	0.330	0.123	0.488
162	0.180	0.032	0.095	0.087	0.264	0.051
163	-0.216	0.229	0.263	0.099	-0.057	0.176
164	0.315	0.222	0.142	-0.004	0.166	0.316
165	0.089	0.024	0.048	0.449	0.310	0.047
166	0.509	0.528	0.355	0.050	0.251	0.224
167	0.414	0.565	-0.074	0.281	-0.077	0.264
168	0.268	-0.218	-0.134	-0.351	-0.387	-0.505
169	-0.342	-0.386	-0.309	-0.258	-0.136	-0.330
170	-0.368	-0.293	-0.289	-0.687	-0.586	-0.334
171	-0.543	-0.427	-0.266	-0.598	0.010	-0.172
172	0.165	-0.279	-0.246	-0.342	-0.355	-0.036
173	-0.259	-0.379	-0.434	-0.215	-0.143	-0.406
174	-0.347	-0.064	0.111	0.519	0.131	0.149
175	0.136	0.071	0.263	0.038	0.164	0.078
176	0.312	0.572	0.372	0.236	0.346	0.292
177	0.517	0.085	0.225	0.014	0.246	0.286
178	-0.173	0.026	-0.423	-0.032	-0.154	-0.102
179	-0.470	-0.176	-0.029	-0.124	-0.679	-0.159

By making comparison of the old (Fig. 2) and the new (Fig. 3) circle corrections one realizes that our circle's division did not undergo any appreciable change in 16 years elapsed, even though some damaging is now noticeable, which previously was not present. No wonder then that the general features of the LVC circle corrections demonstrate close resemblance with those of the LMC corrections (Sadžakov, Šaletić, 1968; Trajkovs-

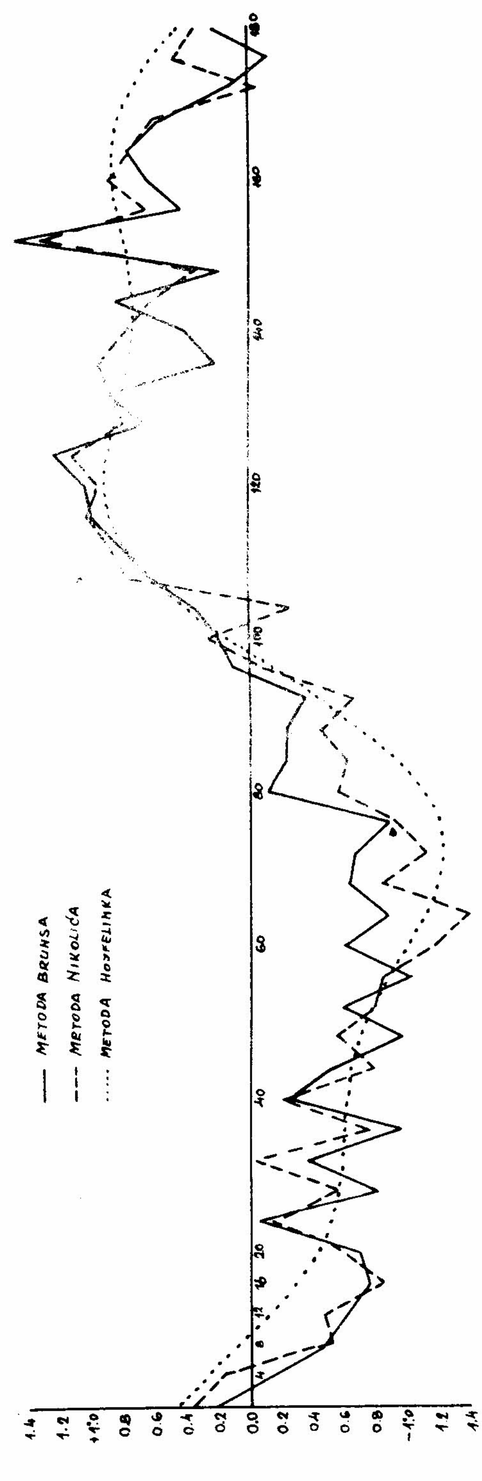

Fig. 2. Circle corrections of the LVC of the Belgrade Observatory determined in 1964. (Nikolić, 1968a)

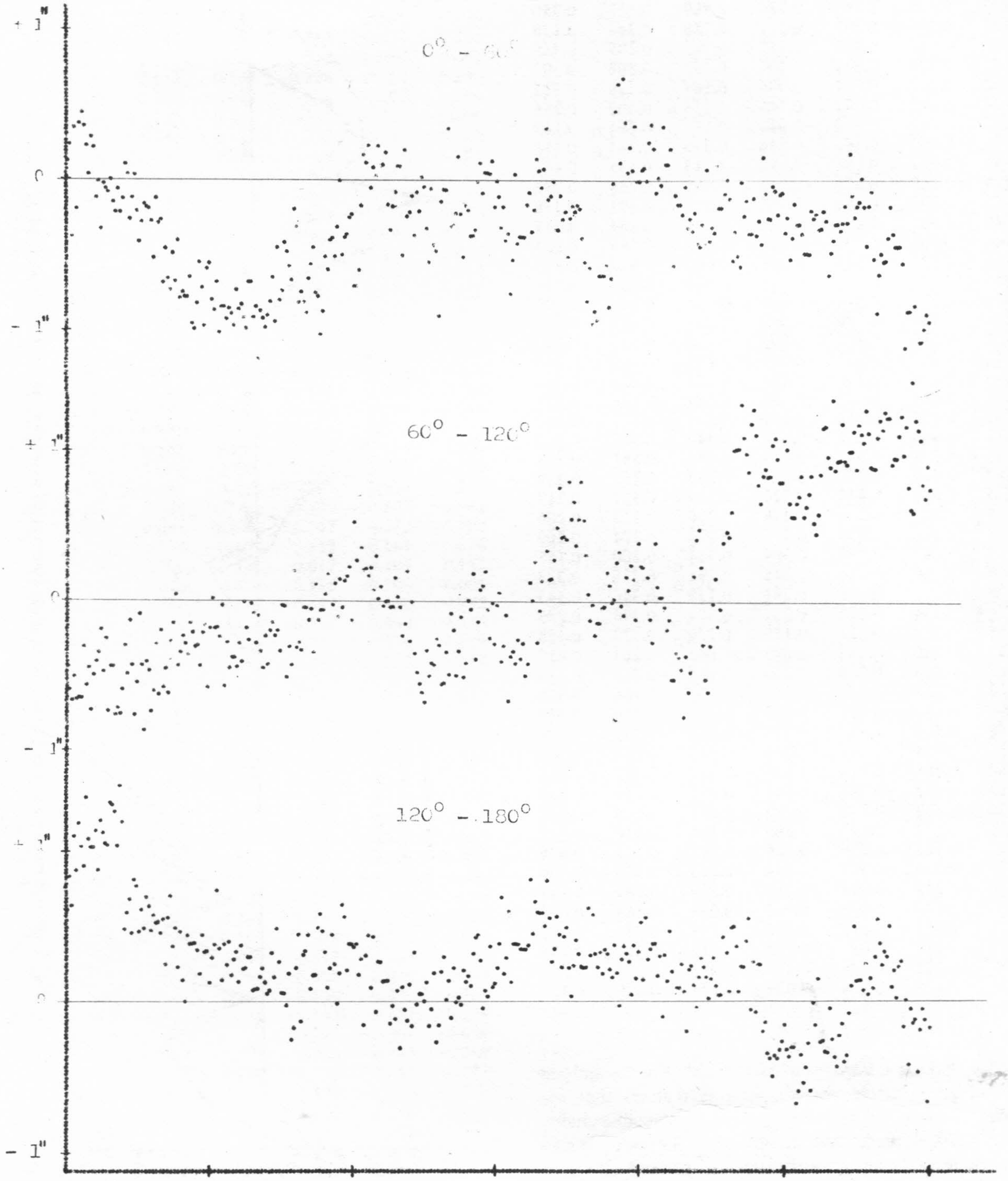

Fig. 3. Diameter corrections of the Belgrade LVC determined in 1980.

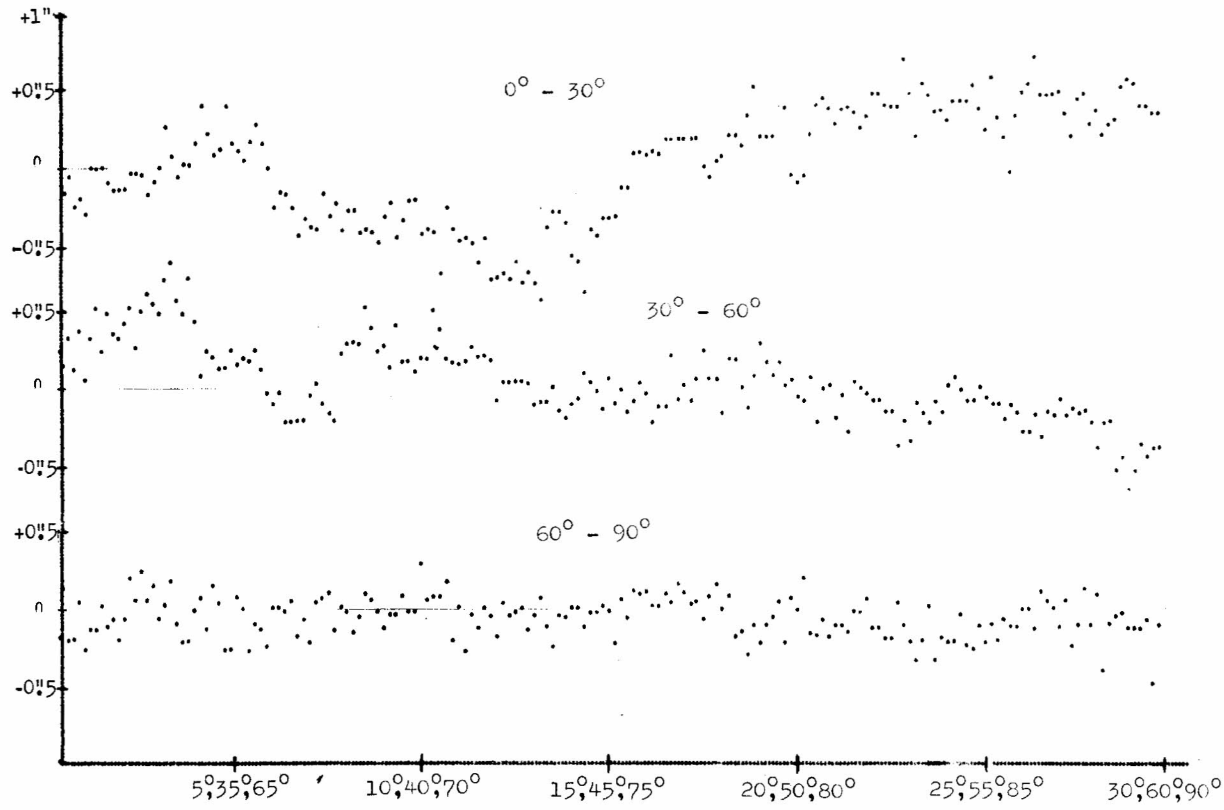

Fig. 4 Corrections to the mean readings of two perpendicular diameters.

ka, 1979). This may, in some way, be taken as providing confirmation of the corrections, brought out by this investigation, being real ones, as both circles have been manifactured at Askania at about the same time (early twenties).

The corrections to the mean readings of two diameters, lying at 90° to each other, are illustrated in Fig. 4. It can be seen that these mean corrections, denoted by $\bar{E}$, are all within the ± 0."85 limits. We calculated, as before

$$\left(\frac{\Sigma \bar{E}^2}{539}\right)^{\frac{1}{2}} = \pm 0.27; \quad \left(\frac{\Sigma (\bar{E}_i - \bar{E}_{i+1})^2}{539}\right)^{\frac{1}{2}} = \pm 0.17;$$

$$\frac{\Sigma |\bar{E}|}{540} = 0.21; \quad \frac{\Sigma |\bar{E}_i - \bar{E}_{i+1}|}{540} = 0.14$$

From the above numerical values, as well as from the curve illustrating the mean corrections Fig. 4, one realizes that they are not large.

The determination of the mean square error of the corrections to 1080 diameters at 10' spacing, procceds by inserting in the expresions (10) and (11), developed for the accuracy estimate of the correction determination by Nikolić's method: the number of programmes (p=4), number of microscope pairs (k=5), and the number of circle positions for one of rotation senses (n=18).

In order to determine ϵ_x – mean square error of the mean value of two readings the same diameter, the readings made at both direct and reverse circle rotation were analysed. In this, the measurements of the same diameters in the framework of 36 series (12 series had to be left unused on account of an unexpected technical difficulty) were emploed. The results was $\epsilon_x = \pm$ 0". 18.

Our measuring series lasted, on the average, four times 30^m – the usually admitted duration of a series. Hence, we tried to bring out, if possible, the diameter changes depending on time. It was demonstrated by analysis that some changes of the kind were present in the course of practically all the series. Yet, this dependence turned out to be mostly weak, the correlation coefficients being usually bellow 0.5. This was also confirmed by the error $\epsilon_x = \pm$ 0".155, deduced from the differences of reading the same diameter relieved of the time dependent effects.

There were, in the course of these measurements, seven days in a row on which no interference whatever with the microscopes has taken place (e.g. illumination adjustment, lamp bulbs replacements, microscope drum displacings accidental knocks against some from among the microscope „forest"), except for the focusing. Over this period the values B_i in (4), characterizing the microscope positions relative to the fictitious mean one, do not practically display any variation. This, in turn, lends a kind of confirmation of high stability of the microscopes, having once been fastened in their places. Hence our inclination to regard the slight displacements of the microscopes during the measurements as being due to the observers' fatigue. One should keep in mind that the mean reading of any diameter is formed from the readings made at both direct and reverse circle rotation, entailing approximately the same mean time for all mean diameter readings. Consequently, the slight variations stated in the diameter readings are largely conpensated and do not practically affect the mean readings. All things considered, the mean square error (in the diameter double readings) we adopt, is $\epsilon_x = \pm 0''.15$. It is obvious at once that it is practically equal to the conventional error of a *single* reading by visual microscopes, resulting from series four times as short (Zverev, 1954).

Owing to the neglectings, above indicated, entailed by the method as such, an error is comitted whose amount can be estimated in the following way. With regard to the uniform distribution of the diameters, their systematic error can be assumed as largely removed (save the short period ones). Consequently, the accidental diameter errors are the only ones left over. From the differences of the neighbouring corrections we find the accidental errors in our circle diameters $e = \pm 0''.18$, $e = \pm 0''.25/\sqrt{2}$. On inserting these values in the second term in (11), its value becomes $(\pm 0''.04)^2$. However, as the possible existence of short period division errors are disregarded by this way of treating, we scrutinized the values of the sums $(1/15)\Sigma E$ and $(1/20)\Sigma E$. The deduced values have further been treated as random quantities. Their possible disregarding would produce errors $\pm 0''.06$ and $\pm 0''.05$, respectively. Even though these values have, in their turn, been obtained from corrections affected by errors, it still seems to us that the value $(\pm 0''.06)^2$ of the second term in (11) is a fair representative of the error comitted by the said neglectings.

On inserting the above values in (10) and (11) we obtain $\epsilon_E = \pm 0''.11$ for the mean square error of our circle division corrections.

The trustworthiness of the mean square error just stated can be judged from the measurings executed in the first series, repeated twice, of the first programme. The second measuring tour of the first series differed from the first tour in that each circle line was set on twice. The necessary time for such a measuring series to be performed by a single observer amounts to 4^h30^m, which is far to long. We, therefore, abstained from this sort of measurements. The results of this lengthy measurement series were processed but were omitted from the actual derivation of corrections. Since the same diameters were measured in both series, 90 values according to (5) were furnished by each one of the series. From the differences of the corresponding values we deduced $\epsilon_{E_{ii}} = \pm 0''.24$. The fact being that the corrections are practically obtained as the mean value of four independent values (5) (one from each programme, for each diameter), we have $\epsilon_E = \pm 0''.12$, which agrees well with the adopted one.

The mean correction to two perpendicular diameters investigated were determined with the accuracy $\epsilon_E = \pm 0''.09$.

Considering that, at determining the zenith distance of the observed celestial object, two positions of the instrument and the circle (CE and CW) are made use of, the zenith distance can be assumed free from the systematic errors in the circle diameters involved, with an accuracy of $\pm 0''.06$.

5. CONCLUSIONS

From what has above been brought foreward the following may be stated:

1. The Nikolić's method of circle investigation proved once again highly efficient. It can, therefore, be recommended for such investigation, in defiance of some minor deficiencies. This applies in particular to investigations involving automatic circle reading. If the version b. of the method is used, as we ourselves did, it is desirable to accomplish k = 3 programmes. where k — the number of microscope pairs. For higher accuracy it is necessary, before starting *k* new programmes, to have microscope pairs redistributed, ect.
2. The investigation of the Belgrade LVC circle diameters at 10' spacing has been inplemented with the mean error $\epsilon_E = \pm 0''.11$. All the corrections are found within $\pm 1''.5$ limits, displaying a manifestly systematic character. There are no distinct jumpings from one division line to its next, so all the measurements can be assumed as having been executed without gross errors.
3. It follows from our investigations that LVC circle is of good quality, its main features having not undergone any noteworthy changes in 16 years elapsed since its first investigation.

ACKNOWLEDGMENTS

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INVESTIGATION OF WIND EFFECTS ON THE BELGRADE LATITUDE OBSERVATIONS

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SUMMARY: It is demonstrated that the alterations (thermal insulation of the zenith telescope, rebuilding of the pavilion, improvements in the observational procedure and data processing) effected in the period 1968–1970 (Milovanović et al., 1981) resulted in a notable reduction of the wind effects on the Belgrade latitude observations and a general enhancement of the accuracy of observation. It is found that in the period 1976–1981 the systematic effects of winds from N–W quadrant are stronger than those produced by winds from S–E quadrant (most of our observations are made by S–E winds). The suitability to application of some expressions for the calculation of wind effects on latitude is considered.

1. INTRODUCTION

Wind effects or, more broadly, the air flow effects, on the latitude observations made with „Askania" zenith telescope, 110/1285 mm, at Belgrade Observatory, have repeatedly been studied (Ševarlić, 1961; Teleki, 1967; Grujić, 1975). That we, once more, return to this question, is not a result of our mere wish to routinely reiterate such kind of investigation. It is rather a consequence of two important novel facts connected with our latitude observations:

First, in the period 1968–1970 alterations (Milanović et al., 1981) have been effected, implying: thermal insulation of the zenith telescope, rebuilding of the pavilion, improvements in the observational procedure and data processing.

Second, from 1976 on, both the wind direction and velocity at 12 m altitude, are regularly measured at observing each single star pair by means of an anemometer. No such systematic measurements have been made before 1976. Instead, only mean characteristics of the wind during observation have been roughly estimated from an ordinary weather vane.

Milovanović et al. (1981) have demonstrated that in consequence of the above quoted alterations the effects of the external factors have successively been diminished, i.e. the accuracy of the latitude determination has grown considerably higher. It has been established, however, that the internal accuracy has increased perceptibly more than the external one.

In our considering the question of why this is so we made inquiry into the wind effects on observations carried out in the five years period 1976–1981, that is, the period following the installation of the anemometer. The fact should particularly be kept in mind that there are in the ceiling only two narrow slits, through which the observations are made, and that the dew cap of the instrument all but reaches the ceiling. Accordingly, the instrument is insulated, in the course of observation, to the maximum possible degree, from the external influences, unlike its previous condition (i.e. before alterations implemented in 1968 to 1970), when it was practically in the open air during observation. We had, therefore, all reasons to expect substantially reduced wind effects on the observed latitude, and an improved accuracy of observation. This applies in particular to the internal accuracy. The present analysis has been performed in order to verify to what extent our expecations were justified.

2. BASIC FORMULA

Basic quantities operated with in our analysis are

$$\Delta\varphi = \Delta\varphi_{cal} - \Delta\varphi_{obs} \qquad (1)$$

supplied by each one of the subgroups in our observing programme in the period 1976–1981. φ_{cal} denotes the calculated latitude values according to the pole coordinates as published by BIH and the mean Belgrade latitude +44°48' 10."354. φ_{obs} is the mean latitude value resulting from the observation of five star pairs – that many as each one of the subgroups is constituted of.

3. DEPENDENCE OF $\Delta\varphi$ ON THE WIND VELOCITY

The following simple relation between $\Delta\varphi$ and the wind velocity V(m/s) is assumed

$$\Delta\varphi = a + b\,(V - V_o) \qquad (2)$$

where a and b are unknown and V_o a constant (= mean value of the totality of quantities V).

In this way we obtain, with a small correlation coefficient r = 0.05,

$$\Delta\varphi = -\,0''.0167 + 0.0041\,(V - 2.1)$$

and

$$\Delta\varphi = -\,0''.0253 + 0.0041\,V$$

The latter formula can be compared with the one derived by Ševarlić (1961) from the observations with the same instrument in the period 1949 to 1957:

$$\Delta\varphi = -\,0''.014 + 0.008\,V$$

From these data there follows – although not quite convincingly – that the systematic wind velocity effect on φ has been cut by two.

4. DEPENDENCE OF $\Delta\varphi$ ON THE WIND DIRECTION

The probability of $\Delta\varphi$ being dependent on the wind direction has been examined by means of χ^2 distribution. If the observational material is treated as a whole then a very low probability value is obtained. But some regularity in the systematic effects can be expected on considering the winds by separate quadrants, i.e. S–E quadrant winds (66% of all winds) and N–W quadrant (14%). The probability is somewhat larger with N–W winds than S–W winds.

The equations of conditions were of the form

$$\Delta\varphi = c + d\,(A - A_o) \qquad (3)$$

where c and d are unknowns, A stands for azimuth (counted from S through E), and A_o is a constant (= mean value of the totality of azimuths).

Thus was derived for the S–E quadrant, with the correlation coefficient r = 0.10,

$$\Delta\varphi = -\,0''.0031 + 0.0004\,(A - 46^{o})$$

The values c and d for each subgroup are listed in Table I.

One can notice a relatively high correlation with some of the subgroups and some kind of annual periodicity in the coefficient d.

Ševarlić (1961) found the following relation on the basis of observations carried out in the period 1949 to 1957:

$$\Delta\varphi = 0''.011 + 0''.031\,\sin(A + 95^{\circ}.5) + 0''.005\,\sin(2A + 11^{\circ}.2)$$

Let's disregard the third term. On comparing the mean effect of the term $0''.031\,\sin(A + 95^{\circ}.5)$ for the S–E quadrant (−0.0190) we find it to be about fifty times as large as the one relating to the period 1976–1981.

Table I. Values of the coefficients *c* and *d* in the expressions (3) for each subgroup separately and for the whole of the programme. By *n* is denoted the number of equations of conditions and by *r* the correlation coefficient.

Subgroup	c	d	n	r
Ia	− 0.088 2	− 0.000 3	11	0.12
Ib	− 92 3	+ 1 0	14	0.54
IIa	− 14 7	+ 0	13	0.01
IIb	+ 96 6	− 1 4	18	0.57
IIIa	+ 242 4	− 2 6	9	0.42
IIIb	+ 139 0	− 6	13	0.21
IVa	+ 142 4	− 4	8	0.16
IVb	− 29 8	+ 8	8	0.32
Va	− 21 4	+ 1 4	8	0.51
Vb	+ 28 3	+ 0	8	0.01
VIa	− 158 7	+ 8	18	0.29
VIb	− 0.144 2	+ 0.000 5	16	0.24
Whole of programme	− 0.031 3	+ 0.000 4	144	0.10

Due to the relatively low number of nights with N–W winds, the relevant coefficients c and d have not been calculated for each subgroup separately but for the programme as a whole only. For the quadrant concerned we found:

$$\Delta\varphi = -\,0''.0134 - 0.007\,(A - 227^{o})$$

the correlation coefficient being $r = 0.22$. This result is, accordingly more dependable than the one pertaining to the S–E winds.

From Ševarlić's expression there follows the value $+\,0''.018$ of the mean effect produced by N–W winds, thus again an appreciable higher amount than the one resulting from the observations in the period 1976 to 1981.

The conclusion can, therefore, be drawn – with a fair probability – that the wind effects, alike those depending on velocity and on direction, on φ, have considerably been reduced in consequence of alterations implemented during 1968 to 1970.

5. TOTAL DEPENDENCE OF $\Delta\varphi$ ON THE VELOCITY AND DIRECTION OF WINDS

We attempted also to provide an estimate of the sum effect of the direction and velocity of winds on φ, supposing it to be adequately expressed in the form:

$$\Delta\varphi = e + f\,V\cos(A - A_0) \qquad (4)$$

where e and f are unknown quantities.

For the three variants considered we obtained:

a) From the entire observational material, with $r = 0.06$:

$$\Delta\varphi = -\,0''.0154 + 0.0047\,V\cos(A + 24^{\circ})$$

b) From the observational material acquired by N–W quadrant winds, with $r = 0.29$:

$$\Delta\varphi = -\,0''.0133 + 0.0311\,V\cos(A - 29^{\circ})$$

c) From the observational material acquired by S–E quadrant winds, with $r = 0.03$:

$$\Delta\varphi = -\,0''.0153 + 0.0032\,V\cos(A + 22^{\circ})$$

As evident, the only relation between $\Delta\varphi$ and the two wind parameters of any reliability can be established with the N–W quadrant winds.

These winds produce the strongest effect, about 10 times as large as the one exerted by the S–E quadrant winds.

The investigation by way of the expression (4) have not previously been done at our observatory. Teleki (1967) has analysed the z–term in the Belgrade observations, selecting those among them during which air flows, characteristic of Belgrade, have been blowing. He found that the strongest and most systematic effects are produced by SE air flows, whereas the effects, produced by NW air flows, are the most variable. Similar conclusion was reached by Grujić (1975).

However, the results of our present analysis present, as evident, a contrary picture. The question is now how to explain this. Whether by the contingency of the air flows indicated not being characteristic of all the winds of a given quadrant or by changes that have possibly taken place in the wind effects on the observed latitude. In principle, neither the first nor the second possibility is to be rejected, but the first contingency seems more real.

6. ACCURACY OF OBSERVATIONS

The star path across the field of view presents an importance source of information on the refractional anomalies and the observational errors. For this reason a special study in the matter has been performed. In Table II a presentation is given of the mean standard deviation σ calculated from the deflections of the star paths of different subgroups (note that the star is set upon four times during its transit across the field of view).

Table II. Mean standard deviation σ of the star path in different subgroups in 0.0001 of the micrometer revolution.

Subgroup	σ	Subgroup	σ
Ia	70	IVa	75
Ib	69	IVb	68
IIa	76	Va	71
IIb	66	Vb	67
IIIa	66	VIa	63
IIIb	69	VIb	65
		Whole of programme	68

No clear annual variation can be stated. On the other hand the fact is that σ is the smallest in the VI group, which is observed from 1 July to 15 October. This is the period in which we in Belgrade usually have the greatest number of observations.

The correlation between the wind velocity and σ has also been studied. For this we used the linear relation of the form:

$$\sigma = g + h\,(V - V_0) \qquad (5)$$

As evident in Table III, no unequivocal relation exists between σ and V since the values of h differ from one subgroup to another. Concerning the whole of the programme, the relationship is rather uncertain. Otherwise, with the winds up to 2.1 m/sec, the effects are negligibly small.

Table III. Values of the coefficients g and h in the formula (5) separately for each subgroup, and for the group as a whole. The correlation coefficient is denoted by r.

Sugbroup	g	h	r
Ia	+0.008 0	−0.000 50	0.43
Ib	+ 7 2	− 16	0.19
IIa	+ 8 2	− 17	0.20
IIb	+ 6 8	+ 7	0.07
IIIa	+ 6 3	+ 25	0.32
IIIb	+ 7 4	− 22	0.29
IVa	+ 7 0	+ 25	0.15
IVb	+ 8 2	− 57	0.42
Va	+ 8 6	− 24	0.17
Vb	+ 8 2	− 63	0.33
VIa	+ 6 6	− 7	0.08
VIb	+ 6 3	+ 16	0.14
Whole of programme	+0.007 2	−0.000 08	0.07

Another important question is: how much does σ affect the latitudes, derived respectively from a single pair and from a subgroup (=5 star pairs). The answer is: mean effect in the former case amounts to $\pm\,0''.096$, and in the latter it is $\pm\,0''.043$.

From Ševarlić's (1961) data one finds, for the period 1949 to 1957, the mean effect on φ produced by one single pair to be $\pm$ 0".122, that is about 21% stronger than it is at present.

According to Høg (1968), the average accuracy of observation of a single star with a good PZT, astrolabe or meridian instrument, is limited, in the first place, by the „image motion" effect, entailing mean error at the zenith

$$\sigma_T = 0''.33\,(T + 0.65)^{-0.25} \qquad (6)$$

This formula is valid for all integration times T ≥ 0^s.2. In our case T = 40^s, therefore σ_T = 0".131. On the other hand, proceeding from our measurements of σ (= 0.0068 micrometer revolution on the average) we find for the zenith zone 0".137 (0".129 for the VIth group).

If account is taken of the fact that the value σ comprises also the effects of the anomalous refraction (among which „image motion" effect also), as well as the errors of setting (there were four settings on each star), and the effects resulting from the instrument's possible instability, then, on comparing σ and σ_T furnished by the formula (6), one must assess our observations as being of good quality. This, after all, has been demonstrated, particulary as far as the internal accuracy is concerned, in the paper of Milovanović et al (1981).

7. SUM EFFECT $\Delta\varphi$ OF THE WIND VELOCITY, HUMIDITY AND AIR PRESSURE

In our searching for the most convenient mode of investigating the wind effects on the latitude we employed also the equation of condition of the form

$$\Delta\varphi = i + j\,(H-74) + k\,(V-2.1) + l\,(P-741.6) \qquad (7)$$

where:

H – relative humidity
V – wind velocity in m/sec
P – air pressure in mm Hg
i,j,k,l – unknown quantities.

The results obtained are summarized in Table IV. These data do not allow any firm conclusion to be made concerning the general characteristics of the coefficients *j,k* and *l*, valid for all the subgroups and the programme as a whole. The coefficient *i* is the only one displaying some kind of regularity in its changes, so it will be the object of our attention in Section 9.

Table IV. Values of the coefficients *i,j,k,* and *l* in the formula (7) for each subgroup and for the programme as a whole, the unit being 0.0001 of the micrometer revulution. The correlation coefficient is denoted by *r*. *n* is the number of equations of condition.

Subgroup	i	j	k	l	n	r
Ia	− 941	18	− 93	49	21	0.41
Ib	410	+ 11	77	+ 28	23	0.41
IIa	− 401	+ 34	+ 190	+ 6	18	0.32
IIb	+ 168	−13	+ 9	+ 9	25	0.24
IIIa	+ 594	10	+ 145	− 71	19	0.50
IIIb	+ 1122	10	39	− 28	19	0.28
IVa	+ 1126	+ 11	187	+ 82	15	0.49
IVb	+ 19	− 4	+ 221	+ 44	15	0.40
Va	+ 513	+ 16	498	−115	12	0.61
Vb	+ 108	+34	153	− 59	13	0.44
VIa	1325	+ 1	+ 41	− 16	26	0.12
VIb	1210	+ 14	+ 30	+ 14	24	0.23
Entire programme	167	+ 2	− 4	− 10	230	0.05

8. DIFFERENT COMPLEX INVESTIGATIONS

If the formula (7) is widened so as to include the term, depending on the „image motion", we obtain:

$$\Delta\varphi = i' + j'\,(H-74) + k'\,(V-2.1) + l'\,(P-741.0) + m\,(\sigma - 0.0070) \qquad (8)$$

On comparing results, furnished by (8) and presented in Table V, with those listed in Table 4, one realizes a remarkable improvement of the correlation coefficient *r*: the one relating to the subgroups is by about 20% better, and if the programme as a whole is considered, the increase is also visible: from 0.05 to 0.22.

Table V. Values of the coefficients i', j', k', l' and m in the formula (8), for each subgroup and the programme as a whole, the unit being 0.0001 of the micrometer revolution. The correlation coefficient is denoted by *r* and the number of the equations of condition by *n*.

Subgroup	i'	j'	k'	l'	m	n	r
Ia	761	−19	175	42	− 15.2943	21	0.48
Ib	− 666	+ 16	101	+ 28	−16.5213	23	0.54
IIa	− 676	+ 43	+ 209	+ 43	23.8864	18	0.43
IIb	+ 139	10	+ 27	+ 20	11.6014	25	0.36
IIIa	+ 546	10	+ 169	72	8.9218	19	0.52
IIIb	+ 1116	− 4	72	23	15.5711	19	0.34
IVa	+ 1290	+ 11	− 187	+ 83	+ 0.1481	15	0.49
IVb	+ 70	− 3	+ 33	+ 28	−31.3933	15	0.73
Va	+ 284	+ 18	465	−96	− 2.1531	12	0.61
Vb	− 58	+ 33	−163	56	− 1.3878	13	0.44
VIa	−1359	− 2	+ 29	14	8.0309	26	0.15
VIb	−1203	+ 14	+ 30	+ 14	− 0.1921	24	0.23
Whole of programme	− 166	9	7	− 44	− 0.5770	230	0.22

On assuring ourselves of the preference to be accorded to the formula (8) over the formula (7), we attempted an analogous widening of the formula (4) by a term, depending on the „image motion". Accordingly

$$\Delta\varphi = e' + f'V \cos (A - A_0') + m' (\sigma - \sigma_0) \qquad (9)$$

The following results have been obtained:

– For the whole of the observational material, with r = 0.05,

$$\Delta\varphi = -0''.0139 + 0.0042\ V \cos (A + 23^o) - - 0''.136 (\sigma - 0.0070)$$

– For the observations by N–W quadrant winds, with r = 0.29

$$\Delta\varphi = -0''.0133 + 0.0282\ V \cos (A - 23^o) + + 6.4553 (\sigma - 0.0071)$$

– For the observations by S–E quadrant winds, with r = 0.11

$$\Delta\varphi = -0''.0156 + 0.0042\ V \cos (A + 13^o) - - 8.6935 (\sigma - 0.0069).$$

Now, let's compare the above results with those furnished by the formula (4). All that can be said is that the formula (9) yields somewhat more reliable results with the S–E quadrant winds. The ratio of the magnitude of effects, produced by winds from both quadrants, remains practically the same.

9. CORRECTION TO THE MICROMETER REVOLUTION VALUE

It has been remarked in Section 7, that *i*, the free term in (7), displays a certain regularity in its variation from one subgroup to another. The same can be said of i' in (8).

In our searching for the cause of this variation we found a relation, distinct by its high correlation r = 0.81, between *i'* and the mean values of differences of the micrometer readings (ΔM) of individual subgroups:

$$i' = -0''.0046 + 0.0090 (\Delta M - \Delta M_0) \qquad (10)$$

ΔM_0 denotes the mean value of all ΔM. Evidently, the mean angular value of the micrometer revolution requires a correction of 0".0180. Accordingly, the values of φ from all the subgroups observed in 1978, were corrected by *i'* from (10). A better consistency of latitude values, furnished by individual subgroups, was thereby achieved: the external error has been reduced from ± 0".117 down to ± 0".092, that is by about 21%.

The correction to the micrometer revolution of 0".0180 may be considered as a real one. Đokić (1981) has derived the corrections to the micrometer revolution from the observations carried out in the period 1971 to 1974, of the scale pairs. He demonstrated the variabillity (between – 0".0055 and+ 0".0187) of these corrections depending on observing programme and the system of catalogue used. If data under programme 1 (Washington stars) are used and processed within the AGK3 system, a correction of 0".0187 is obtained. It agrees well with the above cited value 0".0180. It should be noted that no technical interference with the micrometer whatever has been undertaken after the period 1971–1974.

10. CONCLUSIONS

The wind effects on the latitude observations present a very intricate phenomenon. These effects cannot, at least for the time being, be exactly predicted nor exactly calculated. Yet, some partial insight into this question can be acquired through analyses and by way of such simple formulae as presented in this paper. That is why they remain useful in spite of their shortcomings.

Our conclusions are as follows:

(1) Our analysis clearly show that the alterations executed in the period 1968 to 1970, have resulted in an appreciable reduction of the wind effects on the Belgrade latitude values. The following facts go to support this assertion:

(1a) The wind effects on φ are diminished: those depending on the wind velocity by about half, and those depending on the wind direction by about one order of magnitude (see: Sections 4 and 5). Although the values obtained are lacking full certainty, they nevertheles point to their being diminished.

(1b) By the analysis of the deflections of the star apparent motion across the field of view from its mean path it could be established that their amounts in the period 1976 to 1981 are by about 21% lower than they were in the previous period (1949 to 1957). It can be demonstrated that our observations as being of good quality (Section 6).

However we were not able to firmly establish whether the internal accuracy has been risen more than the external one, as was stated by Milovanović et al. (1981).

(2) Systematic wind effects produced by N–W quadrant winds are stronger than those generated by S–E quadrant winds (most of our observations are made by S–E winds). The total wind effects on the latitude determination, in general, are small, being,

however, appreciable with some of the subgroups, i.e. within some of the observational periods. This is, in all probability, a consequence of different wind features (Sections 3, 4 and 5).

(3) Instead of studying the wind effects on latitude separately by velocity (eq. 2) and by direction (eq. 3), it is recomendable – as a more real approach – to use the more comprehensive formula (4) or, still better, the formula (9). The formula (8) is also suitable for use.

(4) The data on latitude, acquired in the period 1976 to 1981 call for a small correction to the mean value of the micrometer revolution (Section 9).

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ACCURACY OF TIME DETERMINATION WITH THE BELGRADE TRANSIT INSTRUMENT

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SUMMARY: Variations of some basic parameters, connected with the time determination on the Belgrade transit instrument, are discussed. It is demonstrated that, under current conditions, the accuracy of the clock correction determination from he observation of a single star, amounts to ± 0^{s}030. Highly correlated seasonal components in the inclination differences are brought out, depending on the order of observation (E–W effect), as well as the correlation of the Temperature differences of the east and west room walls with the seasons.

1. INTRODUCTION

The purpose of the present work is the accuracy estimation of the observational results, acquired with the transit instrument „Bamberg" (10/100 cm) of the Belgrade Observatory in the period 1969–79, as well as the singling out of some systematic errors, which are found discussed later.

2. ESTIMATE OF THE APRIORI MEAN ERROR OF THE CLOCK CORRECTION DETERMINATION

Provided the instrument line of sight is describing the meridian plane, there will be

$$t = s - \alpha = T + C - \alpha = 0, \qquad \text{i.e. } C = \alpha_{app} - T_p$$

where α_{app} – the apparent right ascension, T_p – registered time of transit, C – the clock correction. However, the observations never being performed in the meridian plane, we have:

$$T'_p = T_p + \tau(A, \beta, c),$$

where τ – the angle defining the instrument position: A – the azimuth, β – the inclination, c – the collimation. Thus

$$C = \alpha_{app} - (T_p + \tau(A, \beta, c)).$$

In the well known Mayer formula the function τ is

$$\tau(A, \beta, c) = M \cdot A + N \cdot \beta + c \sec \delta,$$

where M, N and c are the azimuth, the inclination and the collimation coefficients, respecitvely. The collimation coefficient encloses also the terms, accounting for the contact widh and the diurnal aberation

$$R = (R_0/2) \sec \delta \mp \partial_a = (\text{const.} \mp 0^s021 \cos \varphi) \sec \delta,$$

Accordinly, the clock correction is a function of several arguments, C = C (α, T', β, R, A, c). But the collimation proper is removed by the instrument being reversed in the course of observation. Consequently, the ac indental error in the clock correction resulting from the observation of a single star, can be expressed by

$$E^2 = E^2(\alpha) + E^2(T) + E^2(\beta) + E^2(R) + E^2(LG) + E^2(MF) \qquad (1)$$

where: E(α) – error in he right ascension of the observed star, E(T) – bisection and the registering error, E(β) – the inclination error, E(R) – contact width and lost motion error, E(LG) – personal error, E(MF) – error produced by the meteorological factors.

The values of particular errors can be estimated in the following way:

a) The expression E(α) = ± 0^{s}002 sec δ (Podobed, 1968) is adopted as yielding the mean error of the right ascension of stars, brighter than 6^m.
b) The bisection error, and error in the registered transit time, can be deduced from the contact reading

$$E^2(T) = (E^2(K))/20,$$

as 10 contact pairs are read. E(K) denotes the error of a single contact. More details are presented in Table I.

Table I. Mean square errors E(K) of the contanct width determination according to declination (Part A) and magnitude (Part B). The units are $0^{\mathrm{s}}.001$. vs stands for visual and pho for photoelectric observations.

Part A								
δ	15°	25°	35°	40°	45°	55°	60°	65°
E (K, Belgrad, vs)	32	29	36		37	44		51
E (K, Pulkovo, pho)	27	28		29		34		
E (K, Sverdl., vs)		38		44			73	

Part B					
m	$2^{m}.5$	$3^{m}.0$	$4^{m}.0$	$5^{m}.0$	$5^{m}.5$
δ	$32^{\circ}.6$	$45^{\circ}.2$	$27^{\circ}.0$	$36^{\circ}.5$	$45^{\circ}.3$
E (K, m) cos δ	30	33	29	59	32

On the other hand it is known that the registering accuracy of the transit time is inversely proportional to the telescope magnification U and the rate V of the star motion across the field of view (Afanas'eva, 1957b), that is

$$E^2(T) = b^2 \sec^2 \delta, \; b^2 \sim (UV)^{-1}, \qquad (2)$$

Due to the defects in the registering system even small values of $b^2 \sec^2 \delta$ can produce appreciable E(T). We put therefore

$$E^2(T) = a^2 + b^2 \sec^2 \delta. \qquad (3)$$

The accounting for the meteorological factors requires a widening of the formula (3) by the term $c^2 \sec^2 \delta \, tg^2 z$ (Dolgov, 1952a). However, we abstained from this additional term since the contact reading for 100 stars, distributed between $+30^{\circ}$ and $+60^{\circ}$ declination, yielded

$$c = 0^{\mathrm{s}}.0014 \pm 0^{\mathrm{s}}.0011$$

The coefficients *a* and *b* have been determined in the following way. Let T (0) be the mean transit time, resulting from the reading of 10 pairs of contact T(−10), . . . , T(−1), ... , T(10). Then approximately

$$E(K) = (1/2)\,(T(-K) + T(K)) - T(0) \qquad (4)$$

is the error of a single contact. Knowing these values, the coefficients *a* and *b* in (3) were determined by the method of least squares. From the contatc readings for 266 stars, observed in 1979, we singled out the ones of 210 stars, located in the zone $+10^{\circ}$ to $+70^{\circ}$ declination. Thence we found:

$$a = 0^{\mathrm{s}}.0227 \pm 0^{\mathrm{s}}.0004, \; b = 0^{\mathrm{s}}.0196 \pm 0^{\mathrm{s}}.0001$$

From 245 stars in the zone -10° to $+70^{\circ}$ declination we obtained

$$a = 0^{\mathrm{s}}.060, \quad b = 0^{\mathrm{s}}.018.$$

The divergence of the two *a* values is an indication of the unsatisfactory condition of the registering system, i. e. the present one should be replaced by another, more up–to–date system.

From 100 stars in the zone $+30^{\circ}$ to $+60^{\circ}$ declination we had

$$a = 0^{\mathrm{s}}.010 \qquad b = 0^{\mathrm{s}}.0233$$

Afanas'eva (1957c) obtained for the Pulkovo zenith zone $+40^{\circ}$ to $+74^{\circ}$ declination, with their photoelectrical transit instrument.

$$a = 0^{\mathrm{s}}.026 \qquad b = 0^{\mathrm{s}}.0233$$

The difference of the Belgrade and the Pulkoovo γ values is, in all probability, due to the qualitative difference in the registering methods – the one is visual, the other is photoelectrical one. Hence, the observer's influence can be estimated at about $0^{\mathrm{s}}.010$.

The error of the mean instant determination is $E(T(0)) = \pm 0^{\mathrm{s}}.007$. It has been determined from 6 to 10 contact pairs, symetrically distributed with respect to the instrument meridian. The error grows rapidly with the dimnishing if the number of contact used, an indication of the nonuniform distribution of the recorded contacts.

c) The inclination of the instrument horizontal axis is measured with a bubble level, thoroughly examined by the Vassilev method (Đurović, 1969). The level division values were found to vary with temperature in the following way

Temperature (in $1C^{\circ}$)	1	1–11	11–21	21–31
Level divisions (in $0^{\mathrm{s}}.001$)	70	71	72	73

Check examination by Wanach method, executed in the period 1964–78 at an average temperature of 14°C furnished $0^{\mathrm{s}}.072$ for the level division value. It is assumed that this division value has not been changing with time.

The accuracy of the inclination determination has not been deduced from the observational data available. Instead, we adopted the mean value as given by Dolgov (1952b)

$$E(\beta) = \pm 0^{\mathrm{s}}.008$$

as being representative of our instrument too.

Previous examinations with the interferometer (Jovanović, 1973) have shown the pivots of the instrument horizontal axis as being of good quality. Therefore, only check examination with a suspension level according to a method proposed by Pavlov (1951) has been carried out. In each one of eight instrument positions the suspension level is read off and the inclination determined:

Instrument position	1	2	3	4	5	6	7	8
Circle	W	W	W	W	E	E	E	E
Tube	N	S	S	N	S	N	N	S

The correction to the inclination, due to the pivot irregularities, is calculated by

$$\Delta\beta(z) = (1/4)\ (\beta(2) - \beta(3) - \beta(4) + \beta(6) - \beta(5) + \beta(7) - \beta(8))$$

where $\beta(i), i = 1{,}8$ are inclinations, corresponding to he above set of instrument positions, and z – zenith distance. The results of these check examinations are presented in Table II.

Table II. Inclination diff. $\Delta\beta(z)$

z	I measurment	II measurment	III measurment	Mean
0°	−0ˢ002	−0ˢ006	−0ˢ009	−0ˢ006
10	13	− 9	3	2
20	2	2	15	6
30	2	− 1	− 8	− 2
40	− 7	0	− 4	− 4
50	− 18	− 14	− 10	− 14

At z = 50° a change in the profile of the pivot working section can be assumed, but this should be verified.

d) Dolgov (1952c) has shown that the coarseness of the micrometer contact head attains about 0.1 mm. The error E(R) = ± 0ˢ003 sec δ appears with the given spring force, the contact with being 0ˢ075.

The two months examinations of the contact width by the „ear" method furnished the following results:

- the contact width, resulting from he totality of measurements (15 series in all, comprising between 4 and 12 revolutions) R(0) = 0.593 ± 0.004 division. Since 1 division = 0ˢ069, we have R(0) = 0ˢ040.
- the error of the contact width determination

E° = ± 0ˢ003. This amount represents the estimate of the error E(R).

In addition, the contact width has been determined from the chronograph recordings of the transit of 554 stars. The results obtained are given in Table III.

Table III

1 – the number of stars observed, 2 – declination interval of the observed stars, 3 – contact widht obtained, 4 – retardation of chronograph pens.

1	2	3	4
544	− 5°, + 70°	0ˢ0390 ± 0ˢ0002	0ˢ0288 ± 0ˢ0002
442	+10 + 70	402 2	258 2

No seasonal variation in the contact width has been disclosed.

On insering the results under a), b), c) and d) in the formula (1) and knowing the declination of the Belgrade zenith point to be+45° (thus N = 1.4), we obtain

$$E^2 - E^2\,(LG) - E^2(MF) = \pm\ 0^s020.$$

According to Dolgov (1952d) we have

$$E(LG) = \pm\ 0^s018, \qquad E(MF) = \pm\ 0^s012$$

Thus we derive

$$E = \pm\ 0^s030.$$

This values represents the limit of accuracy, attainable with the Belgrade transit instrument, provided the systematic effects have all been accounted for.

3. SYSTEMATIC DIFFERENCES IN THE HORIZONTAL AXIS INCLINATIONS IN TERMS OF THE ORDER OF OBSERVATION

The mean value of $\Delta\beta = \beta(EW) - \beta(WE)$ derived for the period 1969–78 is

$$\Delta\beta = -\ 0^s0030 \pm 0^s0004.$$

The results according to years are given in Table IV.

A sudden rise of the mean annual value $\Delta\beta$ from 1972 to 1973 and a drop in 1975, as well as its great changeability over the last years is manifest. It could be established by inspecting the observer's notbook, that up till the middle of 1973 the instrument and the bubble have had a protective aluminium covering, which thereafter has been removed. This may be taken as confirming an earlier finding of Brkić (1961) to the effect that the observer seated east of the instrument produces a different influence than he does when seated west of it, the difference in influences being of the order of 0ˢ001.

Table IV. Mean annual value

year	0ˢ0001	Observer
1969	– 22	MJ, Dv
70	– 29	Mj, DV
71	– 25	MJ, DV
72	– 21	MJ, DV
73	– 34	MJ, DV
74	– 34	MJ, DV
75	– 24	MJ, LD
76	– 37	MJ, LD
77	– 29	MJ, LD
1978	– 44	MJ, LD

MJ – M. Jovanović, DV – D. Vesić, LL – L. Đurović

The monthly means (column 2 in Table V) have, in further analysis, been approximated by the equations of condition of the form

$$\Delta\beta = \Delta\beta o + \Delta\beta_1 \cos(t + \psi_1) + \Delta\beta_2 \cos(2t + \psi_2),$$

where $\Delta\beta_o$ – the free term, $\Delta\beta_1$, ψ_1 – amplitude and phase shift of the annual term, $\Delta\beta_2$, ψ_2 – amplitude and the phase shift of the semi–annual term, respectively; t – the time. The following values have been obtained from the total of the observational material

$$\Delta\beta_o = -0^s\!.0030, \Delta\beta_1 = -0^s\!.0007, \Delta\beta 2 = -0^s\!.0004;$$
$$\psi_1 = 21^d0, \psi_2 = -33^d7.$$

The results by months are displayed in Table V and illustrated in Fig. 1.

Table V Monthly mean of $\Delta\beta$

Column 1 – month, 2 – monthly mean $\Delta\beta$, 3 – approximated values of $\Delta\beta_G = \Delta\beta_o + \Delta\beta_1 \cos(t + \psi_1)$, 4 – residuals $R = \Delta\beta - \Delta\beta_G$, 5 – approximated residuals $R_c = \Delta\beta_2 \cos(2t + \psi_2)$, 6 – approximated $\Delta\beta_{(C)} = \Delta\beta_0 + \Delta\beta_1 \cos(t + \psi_1) + \Delta\beta_2 \cos(2t + \psi_2)$, 7 – residuals $\Delta\beta - \Delta\beta(C)$.

1	2	3	4	5	6	7
I	–0ˢ0030	–0ˢ0036	0ˢ0006	–0ˢ0004	–0ˢ0040	0ˢ0010
II	– 40	– 33	– 7	– 2	– 35	– 5
III	– 27	– 29	2	2	– 27	0
IV	– 24	– 26	2	4	– 21	– 3
V	– 15	– 23	8	2	– 22	7
VI	– 29	– 23	– 6	2	– 26	– 3
VII	– 30	– 25	– 5	– 4	– 29	1
VIII	– 29	– 28	– 1	– 2	– 29	0
IX	– 27	– 31	4	2	– 28	1
X	– 29	– 34	5	4	– 30	1
XI	– 38	– 37	– 1	2	– 35	– 3
XII	– 43	– 37	– 6	– 2	– 40	– 3

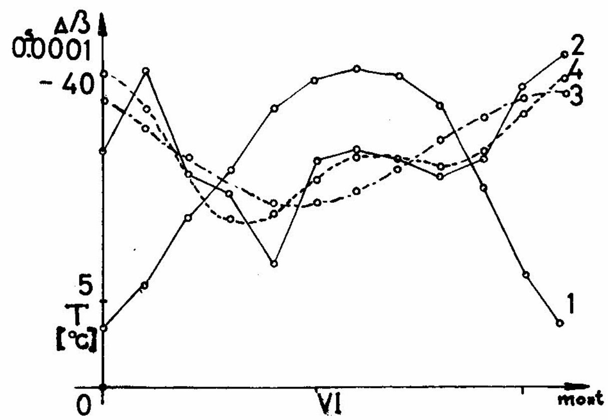

Fig. 1. Curves: 1 – monthly means of the instrument temperature (Table 6); 2 – montly means of the inclinationation differences $\Delta\beta$; 3 – values of $\Delta\beta_G$; 4 – values of $\Delta\beta(C)$.

The hypothesis $H_o : \rho_{23} = 0$ (also $\rho_{26} = 0$) has been tested against the alternative $\rho_{23} \neq 0$ (also $\rho_{26} \neq 0$), the level of significance being $\alpha = 0.05$. It could be shown that the zero hypothesis was to be rejected, as the correlation coefficient differed considerably from zero.

We see in Fig. 1 that there is a phase shift between the respective extrema of $\Delta\beta_G$ and the temperature of 32.6 days, which is in good accordance with value derived by Brkić (1961).

In our quest for he possible origin we stated similar seasonal fluctuations in the difference ΔT of temperature readings of the pair of termometers, the one being fixed on the east and the other on the west pavilion walls.

The approximations used: $\Delta T = \Delta T_o + \Delta T_1 \sin(t + \psi_1)$, where $\Delta T_o = 0^\circ\!.409$; $\Delta T_1 = 0^\circ\!.112$ and $\psi_1 = 35^d\!.5$; $\Delta T(C) = \Delta T_o + \Delta T_1 \sin(t + \psi_1) + \Delta T_2 \cos(2t + \psi_2)$, where $\Delta T_2 = 0^\circ\!.044$ and $\psi_2 = 59^d9$.

Table VI. Monthly means of the instrument temperatures in the period 1969–79.

Month	Temperature	Frequency
I	3°50	7
II	6.43	6
III	10.58	8
IV	13.62	7
V	17.55	7
VI	19.74	9
VII	20.25	9
VIII	20.00	8
IX	17.60	8
X	12.69	7
XI	6.99	9
XII	3.33	9

The coefficient of correlation of the measured ΔT and the values $\Delta T(C)$ is 0.90. The same statistics as the one applied previously discloses that this correlation coefficient is differing considerably from zero.

Table VII. Monthly mean ΔT

Columns: 1 – Monthly mean values of ΔT; 2 – Number of determinations; 3 – Approximation of ΔT; 4 – Approximation of $\Delta T(C)$.

Month	1	2	3	4
I	0º492	131	0º495	0º495
II	427	135	519	481
III	475	190	511	476
IV	514	191	477	480
V	458	179	425	466
VI	400	238	366	408
VII	294	203	320	323
VIII	254	222	298	260
IX	338	247	308	266
X	308	283	345	338
XI	377	137	400	429
XII	486	96	457	486

The calculus of the correlation coefficient between $\Delta\beta(C)$ and $\Delta t(C)$ furnished $\rho = 0.73$.

Such a high degree of correlation is an indication that one of the primary causes, producing the differences $\Delta\beta$, is the presence of the temperature gradient and its seasonal fluctuations.

As the clock correction is affected by the presence of these differences and their fluctuations, it is necessary to perform adequate analysis of the matter – that is just what will be the subject of another work of ours.

4. CONCLUSIONS

The results, arrived at in Section 2, indicate that under the present conditions of observation with our transit instrument, it is possible to keep satisfactory accuracy standards. Nevertheless, the introduction of a more objective registering technics would be very useful.

Maximum of the inclination difference $\Delta\beta = \beta(EW) - \beta(WE)$ amounts to about 0ˢ003. There is a systematic difference between the sommer and winter values. The thermal insulation of the instrument and the bubble level by the aluminium sheets brings about a diminishing of $\Delta\beta$ values, yet their seasonal fluctuations remain unaffected. The seasonal variations in the inclination differences are distinctly correlated with the variations in $\Delta T = T(W) - T(E)$, disclosing the temperature variations as being their principal originator.

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EFFECTS OF EXTRAFOCAL OBSERVATION WITH THE SOLAR SPECTROGRAPH OF THE BELGRADE ASTRONOMICAL OBSERVATORY. II. CASES OF VARIOUS WAVELENGTHS AND SPACE–RESOLUTIONS

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SUMMARY: According to an already published procedure, the space–averaging of the solar image within square regions from 3'.8 to 0'.5 side and for wavelenghts 630 nm, 500 nm and 400 nm have been calculated. For a selected sample of P and B_o the effect has been found amounting up to 33 ms^{-1}.

1. INTRODUCTION

The influence of finite space–resolution within the solar image in the course of evaluation of photospheric line–of–sight velocities was treated in Paper I (Kubičela and Vince, 1983). The space–resolution of 3°.8, regularly used in the Belgrade research program, was considered and applied to the solar rotation line–of–sight velocity field observed around the wavelenght 630 nm.

The problem is now being somewhat generalized in order to comprise some other space–resolutions and wavelengths.

2. CALCULATIONS

Using the procedure described in Paper I, the differences ΔV^I (equation (4) of Paper I) between the space–averaged solar rotation line–of–sight velocity within a set of square regions around a series of points at the solar disk and the corresponding non–averaged line–of–sight velocity at the same points have been calculated. Four geocentric angular sizes of the square sides of the integration areas are: a_1 = 3'.8, a_2 = 2'.0, a_3 = 1'.0, and a_4 = 0'.5. The calculations have been also done for three different wavelength regions: λ = 630 nm, 500 nm and 400 nm, interpolating accordingly the value u_1 in the well–known limb–darkening law of the solar disk (Allen, 1977).

The results for a selected pair of heliographic parameters P = 0°.0 and B_o = + 3°.5 (e.g. begining of July) when difference ΔV^I reaches its extreme values, are shown in Table I. Here the first column contains the points of the solar disk regularly used in Belgrade observations indicating either the central meridian (CM) or the pairs of other, east–west around CM symmetrically situated points. The X– and Y–columns give the corresponding rectangular coordinates of the mentioned

Table I. Line–of–sight velocity differences ΔV^I for different wavelengths and space–resolutions (in ms^{-1})

Points	Position at the disk		ΔV^I											
			λ = 630 nm				λ = 500 nm				λ = 400 nm			
	X	Y	a_i = 3'.8	2'.0	1'.0	0'.5	a_i=3'.8	2'.0	1'.0	0'.5	a_i=3'.8	2'.0	1'.0	0'.5
CM	0.000	any	0	0	0	0	0	0	0	0	0	0	0	0
RE, RW	±0.790	0.000	18	5	1	0	24	6	1	0	33	8	2	1
T, U	±0.658	0.000	11	3	1	0	14	4	1	0	18	5	1	0
N, K	±0.500	0.000	7	2	0	0	8	2	1	0	11	3	1	0
M, L	±0.250	0.000	3	1	0	0	4	1	0	0	4	1	0	0
G2, F2	±0.250	0.658 S	4	1	0	0	5	1	0	0	6	2	0	0
G1, F1	±0.250	0.500 S	4	1	0	0	5	1	0	0	6	2	0	0
G, F	±0.250	0.250 S	3	1	0	0	4	1	0	0	5	1	0	0
Q, P	±0.250	0.250 N	3	1	0	0	4	1	0	0	5	1	0	0
Q1, P1	±0.250	0.500 N	4	1	0	0	5	1	0	0	6	2	0	0
Q2, P2	±0.250	0.658 N	5	1	0	0	6	2	0	0	8	2	1	0
H1, E1	±0.500	0.500 S	9	3	1	0	11	3	1	0	15	4	1	0
H, E	±0.500	0.250 S	8	2	1	0	9	2	1	0	12	3	1	0
R, O	±0.500	0.250 N	8	2	1	0	9	2	1	0	12	3	1	0
R1, 01	±0.500	0.500 N	10	3	1	0	12	3	1	0	15	4	1	0

points in units of the radius of the solar disk – S and N meaning south and north respectively. The ΔV^I values, in ms^{-1}, are given in the remaining 12 columns grouped for three indicated wavelenghts and, within a group, for four a_i (i = 1, 2, . . . 4) space–resolutions (from 3:8 to 0:5).

The sign of ΔV^I is such that absolute value of the averaged line–of–sight velocity is always smaller than the non–averaged line–of–sight velocity at the centre of the integration area. To correct the observations for this effect, one has to increase the absolute value of the observed line–of–sight velocity.

3. CONCLUSION

From Table I one can see how the space–averaging effect in the field of solar rotation line–of–sight velocities increases while the integration area increases and the wavelength decreases. At one–ms^{-1} level the effect can be neglected for space–resolutions better than 0:5 and throughout quite a wide range of visual wavelenghts. For the space–resolutions of 2' to 4', sometimes used in contemporary photospheric velocity observations, it is not at all negligible and the adequate corrections, reaching up to 33 ms^{-1} have to be calculated and applied.

Table I shows only some high–value samples of space–averaging effect on solar rotation line–of–sight velocities. If desired, the other values for different combinations of P and B_0 as well as for other wavelengths and space – resolutions can be easily calculated.

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PROGRESS REPORT ON THE ASTRONOMICAL REFRACTION

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SUMMARY: A presentation is given of works on astronomical refraction, published in the period 1979 to 1982. Particular emphasis is given to research currently of special interest to astrometry, as for instance that relating to three dimensional refraction, atmospheric turbulence etc.

1. INTRODUCTION

In a previous paper of ours (Teleki, 1981) an overview was given of research into astronomical refraction and, partially in refraction in general, on the basis of papers published in the period 1976 to 1979. That review is now continued on the basis of papers (available to us) appearing in the period 1979 to 1982. Occasionally, some earlier papers will be mentioned but only where continuity and clarity of presentation makes it imperative.

The intensity of research in refraction is not declining – as many as 107 papers are on record in the last three years. Most of the papers were published in the USSR – in the period concerned about 60% of the world total. One cannot help noticing the impetus produced by meetings dedicated to astronomical refraction: the majority of the published papers have been presented at just these assemblies. The following meetings may be noted: on atmospheric optics at Tomsk (USSR, 1980), on atmospheric influences in astronomic observations within optical and radio waves lengths at Irkutsk (USSR, 1980) and on three–dimensional refraction at Dubrovnik (Yugoslavia, 1981). The sponsors of the Dubrovnik Meeting were jointly the Working Group on Astronomical Refraction of the IAU Commission 8 and the Special Study Group 1.42 „Propagation of the Electromagnetic Waves and the Atmospheric Refraction" of the International Association of Geodesy. Meetings dedicated to terrestrial refraction will not be referred to herein.

The papers dealt with in the present survey are divided into groups, but – as often happens –some researches are complex and do not „stand" such divisions. Nevertheless, all the works we took into consideration are mentioned at least once in some of the groups.

2. THREE – DIMENSIONAL REFRACTION

The basic questions concerning the three–dimensional components of astronomical refraction are outlined in our previous paper (Teleki, 1981). Relevant research is being continued.

Teleki and Saastamoinen (1982) submitted an account of this problem as it appears from the astrometric standpoint. Three difficulties associated with this matter are pointed out: the strictness of the law of refraction used, the application of the formulae according to which the refractive index is calculated, and the determination of the meteorological field elements along the path of the light ray. The third problem is the most important in practice. It is estimated that it is not necessary to take into account the three–dimensional influence on the pure (normal) refraction values up to 45° zenith distance. However, at larger zenith distances these influences must taken into account with regard to their astronomic significance. At 70° zenith distance the effect on the vertical component (in zenith distance) is of the order of 0".01, and at 80° of the order of 0".1. The influence on the horizontal component (in azimuth), is even larger, about 0".1. All of these values are variable and depend on the position of the observing station on the Earth's surface. The authors draw the conclusion that international refraction tables should be constructed from a global atmospheric model (and that these should serve as standard tables). Values from these tables are to be corrected, when necessary, for regional and local effects. It is suggested that the global atmospheric model proposed by Saastamoinen (1980), and briefly outlined in the paper, or alternatively, an ellipsoidal model more fitting to the Earth's figure be adopted.

Sergienko (1979a, 1979b) derived formulae for computing the astronomical refraction influences on zenith distance and azimuth using a three–dimenzional atmospheric model. As a result he obtained a nonlinear, dynamic system of second–order differential equations with two parameters:

$$\omega = \frac{1}{n}\frac{\partial n}{\partial x} \qquad \epsilon = \frac{1}{n}\frac{\partial n}{\partial y}$$

where: n = refractive index, x and y are rectangular coordinates (horizontal components of the local XYZ rectangular coordinate system), and z = altitude. The solution of these equations is performed by using perturbation theory and by Bernoulli's method. The accuracy of the astronomical refraction values thus obtained is dependent on the accuracy of meteorological data and on the extent of the information available for the meteorological field. For these reasons the posible influence of four layers is considered by the author: that originating from the ground and boundary layer that in the free atmosphere up to 35 km and from the free atmosphere up to 75 km. Sergienko (1979c, 1981) analyses six atmospheric models, paralleling this work by systematicly organizing and acquiring (at his observatory) extensive meteorological data (Sergienko, 1980; Sergienko et al., 1980). The solution of the problem is, evidently, conceived on a broad basis, whereby the principal factors are accounted for. As a result, the accuracy of the astrometric results is enhanced by at least 1.5 to 2 times (Sergienko, 1981). The following are the conclusions reached by this author (1980): a) by taking into account ω and ϵ in calculating the refraction in the meridian plane the refraction is increased provided ω and ϵ have the same sign; b) the values ω and ϵ are directly correlated with the variation of the differences of the refraction given by the Pulkovo Tables and the one furnished by the formulae based on the three–dimensional atmospheric model, and c) the pure refraction and that resulting from the three–dimensional atmospheric model, with $\omega = \epsilon \leqslant 10^{-10}$, are coincident, within ± 0.″001, up to z = 30°. Markov and Sergienko (1981) gave a method for the automation of the refraction formulae determinations based on a three–dimensional model of the atmosphere. These authors also found the solution for the linearization of Sergienko's nonlinear system using the series expansion by ω and ϵ (up to third order).

Hughes and DeLateur (1982) turned to experimental research regarding the possible instantaneous influence of the local atmosphere on astrometric data. According to them the variation of the amount of water vapour and of the isopycnic tilt in time and with the height are so significant (evidence thereof is presented by the authors) that a near real time determination of them is required for astrometric observations. A plan is therefore outlined, involving both water vapour profiling and temperature determination – (thus a three–dimensional approach in the study of the local atmosphere is used) – utilizing LIDAR (Light Detection and Ranging). It seems that water vapour profiling presents no problem and the authors are also confident regarding the feasibility of the determination of isopycnic tilts. The implementation of this plan at the US Naval Observatory, Washington, is expected in 1983–1984.

On the use of the LIDAR system see also the papers of Ivanenko and Maricheva (1980) as well as that of Reagen et al. (1980).

The effects of the atmospheric ellipticity on atmospheric refraction has been analysed by Kushtin (1980).

From a great number of observations at different azimuths and zenith distances Redichkin (1980) was able to infer that the observed refraction values at zenith distances over 70° deviate from the tabulated ones not only on account of the instrumental errors but also as a consequence of the real atmosphere deviating at the moment of observation from the spherical model underlying all the refraction tables. These deviations are generally positive for the eastern half of the sky and negative for its western half. In the case of the observational conditions in both halves of the sky being equal, the deviations are of the same order of magnitude, but with opposite signs. – Although the instruments used by Redichkin cannot be ranked among the highly precise ones, nor can his method of determining refraction directly from the astrometric observations be regarded as reliable one – more about it is the Section 3 – we consider these researches as useful on account of the conclusions just cited. This author's conclusions are attributable in the first place – making allowance for instrumental influences – to the local atmospheric characteristics because, all thing considered – with regard to what has been statedt above (Teleki, Saastamoinen, 1982) – the effects resulting from the global atmospheric model are not of the order of magnitude as quoted by Redichkin.

From their observations at larger zenith distances Korzhinskaya et al. (1981) inferred that the refraction reached larger amounts in the east half of the sky than in the west half. Otherwise, concerning the researches of these authors, the same remarks as those relating to the Redichkin's (1980) researches might be made.

We may, therefore, sum up by stating that astrometry needs answers to questions about possible three–dimensional effects on astronomical refraction. These researches are progressing well and a better coordination of work being performed in this field seems therefore desirable.

3. THE PROBLEM OF REFRACTION DETERMINATION FROM THE ASTROMETRIC MEASUREMENTS

The determination of the refraction, R, directly from astrometric measurements is going on. Dealing with the subjects are for instance: Arkhangelskij, 1979; Maslich et al., 1980; Redichkin, 1980; Kharin, 1980, 1982; Yatsenko, 1980; Krozhinskaya et al, 1981; Poma et al., 1982. Up to about 70° zenith distance the deviations ΔR of the derived values of R from the tabulated ones (or from the data resulting from the aerological measurements) lie within the limits of the

Table I. The refraction determination data from the astrometric observations at larger zenith distances

Authors	Zenith distances	ΔR	ϵ_R	Notes
Vasilenko (1975)	80° – 88° 89°	+1″.2 – 6″.4 –7″.7	3″.0–3″.6 4″.0	With respect to the aerological measurements
Redichkin (1980)	73° – 88° >88°	±2″– ±60″ –121″.4	3″.0 – 9″.0	ϵ_R for the zone 70° to 90°; ΔR most frequently it amounts to 1 –10% and rarely 15 –18% of R
Kharin (1980)	70° – 86°	2″– 3″	3″– 5″	ϵ_R at the zone boundary
Korzhinskaya et al. (1981)	80° – 89° 70° – 83°	–20″– + 17″ –14″– + 8″	– –	Night measurements Daily measurements

observational and computing errors (Redichkin, 1980). At larger zenith distance ΔR is larger being, moreover, very changeable. This is evidenced by the errors ϵ_R of determination of R, as well as changes ΔR from one location to another. To illustrate this some examples are given in Table I.

These, together with similar data, are useful insofar as they can be applied (in the near future at least) to the reduction of astrometric observations. This is to say that they have to be correctly interpreted and their errors must be acceptable from the astrometric standpoint. The fundamental problem is to determine the causes producing the characteristic values in Table 1. In our view the following causes might be enumerated, whereby observations made at larger zenith distances are primarily kept in mind:

3.1. Deficiency of the current refraction theories (tables) and of their applications. Let us for a while put aside the theories, whose unreliability at larger zenith distances is well known, and consider their application. The essential question is what accuracy of meteorological data is needed for the determination of R. It is assumed (Teleki, 1974) that the error in R, due to insufficiently accurate temperature and pressure values (i.e. of the refractive index) is at least about ± 0″.02 tg z; for z = 80° this gives ± 0″.11, and at z = 88° we have ±0″.57; at z = 89° the value ± 1″.16 is obtained. Similar results have been obtained by Nelyubin (1980) in his analysis of effects produced by errors in temperature of ± 0°.1C and errors in pressure of ± 0″.1 mb. These influences, if systematic, can even be larger (Teleki, 1974). If R is determined directly from the aerological measurements then, according to Vinnikova (1974), at z = = 88°, the error amounts to 3″.9 (that is 0.36% of R). Therefore we may conclude that neither the existing refraction tables nor the aerological measurements are a strong basis for the calculation of ΔR for observations at larger zenith distances.

3.2. Instrumental errors, those depending on the atmospheric parameters in particular, are, on the whole, above 0″.1 (Teleki, 1978). This applies to an even greater degree to large zenith distances (Kharin, 1980, 1982).

3.3. The lack of sufficient knowledge of the influence of the inhomogeneity of the meteorological field on the propagation of light rays. For the calculation of R, the current refraction tables use only temperature, pressure and water vapour, as the characteristics of the state of the atmosphere. But even about this matter there is disagreement, for no definitive stand has been taken as to exactly where the meteorological parameters are to be measured – inside or outside the pavilion, close to the instrument or at a distance from it, etc. Moreover, it is evident that the temperature, pressure and water vapour alone (wherever and however they happen to be determined) fall short of being sufficient in providing a complete characterization of the meteorological field. Thus, no atmospheric effect is calculable to the degree necessary in the reduction of astrometric observations. The question therefore arises what supplementary factors are to be taken into account. Several attempts in this respect have been made but they do not, at least for the time being, offer the possibility of being applied generally in astrometric practice. An example is presented by Vasilenko and Kharitonova (1977) the two having tried to apply V.I. Tatarsky's ideas about the statistical orthogonal expansion of the refractive index to the measurements of Vasilenko (1975); the calculated and observed values of R they obtained proved to be in good accord down to z =

= 88°, with the standard deviation not exceeding ±9″ (this value has been derived from the deviations of the individual differences from their mean). But no accordance is found at z = 89°. Alekseev and Kabanov (1980), in their description of the ground layer, made use of the Monin–Obukhov's theory. In this way they raised the accuracy of the calculation of R by 2 to 3 times. Nevertheless their work should be considered as experimental.

The remarks concerning the determinations of the diurnal refraction variations from the photographic observations of the Sun (Arkhangelskij, 1979; Poma et al., 1982) are quite in line with those made in paragraphs 3.1 through 3.3. Besides problems associated with the instrument and the plate reductions, pointed out by the authors themselves, consideration should be given to what is stated in paragraph 3.3. One of the possible causes of these problems has also been pointed out by Nefed'eva (1976).

In view of all the uncertainities inherent to the determination of R from astrometric measurements, we continue to regard this method as being of little merit (Teleki, 1979). This applies with all the greater force to larger zenith distances. Experience with terrestrial refraction (refraction values for z ≈ 90°) shows how justified this opinion is: satisfactory results have not been obtained although various meteorological factors have been allowed for. New methods are necessary for the solution of this problem, the so called dispersion methods in the first place (Tengström, 1982) along with radometric methods (Alekseev et al., 1980).

Sergienko (1980) reaches the conclusion that allowances for the refraction anomalies obtained by using current methods and experimental data, do not result in an improved accuracy of the astrometric results.

It is also interesting to mention Kharin's (1980, 1982) investigations. On the basis of his own observational data, collected with the Wanschaff Vertical Circle in Kiev, at large zenith distances up to 86°, he concluded that meridian observations at large zenith distances (between 75° and 85°) render it possible to demonstrate refraction anomalies, but they cannot be differentiated from instrumental errors.

One can put the question of the utility of determining R from the astrometric measurements. The answer, in terms of refraction, is that it has been demonstrated that the changes in R at larger zenith distances are large and variable with time and dependent on the observing location as well, and that the existing methods and their improved versions fail to represent these variations. It follows therefore that astrometric observations at very large zenith distances should be given up or that other methods should be developed, capable of minimizing the atmospheric influences or their more accurate determination (Tengström, Teleki, 1979).

For more about the computation of the terrestrial refraction as well as the astronomical refraction at large zenith distances (near the horizon) see the paper of Nelyubina and Nelyubin (1980).

4. PURE REFRACTION, REFRACTION TABLES

Guseva et al. (1982) are preparing the Fifth Edition of the Pulkovo Refraction Tables. These refraction calculations are based on Guseva's (1982) method using the Soviet Reference Atmosphere GOST–73. The authors pay utmost attention to the determination of the chromatic refraction. The tables will be given in the traditional logarithmic form as well as in a simplified version of the algorithms and programs for refraction calculations at zenith distances from 0° to 80°.

The quality of Nefed'eva 's new refraction tables (1978, 1981) has been analysed by Yatsenko (1981), wherein he made use of the observations of selected stars with the Kazan Meridian Circle. The observations included stars from 0° to 85° zenith distances and were carried out at temperatures ranging from −25° to +18°C. He found the Nefed'eva's tables to be affected by the same errors as those inherent in the Pulkovo Tables in the zone 0° to 65° zenith distance. However, at zenith distances from 65° to 85° the new tables proved slightly superior to those of Pulkovo.

Using their own method, Fukaya and Yasuda (1982) made computations of the astronomical refraction from the aerological data (up to 30 mb), acquired near Tokyo and from the US Standard Atmosphere 1976 (above 30 mb up to height of 91 km). By comparing their results with the values given by Pulkovo Tables a constant difference (0″.074 at z = 45°) was identified for the dry air as well as a seasonal variation for the humid air (Pulkovo Tables present invariably lower values, as has earlier been indicated). The authors also make computations of the coeficient, c, of the Dale–Gladston equation for various cases and establish a variability that cannot be disregarded.

In a continuation of these explorations, Fukaya (1982) obtained (by way of numerical addition up to 91 km height) new values. There is a very good accordance between his values and those given by the Pulkovo Tables: the differences between them is very small and constant up to the zenith distance of 78°. He thereby used the averaged values of n $[(nr)^2 - (n_0 r_0 \sin z)^2]^{1/2}$ for the upper and lower boundaries of the relevant atmospheric layers.

Fukaya and Yoshizawa (1982) pointed out that the Pulkovo Tables (Forth Edition) are completely reproducible by employing their numerical calculation method of refraction for a given wave length region. The differences between the numerical values and those from the Pulkovo Tables are always less than 0.″02 irrespective of the season for the zenith distances from 0° to 75°.

On the numerical computations of refraction see Fukaya's and Suzuki's (1981) paper.

Nefed'eva (1980) made investigations aimed at establishing which of the wave lengths were actually underlying the refraction tables. This is turn has its bearing upon the chromatic refraction computation. Thus it was found by her, among other things, that the Pulkovo Tables were in fact related to 5960 Å and not to 5753 Å as hitherto assumed. Many of the analysis have therefore to be revised (among others the one of Fukaya and Yasuda (1982) just referred to).

Kushtin (1980a) developed a new method of solution of the refraction integral and suggested the best possible way (1980b) of separating the systematic component in the refraction and its accidental part. A procedure for determining measuring errors is also laid out.

Sugawa (1980, 1981) presented a survey of the current researches into astronomical refraction.

Dimopoulos (1982) considered in detail many questions of the astronomical refraction in general.

Kushtin (1980c) expounds various models for the determination of pure refraction and Mikkola (1981) discusses the effects of errors in the adopted temperature profile of the atmosphere on the astronomical refraction values.

5. ANOMALOUS REFRACTION

A survey is presented herein of the researches into anomalous refraction (= true minus pure refraction values) which cannot, or at least not strictly, be characterized as evolving from a three–dimensional conception.

5.1. Image motion

According to Brunner (1982) the final accuracy of a direction determination in astrometry and geodesy is a function of the instrumental parameters, the atmospheric turbulence intensity and the period of time included in the averaging. Let us have a closer look at the last two factors, to which relatively little attention is paid in astrometry. Why? Firstly, because they are regarded as necessary evils, conditioned by the choice of instrument, of the location where it is installed, atmospheric conditions prevailing there and the method of observation. Yet, it is well known how significantly astrometric observations are affected by them. According to Ivanov (1979) no less than 30% of the accidental observational errors of the Pulkovo Vertical Circle are due to the atmospheric turbulence while the observational errors of the Pulkovo Transit Instrument are, almost entirely, produced by this effect. Høg (1968) inferes that the average accuracy of observations made with contemporary PZT's, astrolabes and meridian instruments is limited by image motion, which causes a mean error in the zenith zone of 0.″33 $(T + 0.65)^{-0.25}$ for all the integration intervals $T \geqslant 0.2$ seconds of time. This error increases approximately with the secans of zenith distance. According to Brunner (1982) typical amplitudes of the image motion for zenith distances 60° to 80° are: 1 to 5 microradians (one microradian ≈ 0.″2) but under daily conditions taken separately values from 10 to 40 microradians are obtained. To diminish these influences the need is emphasized by Brunner of using a sufficiently long signal, by whose averaging the required accuracy can be brought about. The fundamental question thereby arises: what is the duration of that „sufficiently long" signal? Ivanov (1979) maintains that the optimum duration of the astrometric measurements is about 2 minutes and that a continuous measurements averaging is most advantageous. According to the same author the optimum objective diameter of the astrometric instruments is 20 cm (the image motion amplitude is known to depend on the objective diameter, but with the diameters exceeding 20 cm it only slightly decreases).

The researches in the turbulence carried out by Sugawa and Naito (1982) are more complex for they involve also the influence of changes taking place in the internal boundary layer, the advection of cold air masses as well as internal gravitational waves. They analysed, in fact, the probable changes in the atmospheric conditions (density) during the star transit across the field of view of the VZT, PZT and the astrolabe, as well as their influences on the latitude and time values. The respective refraction effect values obtained by them are as follows: 0.″005 to 0.″1 with the VZT, under 0.″03 with the astrolabe and the values that are not less than 0.″01 with the PZT. Thus the influences are of the order of 0.″01, an amount which cannot be ignored in high precision observations.

Lindegren (1980) studied the influence of refraction anomalies on optical differential astrometry by means of a simple model of the large–scale wavefront distortion caused by atmospheric turbulence. He found that in narrow–field astrometry (determination of trigonometric parallaxes, measurements of double stars, etc.) the mean error of the measured angle θ (in radians) between two objects near zenith to be 1.″3 $\theta^{-0.25}\, T^{-0.5}$, where $T \gg 300\,\theta$ is the integration time in seconds. By comparing these values with the internal errors of some differential astrometric measurements it appeared that the above formulae account for the greater part of the observed apparent fluctuations of the Sun's disk (the error of observation is 0.″030 while the one yielded by the formulae is 0.″022), as well as the errors in the measured angles between the stars whose mutual distance equals the Sun's diameter. This author derived a formula valid for the case of stellar position determination with respect to the centroids of several reference stars within a radius R (in radians): the mean error in each coordinate is $0\overset{''}{.}8\ R^{0.25}T^{-0.5}$ (or $0\overset{''}{.}003$ for R = 10' and $T = 1^h$). (It should be noted that differential astrometric observations, made at large zenith distances, can significantly be affected by the tilts of air layers of equal density; with a tilt of, say, 10', zenith distance of 80°, and zenith distances differing by 0°.5, under the medium atmospheric conditions, the anomalous refraction attains about $0\overset{''}{.}5$ (Teleki, 1968)).

Makarov (1980) presents the possibility of modeling, on the basis of star observations, the atmospheric turbulence intensity as a function of altitude.

Information on the influence of the tropospheric refractive index fluctuations on the accuracy of the radioastronomical determination of coordinates of cosmic sources is found in the paper of Stockij (1980). The coordinate measurement accuracy has, in this author's view, attained such a level that taking into account of the tropospheric fluctuation appears necessary. The author states also that tropospheric influences can be reduced by the differential coordinate determination.

5.2. Chromatic refraction

At the Pulkovo Observatory a team of authors has completed some very important investigations of the chromatic refraction and its influence on astrometric measurements. But the greatest contribution made by this team of authors consists of their having developed a procedure to be applied in practice. In the paper of Bagil'dinskij et al. (1981) an analysis is found of the possible influences of the chromatic refraction on the results of observations with the Pulkovo Photographic Vertical Circle. In the paper by Bagil'dinskij et al. (1980) a general model of the chromatic refraction computation is presented, wherein account is taken of the true energy distribution in the extra–atmospheric stellar spectrum and its filtration due to the characteristics of atmosphere, the optics, optical receivers ect. Elaborated are the cases of the visual, photographic and photoelectrical mode of observation. Atmospheric turbulence is also taken into account. These investigations have again and again confirmed the need for rigorously taking into account the chromatic refraction in the determination of declination with astrometric instruments. It should be noted that these author's investigations are being continued.

About the wavelengths of which basic data are presented in the refraction tables see Nefed'eva (1980).

5.3. Dispersion method

Prilepin (1980) made an analysis of the determination of refraction by means of measuring the angular dispersions using two wavelengtths, whereby the influence of atmospheric turbulence has also been taken into account.

Concerning the analysis of the dispersion method see Tengström (1982).

5.4. Origins of anomalies

Proceeding from his measurements of changes taking place in the temperature field surrounding the observation pavilion (see Paragraph 6 of the present paper), Sibilev (1981) derived anomalous refraction values under day time conditions. These effects reach the order of $0\overset{''}{.}1$ at 45° zenith distance but are very changeable depending on the wind direction.

By using aerological data Motrunich and Shvalagin (1980) inferred that there were three factors generating the anomalies: a) unsatisfactory accuracy of the reduction for temperature in the Pulkovo Tables, b) refraction constant not corresponding to the wavelenght 5753 Å, and c) temperature inversions, typical of the night time, are not sufficiently allowed for by the adopted atmospheric model. At small zenith distances the anomalies are mainly due to the first two factors but at $z > 85°$ the temperature inversion influence is so strong as to make the former two effects almost negligible.

Yakovlev (1980) investigated the variations of the refraction as a function of the local climatic conditions, zenith distances and the height of particular air layers. It has been demonstrated by the author that the refraction variations as a function of height above 20 km are practically constant, being independent of the local climatic conditions. Below that height the influence of the air layers varies as a function of the zenith distance of the celestial body under observation.

The anomalous refraction associated with day–time observations with the Nikolaev (USSR) Transit Instrument was studied by Fedorov and Shul'ga (1980). They carried out measurements of the temperature field inside the pavilion. Thence they derived a formula for computing the refraction anomalies and finally fixed plans for their future investigations.

According to Goto (1979) the local atmospheric characteristics in Mizusawa are responsible for an anomalous refraction of up to $0\overset{''}{.}2$ in the latitude observations with the VZT.

Tyuterev (1979) gave a general presentation of the problem of anomalous refraction determinations.

5.5. Radioastrometric, Doppler and satellite observations

Concerning radioastrometric observations attention is called to the paper of Mitnik and Mitnik (1980), Mitnik (1980), Kajdanovskij and Stockij (1980), Woyk (Chvojkova) (1982). As for the VLBI techniques the reader is referred to the papers of Zimovski (1980), Bougeret (1981) and Spoelstra (1982).

Refraction effects in Doppler observations are dealt with by Zhu (1979), Sato and Naito (1979) and Bulygina (1980).

The papers of Bartijchuk et al. (1980) and Rachel (1980) are concerned with artifical satellite observations.

5.6. Techniques

A survey of the current status and development of absolute refractometers as well as dispersiometers (relative refractometers) is presented by Potapov (1980). According to this author this equipment can be expected to attain a sensitivity of 10^{-10} of the refractive index. Information on the use of refractometers in astronomical observation is found in Semenov et al. (1980). These authors consider that the gas refractometer (low weight 2 to 2.5 kg measurement errors ± 1 to ± 1.2 units of N) is best suited to the task.

Ishii (1979) writes about the automatic determination of the meteorological elements needed in the derivation the astronomical refraction.

6. PREVENTION

Teleki (1982) set up criteria (16 in all) for astrometric site selection and, proceeding from them, was able to locate the most suitable places on the Earth's surface. In this analysis he took into consideration the following global influences: seismic, atmospheric (refraction, cloudness), strain, plate tectonics, gravimetric and tidal influences. Clearly, a knowledge of global influences alone is not sufficient for the assesment of how suitable for observations a particular place is, yet they provide initial information about potential sites.

The Repsold Meridian Circle (15/200 cm) is to be transfered from Moscow centre to the mountains, at an altitude of 2600 m. Shamaev (1981) depicts the astroclimatic conditions (number of hours suitable for astrometric observations, image quality, inversion layer thickness, atmospheric transparency, deep sky radiation, direction and speed of winds) prevailing at the locality of Maidanek (Central Asia, near to Kitab), where the instrument is to be erected. Besides astroclimatic parameters, additional criteria, adhered to in selecting this location, were: a) to be as distant as possible from the potential places where new construction (pavilions, residential buildings) is expected, b) the possibility of constructing both near and distant meridian marks, and c) the possibility of making observations at large zenith distances. In connection with b) it is stated that image motion was exceptionally small (for observations of distant objects, too) during all of the day and night, and that atmospheric transparency was also good. The decision was therefore taken ot erect laser meridian marks (Golovko et al., 1982). Unfortunately, it cannot be gathered from the paper how well some of the conditions stipulated for selecting the site of an astrometric instrument are satisfied. It is in any case hard to achieve high precision for observations at large zenith distances.

Khetselius and Tertitskij (1976) developed two methods by which it was possible to give a fairly good short–term forecast of the astroclimatic conditions at Maidanek. In these authors' view their experiences are applicable to other observatories.

Alekseev et al. (1980) suggest the use of the synoptic situation at the site of observations. For this it is necessary to classify temperature profiles according to the basic types of the synoptic processes, making allowance for their seasonal characteristics.

Kikuchi et al. (1981) found out (as some have already done earlier) that trees and buildings in the vicinity of the astrometric instruments provoke changes in the temperature field surrounding the instrument. The intensity of these changes declines with height, vanishing at about 6 m height. As a consequence of these temperature field deformations the refraction anomalies at Mizusawa are estimated at about 0ʺ.01.

Sibilev (1981) explored the temperature field inside and around a pavilion at Nikolaev (USSR) for day–time observing conditions. It could be stated that the temperature field undergoes substantial changes during the day. Under the influence of the winds these changes are intensified. The external air layers in the immediate vicinity of the pavilion keep, on the whole, their pattern, but with growing distances from it the discrepances become larger. Inside the pavilion the air layers are more „tranquil", independent of winds Attention is called by this author to the complexity and changeability of the temperature field and at the same time to the fact that the effects produced by this field are not negligible (see 5). Fairly frequently no possibility exists, according to this author (1980), of computing reliable values of the refraction anomalies under day–time conditions.

Shamaev (1980) investigated possible influences originating inside and outside the pavilion on astrometric results. He especially points to the great significance of the air flows inside the pavilion whose nature and characteristics are hard to establish.

One study of Blank et al., (1980) relates to the correlation between the measured parameters of the temperature field inside the pavilion and the clock corrections obtained with two transit instruments at the Moscow Observatory. No unambiguous interrelationship is found and they arrive at the conclusion that the changes in the room refraction do not exercises a systematic influence on the determination of the clock correction. This, they hold, is a result of the adequate construction of the pavilion, and the rational method of data processing.

Concerning the atmospheric influences on the instrument interesting investigations are carried out by Blank (1980). He found that aluminium sheets are good insulators of the transit instrument tube and that, if temperature gradients still appeared in the instrument, they must be due to the warmth radiated by the observer.

Significant refraction disturbances (of order of 0.″1) due to the temperature gradients inside the double tube of the Pulkovo Horizontal Meridian Circle, were stated by Kiryan et al. (1980). These disturbances can be minimized through ventillation between the outer and inner tubes.

This report of the chairman of the Working Group on Astronomical Refraction of IAU Commission 8 has in part been presented at the Commission 8 session in Patras, Greece, in August 1982.

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Abbrevations: IRKUTSK = „Vliyanie atmosfery na astronomicheskie nablyudeniya v opticheskom i radiodiapazonah" Ed. DF VNIIFTRI, Irkutsk and Pulkovo Observatory, 1980

TOMSK = „Soveshchanye po atmosfernoj optike", Chast 2, Tomsk, 1980

KIEV = „Astronomicheskie issledovaniya", Ed. Naukova dumka, Kiev, 1981

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PRELIMINARY ANALYSIS OF THE BELGRADE TRANSIT INSTRUMENT OBSERVATIONAL DATA ACQUIRED IN 1969–1979

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SUMMARY: The results of individual observers on the Belgrade Transit Instrument shown to be accordant among themselves. By increasing the number of the star gro observed, a rise in accuracy of $0^s\!.002$ per star is achieved. Systematic change of quasi–absolute azimuth has been revealed by which, most likely, systematic change the mean north and south azimuths is produced. The difference DC (E–W) = C(EW) (WE) is found lower than previously. Both the magnitude and the sign of this differe are equivalent to those of the difference Δβ (EW) in inclination, associated with he orde observation. For control and better accuracy another, somewhat modified, program should be observed in parallel with the current one.

1. INTRODUCTION

The observations with the Belgrade Transit Instrument „Bamberg", No. 63131, 10/100 cm. in the period 1969–1979 have been accomplished by the following observers:

D. Vesić	(DV)
L. Đurović	(LD)
M. Lončarević	(ML)
D. Mandić	(DM)
M. Jovanović	(MJ)

A unique list of 297 stars, with magnitudes down to $7^m\!.8$, has been observed all through the period above indicated. The stars have been divided into 27 groups of 11 stars each. Each group enclosed also a star observable at the lower transit. Out of the stars observed at the lower transit there were 18 which were observed at the upper transit as well. Originally, the programme has been composed and adapted so as to allow the processing according to the Nemiro method. However, it is merely in 1969 that some observations of the meridian marks have been carried out. 204 stars are from FK4 list. 47 stars do not belong to the CTS (Catalogue of Time Service of the USSR).

The apparent places of stars on our programme have been computed at the computing centres of the Pulkovo Observatory and the Time Service of the USSR on t CTS system. It proved in the process that some of t apparent places of stars for 1970 and 1971 were in err by a few miliseconds. In addition, the observations fro July and August in 1972, 1973 and 1974 have be omitted from the analysis as stars from other prog mmes have instead been observed over those periods.

By the end of 1971 a synchronous motor for drivi the travelling wire of the impersonal micrometer w mounted on the instrument. However, the motor prov defective in the maintenance of bisection at lower tra sits. We kept it on the instrument until the middle 1973.

In 1978 there were prolonged interruptions in t observations, causing the number of the recorded tra sists in that year to be lowest.

In consideration of all the above facts, the who period of time determination with the Belgrade Tran Instrument was divided into three parts, termed cycle

I cycle	1969–1971
II cycle	1972–1975
III cycle	1976–1979

The analysis of the observational results has be brought into effect according to these cycles.

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UDC 522

PRELIMINARY ANALYSIS OF THE BELGRADE TRANSIT INSTRUMENT OBSERVATIONAL DATA ACQUIRED IN 1969–1979

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SUMMARY: The results of individual observers on the Belgrade Transit Instrument ar shown to be accordant among themselves. By increasing the number of the star grou observed, a rise in accuracy of $0^{s}002$ per star is achieved. Systematic change of th quasi–absolute azimuth has been revealed by which, most likely, systematic change o the mean north and south azimuths is produced. The difference DC (E–W) = C(EW) – (WE) is found lower than previously. Both the magnitude and the sign of this differenc are equivalent to those of the difference $\Delta\beta$ (EW) in inclination, associated with he order o observation. For control and better accuracy another, somewhat modified, programm should be observed in parallel with the current one.

1. INTRODUCTION

The observations with the Belgrade Transit Instrument „Bamberg", No. 63131, 10/100 cm. in the period 1969–1979 have been accomplished by the following observers:

D. Vesić	(DV)
L. Đurović	(LD)
M. Lončarević	(ML)
D. Mandić	(DM)
M. Jovanović	(MJ)

A unique list of 297 stars, with magnitudes down to $7^{m}8$, has been observed all through the period above indicated. The stars have been divided into 27 groups of 11 stars each. Each group enclosed also a star observable at the lower transit. Out of the stars observed at the lower transit there were 18 which were observed at the upper transit as well. Originally, the programme has been composed and adapted so as to allow the processing according to the Nemiro method. However, it is merely in 1969 that some observations of the meridian marks have been carried out. 204 stars are from FK4 list. 47 stars do not belong to the CTS (Catalogue of Time Service of the USSR).

The apparent places of stars on our programme have been computed at the computing centres of the Pulkovo Observatory and the Time Service of the USSR on th CTS system. It proved in the process that some of the apparent places of stars for 1970 and 1971 were in erro by a few miliseconds. In addition, the observations from July and August in 1972, 1973 and 1974 have been omitted from the analysis as stars from other progra mmes have instead been observed over those periods.

By the end of 1971 a synchronous motor for driving the travelling wire of the impersonal micrometer wa mounted on the instrument. However, the motor proved defective in the maintenance of bisection at lower tran sits. We kept it on the instrument until the middle of 1973.

In 1978 there were prolonged interruptions in the observations, causing the number of the recorded tran sists in that year to be lowest.

In consideration of all the above facts, the whole period of time determination with the Belgrade Transit Instrument was divided into three parts, termed cycles:

I cycle	1969–1971
II cycle	1972–1975
III cycle	1976–1979

The analysis of the observational results has been brought into effect according to these cycles.

2. PERSONAL ERRORS

According to the Mayer formula we have

$$U = C + MA, \qquad (1)$$

where C – clock correction, A – azimuth and M – azimuth coefficient.

The azimuth A has been calculated by combining the mean north (marked by n) and mean south (marked by s) fictitious stars

$$A = (U_s - U_n)/(M_s - M_n),$$

$$U_s = \frac{1}{N_s} \Sigma U_k, \qquad \delta_k < 44^\circ.8$$

$$U_n = \frac{1}{N_n} \Sigma U_k, \qquad \delta_k > 44^\circ.8,$$

where N_s and N_n denote the number of the south and north stars, respectively.

The correction to some particular star group has been determined after introducing weights $F_k = \cos^2 \delta_k$. Thus, the correction to a particular star:

$C_k = U_k - M_k A$, and the one pertaining to a star group

$C = \Sigma P_k C_k / \Sigma P_k$, the stars observed at the lower transits having been omitted from the discussion.

Having estimated the number of gross errors at about 2% of the total, we adopted criterion $\Delta C_k = |C_k - C| < 2.5\ E_l$ for the deducation of the exact number of such errors comitted by any observer. E_l denotes the error in he clock correction, resulting from the observation of a single star, $E_l = \pm 0^s030$, thus $C_k \leqslant 0^s075 \sec \delta_k$. In addition, mean values ΔC_k according to declination zones for every observer has also been calculated. The results are presented in Table 1.

Columns 0° through 65° – mean values of ΔC_k according to individual observers and the declination zones; E_l – the error of a single clock correction; E_o – mean valu e error of a star group; F – the average number of a star's transits, GE – the average number of gross errors.

The means in the columsn 0° through 65° have the following mena errors:

0°	−3.2 ± 0.6	
15	2.4	0.8
25	4.3	1.1
35	−2.7	1.5
45	4.6	0.8
55	0.9	0.8
65	−2.6	0.7

The mean values of individual observers (in 0^s001) are

MJ	0.5 ± 0.7	
DV	0.3	0.7
LD	1.0	2.0
ML	−1.0	2.0
DM	3.0	3.0

The general mean value

$$C = 0.025.$$

Table I. Mean values of ΔC_k

zones obs.	0°	15°	25°	35°	45°	55°	65°	E_l	E_o	F	GE
MJ 69	−3	3	10	−10	1	−2	5	31	10	5	2.3 %
70	−3	2	6	− 2	4	0	−2	32	10	5.5	0.8
71	−5	2	7	5	4	2	−5	33	10	5	2.9
72	−2	−7	4	−13	10	−5	−4	34	11	2.8	0.9
73	−2	−1	3	− 8	4	3	−4	34	11	2.9	5.2
74	−2	6	8	2	3	1	−3	34	11	2.9	4.8
75	−4	2	9	0	6	−1	−4	34	11	8	3.8
76–79	−7	4	6	2	10	4	−7	35	11	14.8	1.0
DV 69	0	0	−2	7	1	2	−2	19	6	2	2.1
70	−3	5	−4	− 6	6	0	−2	25	8	2.6	1.0
71	−5	4	6	− 2	6	−1	0	25	8	4	3.0
72	−4	6	3	− 6	9	7	−4	30	10	4	6.1
73	−1	5	−2	1	2	5	−3	31	10	3.9	7.7
74	1	0	−2	−11	0	0	−3	29	9	3.7	2.9
LD											
75–79	−6	2	7	− 2	9	3	−6	36	11	8.9	1.3
ML 69	−1	−1	2	− 7	0	4	−4	20	6	1.9	0.5
DM 69	−7	8	11	4	4	−1	3	30	10	2	0.7

We see that the mean values according to declination zones are above the determination errors and that the results of individual observers differ little among them selves. The general mean value for all the observers taken together is practicurally null.

3. AZIMUTH DETERMINATION

The azimuth A and the clock correction C values, determined, under the condition that the aquations (1) are equal weight, that only accidental errors are present and that $\Sigma M_k = 0$, attain their heighest weight.

The observing programmes of the time services are conformed to the basic demand: the achievement of the highest possible accuracy in the determination of C this is the reason why currently circumzenithal stars are mostly observed. From (1) we have

$$A = (U_k - C_k)/M_k \quad (2)$$

Suppose the time of the star transit over meridian and its right ascension were both unaffected by any error. Let the azimuth A be determined by combining a group of N_z stars (N_z being of the order of 5 to 10 stars) for which $\Sigma M_k = 0$, and some star (*) distant from the zenith. The most probable error of the azimuth is given by

$$E^2 = (E_*^2 - (1/N_z)^2 \; \Sigma \; E_k^2)/M^2 \quad (3)$$

The accidental errors, reduced to he equator must be equal. Therefore, for the zenith zone we obtain

$$E_k^2 = E_o^2 \sec^2 \varphi \; ;$$

by substituting in (3) we get

$$E(A) = \sqrt{(\sec^2 \delta - (1/N_z)^2 \sec^2 \varphi)}/M \quad (4)$$

wherein $E_o = \pm$ 0ˢ025 is most frequently used.

A similar result has been arrived at by V.E. Brandt (1969) at developing the formula for the azimuth weights according to the classical formula:

$$P(A) = N_s N_n \cos^2 \varphi \sin^2 (\delta_n - \delta_s)/(N_s \cos^2 \delta_s - N_n \cos^2 \delta_n) \quad (5)$$

If $N_n = N_z = 5$ (or 10), $N_s = 1$, there will be P(A, 5) = 0.050 (or P(A, 10) = 0.045), whereas with $N_s = N_n = 5$, using the classical procedure we get–for the Belgrade latitude – P(A) = 0.030.

We performed the calculation of the azimuth by combining the mean fictitious zenith star with evry equator or north star. If these individual equator or north stars are substituted by mean south and mean north stars, respectivaly, we obtain the results presented in Table II

Table II. Standard deviation (s.d.) of az.muth
Columns: 1. declination zone and its denomination; 2. corresponding mean declination; 3. secant; 4. squared secant; 5. standard deviation D_s of the azimuth, determined from the combination (z–s); 6. standard deviation (s.d.) D_n of the azimuth, determined from the combination (z–n).

1.		2.	3.	4.	5.
– 7° + 35°	(equatorial)	14°6	1.04	1.07	
+ 35, + 55	(zenithal)	46.7	1.46	2.10	D_s = 0.043
+ 55, + 70	(north)	61.8	2.11	4.47	D_n = 0.075

From the observational material we deduced the following results, displayed in Table III

Table III. Yearly mean of the s.d.
Columns: D_n – yearly means of the s.d. (z–n); D_s – yearly means of the s.d. (z–s); D'_n – s.d. (z–n) after smoothing; D'_s – s.d. (z–s) after smoothing of the clock corrections (Šegan, 1982)

Year	D_s	D_n	D'_s	D'_n
1969	0ˢ051	0ˢ061	0ˢ034	0ˢ048
70	40	55	37	51
71	65	94	38	50
72	42	54	36	49
73	70	83	38	50
74	46	60	34	46
75	52	67	40	57
76	51	68	42	63
77	55	69	44	62
78	49	77	40	61
1979	0.050	0.070	0.042	0.065

The general means of D'_s and D'_n are 0.039 and 0.056, respectively. The ratio D_s/D_n (Table II) has the value 0.7. The ratio of the mean values of D'_s and D'_n (Table III) is 0.6. It is probable that a minor change in the observing programme would result in these ratios becoming equal, i.e. the azimuth would assume a greater weight. Let us revert to the formulae (4) and (5). For the Belgrade zenith $\delta(Z) \sim 45°$ and $\delta_k \sim 60°$, $M_* = M_s$, there will be (with eight zenith stars)

$$E_{45}(A) = E_o \sqrt{0.75}/0.65,$$

$$E_{60}(A) = E_o \sqrt{0.50}/1.3,$$

$$P(A, 45) = 0.8, \quad P(A, 60) = 1.85,$$

P denoting approximate weights.

At the Belgrade observatory, the azimuth and the clock corrections are derived from the observations of series consiting of 11 stars, whereby the number of the zenith stars does not surpass 5. The foregoing result suggests the need of modifying the observational programme in the sense of increasing the number of zenith stars and preserving the number of the south and north stars. This applies to the Belgrade Observatory. As to the Observatories located more to the north, additional systematic errors could be introduced by their north stars are affected by significant errors. In that event the advantages gained even be ruined.

In Table IV are given the mean square errors of the azimuth $E_z(A)$, $E_n(A)$ and the clock correction $E_z(C)$, $E_n(C)$ and E'_z and E'_n. E(C) pertain to the unsmoothed and E'(C) to the smoothed clock corrections.

Table IV. Mean square errors

cycle	$E_z(A)$	$E_n(A)$	$E_z(C)$	$E_n(C)$	$E'_z(C)$	$E'_n(C)$
I	0ˢ057	0ˢ028	0ˢ043	0ˢ039	0ˢ038	0ˢ034
II	58	26	42	38	38	34
III	59	28	47	42	43	38

The results in he two first cycles can be regarded as accordant, whereas a decrease in accuracy is evident in the later observations.

4. CLOCK CORRECTION DETERMINATION

The first step of the treatment involved only those of the observational nights, where two or more groups have been observed. The treatment consisted in the following: the instrument azimuths and the clock corrections were computed for each of the observing nights and for each of the „conditional observing nights". The conditional observing night is one during which two star groups have been observed.

This parallel calculus proved justified as thereby a more accurate azimuth variation in the course of observation, and the mean error of the clock correction, derived by combining two adjacent groups, turned by 0ˢ002 (in modulus) less than the one obtained by the procedure first referred to, has been achieved. By linking two observing nights, on which less than two complete star groups have been observed, the erros regained their previous amounts, but the number of the observational units, conforming to the principles imposed by the treatment, was increased. However, the observing nights with less than 10 star transits were thereby rejected.

The azimuth, associated with each single star for which

$|\delta_k - \varphi| < 10^{\circ}$, was computed according to the formula

$$A'_k = (U_k - U_z)/(M_k - M_z), \tag{6}$$

where U_z and M_z are mean values of the Mayer coefficients for the zenith stars. By means of these azimuths, mean „north" and „south" azimuths, corresponding to each one of subsequent groups, were deduced and their difference determined by

$$DA_j = A_s - A_n = (1/P_s)\, \Sigma P_k A'_k - (1/P_n)\, \Sigma P_k A'_k, \tag{7}$$

$$P_k = (M_k - M_z)^2 \cos^2 \delta_k$$

where j denotes the ordering number of the night concerned and P_k is the azimuth weight.

The differences DA_j, being on the whole produced by the $\Delta\alpha(\delta)$ errors, their mean values cannot substantially diverge from one year to another. Since there were no manifest seasonal variations in DA_j in the course of the subcycles (one subcycle = 1 year), the variation in DA_j was controlled from one year to the next through he intermediary of the respective mean values. The results are presented in Table 5.

Table 5.

Year	DA		DA_2	
1969	0ˢ001	± 0ˢ004	−0ˢ020	±0ˢ004
70	−17	5	− 21	2
71	−16	6	− 19	3
72	−17	6	− 19	3
73	−20	9	− 16	3
74	− 2	8	− 14	3
75	−27	7	− 21	3
76	−29	7	− 23	3
77	−39	8	− 22	3
78	−40	9	− 27	3
1979	−46	9	− 19	3

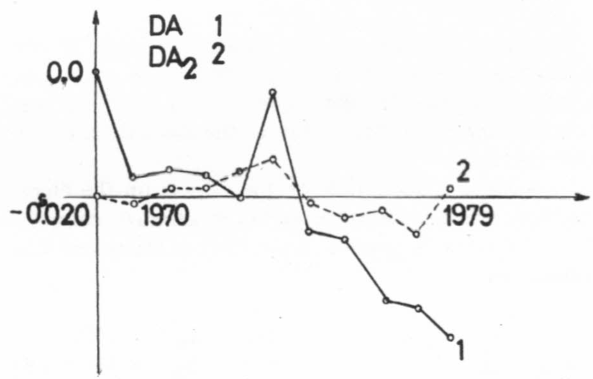

Fig. 1. Yearly mean of DA_j before (1) & after (2) smoothing

The corrections have been deduced by combining the mean north star on the particular night with each one of the stars observed at lower transit. The residual corrections to the quasi–absolute azimuth resulting from the corrections to the azimuth associated with the stars observed at both upper and lower transits, were the measure of the determination accuracy. The results are given in Table VI.

Table VI. Corrections to the quasi–absolute azimuth

Columns: 2 – correction to the quasi–absolute azimuth; 3 – weight unit error; 4 – correction to the absolute azimuth CA(A), after applying the corrections DA(A); 5 – weight unit error of CA; 6 – the number of stars for which the corrections DA(A) and CA(A) are determined.

Year	2	3	4	5	6
1969	0^{s}011	±0^{s}027	−0^{s}004	±0^{s}010	184
70	12	22	− 4	10	125
71	8	25	− 4	10	101
72	–	–	–	–	–
73	–	–	–	–	–
74	15	24	− 5	11	29
75	− 2	14	− 5	11	85
76	− 19	25	− 2	12	84
77	− 15	20	− 2	12	102
78	− 17	18	− 2	12	53
79	− 16	26	− 2	12	66

The assumption of the correction to the quasi–absolute azimuth having changed its sign during 1975 was confirmed by the values listed in Table VI. The origin of this phenomenon might constitute the subject of a separate work. Here we confine ourselves to the analysis of repercussions produced by this result. First, a new distribution of the observational material proved possible – instead of three, only two observational cycles have further been examined:

1th cycle – 1969–74
2nd cycle – 1975–79

Moreover, in view of the identity of signs of the quasiabsolute azimuth and the difference DA − DA_2 in the interval 1972–73, the value DA(A) = 0^{s}012 was adopted as the mean correction to the absolute azimuth for that period.

To achieve a reduction of the effects on the clock correction, resulting from the errors in azimuth determination, the azimuth applied in the further treatment was calculated by

$$A''_k = A'_k + DA_j \quad \text{for} \quad \delta_k > +54^{\circ}8$$
$$A''_k = A'_k \quad \text{for} \quad \delta_k < +34^{\circ}8 \quad (8)$$

where A_k is given by (6) and by (7).

For every night on which $N_n + N_s = 10$ the azimu
variation in time has been calculated according to
method of least squares by the equations of condition
the form

$$A'_k = A_o + \Delta A\ T,\ T = \alpha_k - \alpha_o\ ,\ \alpha_o = (\alpha_M + \alpha_1)$$

where M is the number of stars in the group, α is
right ascension and A_o and ΔA unknowns.

Where, on the contrary, $N_n + N_s < 10$, the
values have been calculated as the mean weighted va
of A'_k. Thus were obtained the corrected azimuths

$$A_k^c = A_o + (\alpha_k - \alpha_o)\,\Delta A$$

by means of which the clock corrections at every s
transit was calculated:

$$C'_k = U_k - M_k A_c^k \quad (9$$

With regard to the previous results pertaining to
inclination differences in terms of the order of observ
on, two groups of the clock corrections C'_k can
assumed. For this reason we calculated annual me
and a general mean value of the difference of
corrections C'(EW) − C'(WE), proceeding thereby fr
the mean value DC_j of the night:

$$DC_j = (C'(EW) - C'(WE))_j$$

The results are listed in Table VI.

Table VII. Annual means of the DC_j

1	2	3
1969	−0^{s}0010	213
70	− 39	147
71	− 20	151
72	− 13	113
73	− 36	75
74	− 9	105
75	− 41	122
76	− 19	101
77	− 70	111
78	− 66	65
1979	−0.0021	86

Columns: 1 – the year; 2 – mean values of DC_j; 3 – the number of the „conditional nights".

The value relating to the entire period is consider
ly lower than is ussualy found in the literature (Brk
1961) for the same kind of instrument. It diff
considerably from the one, found by Brkić for t

instrument (Brkić, 1961), although under different conditions of observation. This value is somewhat lower than the one obtained by Đurović (1976) for the period 1966–69. Djurović's (1976) conclusion of the difference $\Delta\beta = \beta\,(EW) - \beta\,(WE)$ as being the prime generator of the difference DC_j might well be accepted. However, failing appropriate analysis of the changes, produced by the thermic insulation of the instrument and the conditions of observation, it is not possible to supply a more concrete answer as to the origin of these differences.

5. CONCLUSIONS

We have seen in Section 2 how little the results of the individual observers differed among themeselves. Thus, the observational material can, as far as the clock correction determination is concerned, be regarded as being homogenous. Concerning the azimuth determination, several ways of composing the observational programe are offered, as there are several ways of azimuth determination from the existing observational material.

A systematic shift in the quasi–absolute azimuth has been found which, most probably, gives rise to the systematic variation DA of the difference of the mean south and the mean azimuths. The difference C(EW) – C(WE) is less than one, found by Brkić (1961) and Đurović (1976). The magnitude and the sign of this difference in the period under treatment are equivalent to the magnitude and the sign of the inclination difference, itself a function of the order of observation $\Delta\beta = \beta(EW) - \beta(WE)$.

Inasmuch as the difference C(EW) – C(WE) is a result of the inclination difference $\Delta\beta = \beta(EW) - \beta(WE)$, any seasonal component in the inclination variation must be expected to produce analogous component in the clock correction. More precisely, a fluctuation in he clock correction of 1 to 2 milliseconds can be expected in the equator zone, which is multiplied, for the rest of the zones, by the factor N – the inclination coefficient in the Mayer formula.

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Bull.Obs. Astron. Belgrade, No 134 (1984)

LES ORBITES DE QUATRE ETOILES DOUBLES VISUELLES /ADS 2111=BU 83, ADS2609 AB = BU 787AB, ADS3058 = HU 302, GLE 1/

V. Erceg

/Reçu le 28. 12. 1982/

RESUME: on donne les éléments des orbites, les masses, les magnitudes obsolues et les parallaxes dynamiques orbitales de quatre étoiles doubles visuelles, les éléments étant determinés en utilisant la méthode de Thiele–Innes, Van den Bos.

ORBITE DE ADS 2111=BU 83

Pos. (1950): 02^h43^m5; -05^o 10'

Mgn.: 8.0 – 10.6; Type sp. F2

Tableau I. Les éléments orbitaux, les quantités astrophysiques et les constantes

P = 372.86 ans			
n = 0°.9655	A = +0".2350	$\pi_{dyn.orb.}$	= 0".014
T = 1711.89	B = –0".6550	M_A	= 3.7
e = 0.30	F = –0".8150	M_B	= 6.3
a = 0".917	G = +0".0850	$\mathbf{M}_A$	= 1.37 ⊙
i = 127°.6	C = ∓0".5978	$\mathbf{M}_B$	= 0.82 ⊙
Ω = 151°.2	H = ∓0".4129	a	= 67.2 U.A.
ω = 235°.4			
$T_{\Omega, \mho}$ = 1807.81;2053.08			

Tableau II. Les éphémérides

t	θ	ρ
1983.0	35°.5	0".67
1984.0	34.4	0.67
1985.0	33.4	0.67
1986.0	32.3	0.67
1987.0	31.3	0.67
1988.0	30.2	0.67
1989.0	29.2	0.68
1990.0	28.2	0.68
1991.0	27.1	0.68

Tableau III. Les observations et les résidus

N°	t	θ	ρ	Obs.	n	Références	$(O-C)_\theta$	$(O-C)_\rho$
1.	1876.03	121°.3	1".40	D	4	Mis.Microm.V.1, Rome, 1883.	–0°.1	+0".41
2.	1877.81	125.5	1.01	HWE	1	Pub.Cincinati Obs. N.4, 1878.	+4.9	+ 2
3.	1877.95	120.5	1.00	STN	1	Pub.Cincinati Obs.N.4, 1878.	0.0	+ 1
4.	1886.84	116.4	0.88	LV	3	Univ.Minesota press, 1930.	+0.4	– 7
5.	1886.87	116.0	0.95	MLF	2	Pub.Mc.Cormick Obs. V.1.Pt.4,1889.	0.0	0
6.	1888.87	109.2	0.99	LV	2	Univ.Minesota press, 1930.	–5.8	+ 5
7.	1891.77	111.7	0.90	BU	3	Pub.Lick Obs.V.2, 1894	–1.7	– 3
8.	1896.06	106.6	0.84	SP	6	Misure Stelle Doppie Milan 1909.	–4.4	– 7
9.	1898.79	104.3	1.00	A	3	Pub.Lick Obs.V.12,1914.	–5.2	+ 10
10.	1901.83	103.3	0.92	BRY	1	Greenwich Obs. 1901.	–4.4	+ 3
11.	1901.979	101.7	1.03	DOO	3	Pub.Univ.Pennsylvania, V.2.Pt.3.	–5.9	+ 14
12.	1905.08	105.9	0.96	A	3	Pub.Lick V. 12, 1914	+0.2	+ 9
13.	1907.97	101.5	1.04	WZ	1	Ann.Strasbourg Obs.V.4, Pt.2,1912.	–2.4	+ 18
14.	1908.85	104.9	0.97	NEF	2	Astron.Nachr.V.182,253,1909	+1.6	+ 11
15.	1914.99	99.2	1.00	JON	1	Greenwich Cat. Double Stars, 1921.	0.0	+ 17
16.	1916.87	99.4	0.81	LV	1	Univ.Minnesota Press, 1930.	+2.2	– 1
17.	1917.874	101.7	0.72	COU	1	Pub.Washburn Obs.V.10.Pt.4.	+4.5	– 10
18.	1918.05	101.0	0.74	LV	2	Univ.Minnesota Press 1930.	+3.9	– 7
19.	1919.06	95.7	0.90	LV	2	Univ.Minnesota Press, 1930.	–0.7	+ 9
20.	1925.669	95.2	0.79	VBS	2	Pub. Yerkes Obs. *5*, Pt.1, 1927.	+3.8	+ 1
21.	1931.62	82.8	0.71	VOU	4	Ann. Bosscha Obs. Lembang, *6*, Pt.1.	–3.9	– 5

Table III (Continued)

No	t	θ	ρ	Obs.	n	Références	(O–C)$_\theta$	(O–C)$_\rho$
22.	1935.73	80°1	0"76	B	4	Union Obs. Circ.N.100,481.	–3°1	+ 2
23.	1937.47	78.8	0.76	FIN	4	Union Obs. Circ.N.112,104.	+2.9	+ 2
24.	1939.11	75.8	0.62	BAZ	1	J.Obs. *37*, 073.	–4.5	– 11
25.	1942.65	83.8	0.81	VOU	3	Manuscript, See J.Obs. *38*, 109.	+6.7	+ 9
26.	1948.99	73.7	0.66	B	3	Union Obs.Circ.N.111,13.	+2.6	– 4
27.	1953.02	74.7	1.02	VBS	2	Pub.Yerkes Obs. *9*, Pt.2.	+7.6	+ 33
28.	1953.92	70.4	0.71	COU	2	J. Obs. *37*, 37.	+4.2	+ 2
29.	1957.73	62.6	0.60	B	3	Astrophys. J.Supp. *4*, N.36, 45.	+0.3	– 8
30.	1959.94	58.9	0.57	B	4	Union Obs. Circ. N. 119, 321	–1.1	– 10
31.	1960.74	57.7	0.69	WOR	4	Astron. J. *68*, 114.	–1.5	+ 2
32.	1962.00	52.4	0.75	B	4	Astron. J. *68*, 582.	–5.5	+ 8
33.	1962.52	55.2	0.64	B	6	Astron. J. *68*, 582.	–2.1	– 3
34.	1962.98	52.0	0.60	COU	3	J. Obs. *46*, 155.	–4.8	– 7
35.	1964.03	48.9	0.66	COU	3	J. Obs. *47*, 229.	–6.8	– 1
36.	1968.01	50.9	0.68	KNP	1	Republic Obs.Circ. N. 128, 177.	–0.6	+ 2
37.	1969.67	56.2	0.67	VBS	4	Astrophys.J.Supp. *28*, 413, 1975.	+6.5	+ 1
38.	1975.86	43.1	0.69	HEI	3	Astrophys.J.Supp. *37*, 343, 1978.	0.0	+ 3
39.	1977.91	38.8	0.65	HEI	3	Unpublished	–2.1	– 1
40.	1980.109	35.8	0.72	WOR	4	Unpublished	–2.8	+0.06

ORBITE DE ADS 2609AB = BU 787AB

Pros. (1950): 03^h30^m8; +48°27'

Mgn.: 7.2–11.2; Type sp. AO

Tableau IV. Les éléments orbitaux, les quantités astrophysiques et les constantes

P = 400.22 ans		
n = 0°8995		
T = 1831.93	A = –1"5000	$\pi_{dyn.orb.}$ = 0"046
e = 0.54	B = +2"3333	M_A = 5.5
a = 2"861	F = –2"3000	M_B = 9.5
i = 31°4	G = –1"0833	$\mathfrak{M}_A$ = 0.99⊙
Ω = 147°3	C = ∓0"7021	$\mathfrak{M}_B$ = 0.53⊙
ω = 331°9	H = ± 1"3129	a = 62.5 U.A.
$T_{\Omega,\mho}$ = 1840.03;1712.66		

Tableau V. Les éphémérides

t	θ	ρ
1983.0	287°5	3"92
1984.0	287.8	3.94
1985.0	288.2	3.95
1986.0	288.5	3.96
1987.0	288.9	3.97
1988.0	289.2	3.98
1989.0	289.5	3.99
1990.0	289.9	4.00
1991.0	290.2	4.01

Tableau VI. Les observations et les résidus

No	t	θ	ρ	Obs.	n	Références	(O–C)$_\theta$	(O–C)$_\rho$
1.	1881.69	228°5	2"05	BU	3	Pub. Washburn Obs. *1*, 1882.	+2°3	–0"05
2.	1885.96	227.3	2.35	STH	1	Pulkovo Publ. Ser. 2, *12*, 1901.	–3.8	+ 16
3.	1888.588	233.1	2.02	COM	5	Pub. Washburn Obs. *6*, Pt.2.	–0.8	– 23
4.	1898.704	245.6	2.39	HU	1	Lick Obs. Bul. *2*, 115, 1903.	+2.0	– 8
5.	1899.13	243.3	2.40	BU	1	Publ.Yerkes Obs. *1*.	–0.6	– 8
6.	1899.983	241.0	2.64	DOO	3	Pub. Univ. Pennsylvania *1*, Pt.3.	–3.7	+ 14
7.	1925.17	256.2	2.54	FOX	1	Ann. Dearborn Obs. *6*, 1.	–6.1	– 48
8.	1927.14	268.2	2.52	GCB	2	Paris Obs. Cat. 1934.	+4.8	– 54
9.	1933.17	267.1	3.23	GCB	1	Paris Obs. Cat. 1934.	+0.4	+ 6
10.	1939.30	272.4	3.14	VBS	4	Pub. Yerkes Obs. *8*, 159.	+2.6	– 15
11.	1958.08	281.6	3.81	B	1	Pub. Yerkes Obs. *9*, Pt.1.	+3.4	+0.21

ORBITE DE ADS 3058 = HU 302

Pos. (1950): 04^h10^m2; + 22°50'
Mgn.: 10.2 – 10.2; Type sp. KO

Tableau VII. Les éléménts orbitaux, les quantités astrophysiques et les constantes

P = 290.42 ans		
n = 1°.2396		
T = 1728.64	A = –0".1230	$\pi_{dyn.orb.}$ = 0".004
e = 0.28	B = +0".1030	M_A = 3.3
a = 0.253	F = –0".2068	M_B = 3.3
i = 54°.0	G = –0".1350	$\mathfrak{M}_A$ = 1.41⊙
Ω = 23°.2	C = ±0".1960	$\mathfrak{M}_B$ = 1.41⊙
ω = 106°.6	H = ∓0".0584	a = 61.9 U.A.

$T_{\Omega,\mho}$ = 1959.11; 2055.16

Tableau VIII. Les éphémérides

t	θ	ρ
1982.0	43°.1	0".20
1983.0	44.3	0.19
1984.0	45.5	0.19
1985.0	46.8	0.19
1986.0	48.1	0.18
1987.0	49.5	0.18
1988.0	50.9	0.18
1989.0	52.4	0.17
1990.0	53.9	0.17
1991.0	55.5	0.16

Tableau IX. Les observations et les résidus

N°	t	θ	ρ	Obs.	n	Références	$(O-C)_\theta$	$(O-C)_\rho$
1.	1901.72	164°.1*	0".25	HU	2	Lick Obs. Bul. *1*, 82, 1901.	–1°.3	–0".01
2.	1922.219	178.0*	0.25	VBS	5	Pub.Yerkes Obs. *5*, Pt.1, 1927.	–1.7	+ 1
3.	1922.67	0.0	0.28	A	2	Lick Obs. Bul. *11*, 58, 1923.	0.0	– 2
4.	1944.78	15.2	0.24	VOU	4	Manuscript, See J. Obs. *38*, 109.	+1.4	+ 3
5.	1944.84	13.1	0.27	VBS	1	Pub. Yerkes Obs. *8*, 159.	–0.7	0
6.	1946.81	21.0	0.25	VBS	1	Pub. Yerkes Obs. *8*, 159.	+5.9	– 2
7.	1951.80	19.7	0.22	VBS	3	Pub. Yerkes Obs. *9*, Pt. 2.	+1.4	– 4
8.	1959.07	24.1	0.28	COU	3	J. Obs. *42*, 17.	+0.9	+ 3
9.	1962.96	27.2	0.25	B	4	Astron. J. *68*, 582.	+1.3	0
10.	1967.12	25.5	0.25	COU	3	J. Obs. *51*, 337.	–3.6	+ 1
11.	1971.95	33.1	0.24	HEI	4	Astrophys. J. Supp. 29, 315, 1975.	0.0	+ 1
12.	1975.07	218.4*	0.23	MUL	3	Astron.Astrophys. Supp. *33*, 275, 1978	+2.5	+ 1
13.	1978.85	32.6	0.17	HEI	2	Astrophys. J. Supp. *44*, 111, 1980.	–7.0	–0.04

* Quadrant changé

ORBITE DE GLE 1=IDS 04148S6072

Mgn. 6.9–7.4; Type sp.AO

Tableau X. Les éléménts orbitaux, les quantités astrophysiques et les constantes

P = 370.22 ans		
n = 0°.9724		
T = 1619.98	A = –0".2380	$\pi_{dyn.orb.}$ = 0".010
e = 0.28	B = +0".5460	M_A = 2.0
a = 0".815	F = –0".7700	M_B = 2.5
i = 48°.7	G = –0".0750	$\mathfrak{M}_A$ = 1.80 ⊙
Ω = 168°.7	C = ∓0".5562	$\mathfrak{M}_B$ = 1.62 ⊙
ω = 294°.7	H = ±0".2559	a = 77.6 U.A.

$T_{\Omega,\mho}$ = 2030.10; 1904.69.

Tableau XI. Les éphémérides

t	θ	ρ
1983.0	96°.2	0".40
1984.0	98.8	0.40
1985.0	101.3	0.40
1986.0	103.7	0.41
1987.0	106.2	0.41
1988.0	108.5	0.42
1989.0	110.8	0.42
1990.0	113.1	0.43
1991.0	115.3	0.43
1992.0	117.5	0.44

Tableau XII. Les observations et les résidus

N°	t	θ	ρ	Obs.	n	Références	$(O-C)_\theta$	$(O-C)_\rho$
1.	1894.8	300.°	0.″8	I	2	MN R.Astron.Soc. *55*, 312.544.	−43.°	0.″1
2.	1897.07	342.4	1.34	SLR	3	Astron. Nachr. *186*, 065.	− 2.1	+0.47
3.	1897.3	339.0	0.95	I	1		− 5.6	+0.08
4.	1913.94	353.9	0.84	Vou	4	Ann. Bosscha Obs. Lemb. *1*, Pt.3, C 1.	− 0.2	+0.03
5.	1914.02	351.4	0.76	VBS	2	Union Obs. Circ. N.24, 185.	− 2.8	0.05
6.	1924.96	3.8	0.88	VOU	4	Ann. Bosscha Obs. Lemb. *1*, Pt. 2, B 1.	+ 2.3	+0.13
7.	1928.73	4.4	0.83	BRU	4	Ann. Bosscha Obs. *1*, Pt. 4, 1928.	0	+0.11
8.	1928.92	2.3	0.68	B	4	Union Obs. Circ. N.80, 59.	− 2.2	−0.04
9.	1934.50	10.1	0.53	B	4	Union Obs. Circ. N.94, 149.	+ 0.9	−0.15
10.	1937.74	15.1	0.50	TAN	1	Union Obs. Circ. N.106, 193.	+ 3.0	−0.16
11.	1938.94	16.8	0.59	B	4	Union Obs. Circ. N.107, 259.	+ 3.5	0.06
12.	1942.69	20.1	0.77	VOU	3	J. Obs. *38*, 109.	+ 3.0	+0.15
13.	1943.24	34.0	0.7	HIR	1	MN R. Astron. Soc. *106*, 154.	+16.0	+0.1
14.	1943.28	20.7	0.56	B	4	Union Obs. Circ. N.108, 312.	+ 2.9	−0.05
15.	1944.33	19.7	0.7	HIR	1	MN R. Astron. Soc. *106*, 154.	+ 0.7	+0.1
16.	1945.05	21.6	0.7	HIR	3	MN R. Astron. Soc. *110*, 455.	+ 1.8	+0.1
17.	1946.49	25.7	0.50	B	2	Union Obs. Circ. N.111, 013.	+ 4.2	0.08
18.	1946.89	19.5	0.66	GTB	1	Mem. Commonw. Obs. MT Stromlo.	− 2.4	+0.08
19.	1951.50	30.7	0.47	B	6	Union Obs. Circ. N.115, 266.	+ 2.8	0.07
20.	1959.47	42.5	0.38	B	2	Union Obs. Circ. N.119, 321.	+ 1.9	0.10
21.	1965.00	50.5	0.44	KNP	2	Republic Obs. Circ. N. *124*, 074.	0.9	0.00
22.	1965.28	52.0	0.42	B	4	Republic Obs. Circ. N. *126*, 127.	0	0.02
23.	1967.55	59.0	0.41	KNP	2	Republic Obs. Circ. N. *128*, 177.	+ 2.0	−0.01
24.	1975.720	76.8	0.40	WOR	3	Pub. US Naval Obs. *24*, Pt. 6, 1978.	− 0.4	0.00
25.	1976.114	75.3	0.33	WOR	1	Pub. US Naval Obs. *24*, Pt. 6, 1978.	− 2.9	−0.07

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ORBITS OF TWO VISUAL BINARIES

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SUMMARY: Orbits and dynamical parallaxes are presented for the binaries ADS 4, 9747. Calculated positions are compared with observations and ephemerides are given for each system.

Orbits for two visual binaries have been computed using the methods of Thiele–Innes. Dynamical parallaxes were computed by the method of Baize and Romani (1946) with magnitudes and spectral types taken from the Lick Index Catalogue of Visual Double Stars, 1961.0 (1963). The relevant information is given in Tables I, II, III.

ADS 4 = IDS 23575S0863 = A 428, 9.5 – 9.5, GO

Table I. Elements of the orbital motion and astrophysical quantities

P = 288.00	A = + 0ʺ.2450	M_A = 2.5
n = 1°.2500	B = + 0ʺ.1166	M_B = 2.5
T = 1972.68	F = + 0ʺ.0883	π_{dyn} = 0ʺ.004
e = 0.00	G = – 0ʺ.1866	Σm_{AB} = 3.7 ⊙
a = 0ʺ.27	C = 0ʺ.0000	a = 67.5 U.A.
i = 139°.9	H = ∓ 0ʺ.1739	
Ω = 25°.0	T (Ω) = 1972.68	
ω = 0°.0		

Table II. Observations and residuals

T	P	ρ	Magn.	n	Obs.	(O–C)p	(O–C)p	(O–C)ρ
1902.74	111°.1	0ʺ.22	8.8–8.8	3	A	–0°.8	–0ʺ.00	+0ʺ.01
1903.72	112.7	0.20		2	A	+2.4	+0.01	–0.01
1915.67	91.6	0.25		2	A	+0.3	+0.00	+0.04
1921.62	84.6	0.24		2	A	+2.1	+0.01	+0.02
1925.79	74.7	0.22		2	A	–1.9	–0.01	–0.01
1929.64	72.2	0.23		4	V	+0.7	+0.00	–0.00
1932.58	72.1	0.24		4	V	+4.4	+0.02	+0.00
1932.88	60.4	0.25		2	A	–6.9	–0.03	+0.01
1934.20	64.5	0.26		4	Bos	–1.2	–0.00	+0.02
1935.54	64.0	0.23		4	V	–0.0	–0.00	–0.01
1938.54	61.6	0.27		4	V	+1.1	+0.00	+0.03
1939.66	57.5	0.22		4	Sim	–1.6	–0.01	–0.03
1944.56	48.6	0.22		3	V	–5.0	–0.02	–0.03
1946.38	47.3	0.20		4	Bos	–4.3	–0.02	–0.05
1948.05	42.4	0.26		6	VBS	–7.4	–0.03	+0.00
1958.59	31.6	0.27		3	Bos	–7.4	–0.03	+0.00
1959.72	32.7	0.30	9.3–9.6	2	Bos	–5.2	–0.02	+0.03
1961.62	25.4	0.26	9.4–9.6	4	Bos	–10.7	–0.05	–0.01
1961.82	32.5	0.29		3	Wor	–3.4	–0.02	+0.02
1966.88	37.4	0.26		2	Kni	+6.4	+0.03	–0.01
1967.98	30.3	0.31		3	Wor	+0.4	+0.00	+0.04
1972.68	25.9	0.32		3	Wor	+0.4	+0.00	+0.05
1975.73	24.6	0.26		1	Wor	+2.1	+0.01	–0.01
1975.732	24.2	0.26		4	Wor	+1.7	+0.01	–0.01

Table III. Ephemerides

T	P	ρ	T	P	ρ
1984.0	14°.6	0ʺ.27	1990.0	8°.6	0ʺ.26
1985.0	13.6	0.27	1991.0	7.6	0.26
1986.0	12.6	0.27	1992.0	6.6	0.26
1987.0	11.6	0.27	1993.0	5.6	0.26
1988.0	10.6	0.26	1994.0	4.5	0.26
1989.0	9.6	0.26	1995.0	3.5	0.26

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ADS 9747 = IDS 15369N0047 = A 2176, 8.2–8.2, Ao

Table I. Elements of the orbital motion and astrophyscal quantities

P = 110.40	A = + 0ʺ.2200	M_A = 2.1
n = 3°.2609	B = + 0ʺ.0743	M_B = 2.1
T = 1907.20	F = – 0ʺ.0417	π_{dyn} = 0.006
e = 0.00	G = + 0ʺ.1233	Σm_{AB} = 4.6 ⊙
a = 0ʺ.23	C = 0ʺ.0000	a = 38.3 U.A.
i = 56°.1	H = ± 0ʺ.1935	
Ω = 19°.0	T (Ω) = 1907.20	
ω = 0°.0		

Table II. Observations and residuals

T	P	ρ	Magn.	n	Obs	$(O-C)_P$	$(O-C)_P$	$(O-C)_\rho$
1910.43	25°.7*	0".22	8.2–8.2	n	A	+ 1°.1	+ 0".00	–0.01
1918.50	35.6*	0.19	8.2–8.2	2	A	–5.9	–0.02	–0.01
1923.41	51.2*	0.19		2	A	–4.0	–0.01	+ 0.02
1925.58	60.7*	0.17		3	A	–2.1	–0.00	+ 0.01
1933.48		0.15		1	VBs	(101.0)	–	+ 0.02
1933.57	–	–		3	A	(101.5)	–	(0.13)
1934.49	–	–		1	A	(106.9)	–	(0.13)
1936.1	–	–		1	Vou	(116.2)	–	(0.13)
1936.6	201.1	0.13	8.1–8.1	4	Bos	+82.0	+0.19	–0.01
1937.4	–	–	8.2–8.2	1	Vou	(123.6)	–	(0.13)
1938.3	132.0	0.16	8.0–8.1	5	Bos	+3.5	+0.01	+ 0.02
1940.42	163.1	0.19		1	VBs	+23.9	+0.06	+ 0.05
1941.42	154.6	0.18		2	VBs	+10.7	+0.03	+ 0.03
1944.30	158.2	0.19		2	VBs	+2.6	+0.01	+ 0.03
1945.33	163.0	0.21		3	VBs	+3.7	+0.01	+ 0.04
1945.43	149.4	0.20	8.2–8.5	1	Bos	–10.2	–0.03	+ 0.03
1949.54	172.2	0.23		1	VBs	+0.3	0.00	+ 0.04
1950.32	163.3	0.15		1	VBs	–10.7	–0.04	–0.05
1951.07	168.4	0.14		1	VBs	–7.4	–0.03	–0.06
1953.35	179,5	0.14		3	VBs	–1.6	–0.00	–0.07
1953.57	185,8	0.18	Δm = 0.0	3	Fin	+4.3	+0.02	–0.03
1957.34	186.2	0.21	8.2–8.2	4	Bos*	–3.0	+0.01	–0.02
1958.60	195.1	0.21	8.3–8.3	3	VBs	+3.5	–0.01	–0.02
1959.38	192.6	0.23		3	Cou	–0.5	–0.00	0.00
1960.49	196.2	0.24		4	Baz	+1.0	0.00	+ 0.01
1960.50	191.4	0.24		2	VBs	–3.8	–0.02	+ 0.01
1961.49	196.3	0.23		1	Cou	–0.7	0.00	–0.00
1961.493	202.2	0.24		3	VBs	+ 5.2	+0.02	+ 0.01
1961.52	196.4	0.22	8.0–8.2	3	Bos	– 0.7	0.00	–0.01
1961.58	195.2	0.24		2	Cou	– 2.0	–0.01	+ 0.01
1961.65	200.6	0.24		5	VBs	+ 3.3	+0.01	+ 0.01
1962.20	200.7	0.19	8.0–8.2	4	Bos	+ 2.2	+0.01	–0.04
1963.38	202.1	0.17	Δm = 0.0	4	Wor	+ 1.6	+0.01	–0.06
1964.45	201.0	0.23	8.2–8.2	3	Cou	– 1.4	–0.00	0.00
1966.41	202.8	0.24	8.2–8.4	3	Cou	– 3.3	–0.01	+ 0.01
1967.50	211.8	0.23	8.0–8.0	3	Mrl	+ 3.6	+0.01	0.00
1969.89	213.8	0.19	Δm = 0.0	4	Wor	+ 0.8	0.00	–0.03
1970.33	233.4	0.24		2	VBs	+19.5	+0.07	+ 0.02
1973.52	218.1	0.18	Δm = 0.0	3	HLN	– 2.9	–0.01	–0.02
1974.49	230.9	0.17	Δm = 0.0	4	Wor	+ 7.5	+0.03	–0.03
1977.44	236.0	0.14		3	hz	+ 4.5	+0.01	–0.04

*Quadrant reversed.

Table III. Ephemerides

T	P	ρ	T	P	ρ
1984.0	256°.3	0".15	1990.0	288°.6	0".13
1985.0	261.1	0.14	1991.0	294.5	0.13
1986.0	266.2	0.14	1992.0	300.2	0.13
1987.0	271.5	0.13	1993.0	305.8	0.13
1988.0	277.1	0.13	1994.0	311.1	0.14
1989.0	282.8	0.13	1995.0	316.2	0.14

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MICROMETER MEASURES OF DOUBLE STARS

(Series 37)

G.M.Popović

(Received 1 July 1983)

SUMMARY: Reported are 208 measurements of 97 double and multiple stars.

Thise is the 37th series of the Belgrade measurements of double and multiple stars, carried out with Zeiss refractor 65/1055 cm. The measurements in the present series are a continuation of my own measurements published unter Series 35 (G.M. Popović, 1983). The mean values of the epoch of observation, position angle and separation are weighted values, the weight being expressed by the sum of the image quality estimate and the quality of measurement estimate, 1 denoting the poor and 3 the best respective quality (two addends in the third column of Table 1). The mean values of the estimated magnitudes or of the magnitude difference are alsow weighted values, the weight being identical to the image quality estimate (the first addend in the column 6 of Table 1). The residues 0 – C in orbital pairs have been calculated according to the ephemeris of P.Muller and P.Couteau (1979).

My measurements of the pair J 124 AB = ADS 13012 AB = o Aquilae seem to indicate the path of this pair to be curved. If so, then the components of the pair are physically related. On the other hand, rectilinear trajectory can be assumed as well, if larger residues in the measured separation are taken as real. The latter contingency would be consistent with the proper motion of the A component as given by R.Aitken (1932) and W.J.Luyten (1961). The C component in this pair does not show any position changes with respect to A. Accordingly, its proper motion is the same as the one of A, which is not found registered in W.J. Luyten's Catalogue.

Table I

ADS α, δ m	Disc. 1900–2000 Mult.	Epoch 1900+	θ	ρ	m	Weight	Notes
627 = β 865		82.893	195°.9	1".09	8.5–8.7	1 + 2	Unchanged in angle in 102 years.
00400–455N4251–84		82.920	195.5	1.23	dm = 0.5	1 + 2	
8.5–9.0	AB	**82.906**	**195.7**	**1.16**	**dm = 0.4**	**2n**	
638 = β 866		82.893	77.4	1.33	9.3–9.6	1 + 1	Unchanged in 102 years.
00408–463N4253–86		82.920	71.4	1.48	dm = 0.0	1 + 1	
11.0–11.0	AB	**82.906**	**74.4**	**1.40**	**dm = 0.2**	**2n**	
765 = Es 1298		82.898	141.8	1.77	dm = 0.1	1 + 2	The angle increased by 14° since 1922.
00498–555N4538–70							
10.9–11.1							
888 = Σ 86		82.898	141.3	15.30	–	1 + 1	Optical.
00597–648S0561–29							
9.3–10.0	AB						
1081 = Σ 113		82.926	15.0	1.61	dm = 0.7	1 + 2	The angle increased by 39° since 1836.
01147–198S0061–29							
6.4–7.4	AxBC						
1254 = Σ 138		82.926	50.7	1".64	dm = 0.0	1 + 2	The angle has increased by 30° since 1830.
01308–360N0708–39							
7.7–7.7	AB						

Table I (Continued)

ADS = Disc. / α, δ 1900–2000 / m Mults.	Epoch 1900+	θ	ρ	m	Weight	Notes
1507 = Σ 180	83.926	360°5	7″87	dm = 0.0	1 + 2	Unchanged in angle in 152 years.
01480–535N1848–78						
4.8–4.8 AB						
2257 = Σ 333	82.011	205.6	1.24	dm = 0.2	1 + 2	The angle has increased by 17° since 1830
02535–592N2056–80						
5.2–5.5 AB						
2518 = Hu 1058	82.896	112.0	0.80	8.5–9.0	3 + 2	Unchanged.
03184–250N3952–73	82.902	112.0	0.90	dm = 0.5	1 + 1	
8.4–9.1	**82.898**	**112.0**	**0.83**	**dm = 0.5**	**2n**	
– GP 83	82.735	263.8	0.78	8.0–8.7	1 + 1	GP 83 = COU 1080 = BD + 34°685 (8^m0)
03291–354N3508–28						
8.0–8.8 (8n)						
2897 = Ho 505	83.093	198.2	1.75	–	1 + 1	Very slow angular motion, but there is a marked increase in distance.
03520–583N3228–46						
8.3–10.3						
3029 = Ho 327	82.039	287.9	15.52	m_B = 13.0	1 + 1	Optical.
04033–096N3123–39						
6.9–12.6 AB						
3390 = Σ 577	83.093	20.1	1.09	dm = 0.1	1 + 2	Hock, 1966: + 0°8 – 0″01
04355–423N3719–30						
8.6–8.6						
3712 = Σ 643	82.902	300.3	2.84	dm = 0.0	1 + 1	Unchanged.
05025–079N0816–24						
9.8–9.8						
3940 = Σ 687	83.068	69.2	18.0	8.0–9.0	1 + 1	
05157–223N3342–48	83.093	68.9	17.4	–	1 + 1	
9.4–10.2 AB	**83.080**	**69.0**	**17.7**	**8.0–9.0**	**2n**	Unchanged.
9.4–10.4 A–CD	83.068	154.6	49.1	m_{CD} = 9.0	1 + 1	
	83.093	154.4	48.8	–	1 + 2	
	83.083	**154.5**	**48.9**	**m_{CD} = 9.0**	**2n**	
10.4–11.2 CD	83.093	257.3	0.89	dm = 0.5	1 + 1	
4115 = Σ 728	83.068	46.9	0.90	dm = 1.0	1 + 1	
05254–307N0552–56	83.093	44.7	0.93	dm = 1.5	1 + 1	
4.5–6.0	83.156	48.2	0.90	dm = 1.2	1 + 2	
	83.113	**46.8**	**0.91**	**dm = 1.2**	**3n**	Siegrist, 1950: + 3°2, –0″04
4203 = A 1562	82.129	354.3	0.46	8.5–8.8	2 + 2	Change questionable!
05300–373N4335–39						
9.0–9.0						
4577 = OΣ 125	83.183	2.2	1.32	7.5–9.0	2 + 2	Very slow angular motion.
05537–598N2228–28						
7.6–9.1						
4648 = J 17	82.896	154.3	2.77	9.5–9.7	3 + 3	Unchanged.
05580–652N4303–02						
10.1–10.4						
4696 = OΣ 130	82.896	198.9	0.51	8.0–8.3	3 + 2	Very slow angular motion.
06007–078N4241–40						
7.2–8.6						

Table I (Continued)

ADS α, δ m	Disc. 1900–2000 Mults.	Epoch 1900+	θ	ρ	m	Weight	Notes
5244 = A 2119 06307–367N2144–39 9.7–9.9	AB	82.118	83°.9	0".40	dm = 0.0	2 + 1	To the system belong component C: $\theta_{AB-C} = 47°, \rho \sim 20''$
5290 = HΣ – 06337–392N0944–39 8.6–8.6		83.068	279.3	0.88	–	1 + 1	
		83.156	283.0	0.72	dm = 0.0	3 + 2	
		83.169	281.1	0.67	dm = 0.1	1 + 1	
		83.183	277.3	0.71	dm = 0.0	1 + 1	
		83.147	**280.9**	**0.74**	**dm = 0.0**	**4n**	Unchanged.
5559 = Σ 982 06490–546N1318–10 4.8–7.1	AB	82.022	148.2	7.01	–	1 + 1	
		82.107	146.8	7.07	5.0–9.0	3 + 2	
		82.083	**147.2**	**7.05**	**5.0–9.0**	**2n**	Hopmann, 1949: – 0°.1, + 0".02
5812 = OΣ 165 07026–083N1566–57 5.6–11.3	AB	82.099	10.1	12.21	–	2 + 2	
		82.102	10.5	11.87	–	1 + 1	
		82.100	**10.2**	**12.10**	**–**	**2n**	Optical.
5958 = OΣ 170 07122–172N0929–19 7.6–7.9		83.156	82.4	0.88	dm = 0.2	2 + 2	
		83.183	81.8	0.85	8.0–8.3	2 + 1	
		83.238	82.7	0.91	dm = 0.2	1 + 2	
		83.189	**82.3**	**0.88**	**dm = 0.2**	**3n**	Popović, 1982: – 1°.2, – 0".09
6038 = Σ 1081 07182–241N2139–28 8.5–9.2	AB	83.068	234.2	1.66	7.5–9.0	2 + 2	
		83.153	234.0	1.66	dm = 1.0	2 + 2	
		83.111	**234.1**	**1.66**	**dm = 1.2**	**2n**	The angle has increased by 18° since 1828.
6135 = Σ 1102 07248–305N1363–51 8.5–10.0	AB	83.068	46.0	7.62	8.5–10.0	1 + 2	Unchanged in 154 years.
		83.077	46.6	7.52	7.5–10.0	1 + 2	
		83.072	**46.3**	**7.57**	**8.0–10.0**	**2n**	
10.0–13.9	BC	83.068	1.0	30.09	m_C = 12.0	1 + 2	
8.5–	AD	83.068	131.2	~100	8.5–8.5	1 + 1	
		83.077	131.5	–	–	1 + 1	
		83.072	**131.4**	**~100**	**8.5–8.5**	**2/1n**	There are important changes in motion of components C and D.
– GP 105 07259–325N3555–42 9.8–10.0 (3n)		83.153	51.0	0.79	dm = 0.2	2 + 1	GP 105 = BD + 36°1643, (9^m.2)
6479 = A 2883 07513–590N1675–59 9.6–10.2		82.118	14.0	1.65	dm = 0.3	1 + 1	The distance has increased by 0".7 since 1914.
6613 = Hu 849 08026–092N3732–15 9.8–10.0		83.183	283.3	1.23	9.0–9.1	2 + 1	Unchanged.
6638 = Σ 1194 08053–105N0173–55 9.0–10.7		83.156	322.2	2.88	9.5–11.0	1 + 1	Unchanged.
6663 = Σ 1202 08081–135N1069–51 7.4–9.5		82.118	308.0	2.34	8.0–10.0	2 + 1	
		82.184	309.4	2.14	8.0–10.0	1 + 2	
		82.189	310.1	2.27	–	1 + 2	
		82.206	310.7	2.00	8.0–10.0	1 + 1	
		82.171	**309.4**	**2.20**	**8.0–10.0**	**4n**	The angle has decreased by 27° since 1829.
– GP 111 08084–149N3553–35 9.9–10.1 (3n)		82.099	49.3	0.92	dm = 0.2	2 + 2	GP 111 = BD + 36°1771 (9^m.1)

Table I (Continued)

ADS Disc. α, δ 1900–2000 m Mults.	Epoch 1900+	θ	ρ	m	Weight	Notes
6671 = β 1244	83.153	17°.0	0".91	8.0–9.0	2 + 2	
08086–138N0177–59	83.156	16.3	0.95	dm = 0.7	1 + 2	
8.3–8.5	**83.154**	**16.7**	**0.93**	**dm = 0.9**	**2n**	The angle has decreased by 33° since 1891.
– GP 97	82.099	277.6	0.90	dm = 0.2	2 + 2	
08372–435N3363–41	82.129	280.2	0.79	10.0–10.2	2 + 2	
10.0–10.4 (2n)	**82.114**	**278.9**	**0.84**	**dm = 0.2**	**2n**	GP 97 = BD + 34°1888 ($9^m.5$)
7067 = Σ 1280	82.184	127.0	1.24	dm = 0.3	1 + 1	
08460–557N7071–48	82.190	127.2	1.34	dm = 0.2	2 + 1	
9.3–9.4 AB	83.183	128.2	1.22	dm = 0.2	1 + 1	
	82.472	**127.4**	**1.28**	**dm = 0.2**	**3n**	Heintz, 1973: + 0°.1, + 0".10
7352 = Σ 1348	83.153	317.1	1.90	dm = 0.1	2 + 2	
09192–244N0647–21	83.156	318.2	1.96	dm = 0.1	1 + 1	
7.5–7.6	83.227	318.8	1.93	dm = 0.0	1 + 1	The angle has decreased by 16 since 1831.
	83.172	**317.8**	**1.92**	**dm = 0.1**	**3n**	
7398 = A 1985	83.156	27.9	1.36	dm = 0.0	3 + 2	Retrograde motion, while the distance increased.
09236–300N4242–16						
8.6–8.6						
– GP 56	82.129	216.0	4.91	10.0–10.5	2 + 1	Unchanged in 11 years.
09266–327N3464–39						
11.0–11.4 (2n)						
7613 = 0Σ 210	83.301	259.5	1.26	8.0–9.5	1 + 2	No certain change.
09563–626N4651–22						
8.6–9.4						
– GP 116	82.100	248.6	0.43	dm = 0.3	3 + 3	GP 116 = BD + 43°1996 ($9^m.2$)
10057–120N4252–25						
9.4–9.6 (2n)						
– GP 117	82.099	262.7	0.63	dm = 3.0	2 + 1	
10123–185N4376–46	83.183	259.2	0.53	8.0–9.7	2 + 1	
8.0–9.2 (5n)	**83.141**	**261.0**	**0.58**	**dm = 2.4**	**2n**	GP 117 = BD + 44°1972 ($7^m.7$)
7792 = 0Σ 220	83.153	89.9	0.5	dm = 2.0	2 + 2	
10239–292N1040–10						Orbital motion. Distance closing in.
7.8–9.7						
– GP 73	82.099	204.8	0.77	dm = 0.0	3 + 2	GP 73 = BD + 34°2186 ($9^m.4$)
10511–560N3351–18						
9.7–9.7 (3n)						
8238 = Σ 1558	83.169	172.0	1.01	dm = 0.2	1 + 1	
11315–367N2161–28	83.266	163.1	1.36	9.0–9.5	1 + 2	
10.2–10.7 AB	83.301	163.8	1.20	dm = 0.5	1 + 1	
	83.248	**165.8**	**1.21**	**dm = 0.4**	**3n**	Slow direct motion.
8241 = A 1996	83.169	190.2	1.94	9.0–9.0	2 + 1	
11318–372N4073–40	83.266	189.8	1.84	dm = – 0.1	1 + 2	
9.8–9.8	83.301	188.1	1.89	9.3–9.2	2 + 1	Slow direct motion.
	83.245	**189.4**	**1.89**	**dm = –0.1**	**3n**	
8355 = 0Σ 241	82.100	141.7	1.64	6.5–9.0	3 + 2	
11511–56N3560–27	82.184	142.6	1.25	–	1 + 1	
6.8–8.7 AB	82.190	141.1	1.39	dm = 1.0	1 + 1	
	82.263	142.3	1.48	8.0–10.0	1 + 1	
	82.340	143.8	1.27	–	1 + 2	Orbital motion. The angle has increased by
	82.200	**142.3**	**1.45**	**dm = 1.5**	**5n**	23° since 1849.

Table I (Continued)

ADS α, δ m	Disc. 1900–2000 Mults.	Epoch 1900+	θ	ρ	m	Weight	Notes
8553 = Σ 1643		83.315	11°.4	2″.04	–	1 + 1	
12222–272N2735–02		83.345	14.7	2.32	9.0–9.5	1 + 2	My measures does not fit into the ephemeris
9.2–9.5		**83.333**	**13.4**	**2.21**	**9.0–9.5**	**2n**	of Hopmann's orbit, computed in 1959.
8775 = β 930		83.266	123.6	2.10	–	1 + 1	Slow direct motion.
13014–059N4548–16							
5.7–12.0							
8887 = Ho 260		83.318	71.6	1.04	dm = 0.5	2 + 2	
13189–236N2945–14		83.320	72.8	1.04	dm = 0.3	2 + 1	
9.6–9.8		**83.319**	**72.1**	**1.04**	**dm = 0.4**	**2n**	Ambruster, 1978: – 1°.8, – 0″.05
8974 = Σ 1768		82.340	102.7	1.38	–	1 + 1	
13330–375N3648–17		82.414	102.0	1.62	dm = 1.5	1 + 2	
5.1–7.0	AB	82.416	102.3	1.65	dm = 1.5	1 + 2	
		82.422	101.1	1.61	dm = 3.0	1 + 1	
		82.455	99.7	1.51	dm = 1.5	1 + 1	
		82.410	**101.7**	**1.57**	**dm = 1.9**	**5n**	Wierzbinski, 1955: – 1°.6, – 0″.26
9167 = Σ 1820		82.373	109.6	2.29	8.2–8.5	1 + 2	
14097–131N5548–20		82.376	110.7	2.36	8.4–8.6	2 + 2	
8.8–9.1		**82.375**	**110.2**	**2.33**	**8.3–8.6**	**2n**	The angle has decreased by 63° since 1831.
9174 = Σ 1816		82.373	86.6	0.72	8.4–8.5	1 + 2	
14095–139N2934–06		82.376	85.8	0.77	7.0–7.1	1 + 2	
7.5–7.6		82.414	87.3	0.77	8.0–8.1	1 + 2	
		82.388	**86.6**	**0.75**	**7.8–7.9**	**3n**	
		83.318	85.6	0.71	dm = 0.2	2 + 2	
		83.320	87.2	0.69	dm = 0.2	2 + 2	
		83.413	87.0	0.77	dm = 0.1	2 + 2	
		83.419	85.8	0.70	dm = 0.1	1 + 1	
		83.360	**86.5**	**0.72**	**dm = 0.2**	**4n**	Orbital motion.
9229 = Σ 1834		83.413	103.3	1.35	dm = 0.0	2 + 2	Van den Bos, 1936: – 0°.6, + 0″.09
14166–203N4858–31							
7.9–8.0							
9249 = A 149		82.373	128.2	0.61	9.0–9.1	1 + 2	
14196–233N4763–36		82.414	130.8	0.71	9.7–9.9	2 + 2	
9.8–10.0	AB	82.417	123.8	0.60	9.8–10.0	2 + 1	
		82.403	**127.9**	**0.65**	**9.6–9.8**	**3n**	The angle has decreased by 26° since 1901.
m_c = 13.0	ABxC	82.373	12.5	20.3	m_c = 14.0	1 + 2	
		82.414	12.7	20.7	m_c = 13.5	2 + 2	
		82.417	11.3	21.6	m_c = 14.0	2 + 1	
		82.403	**12.1**	**21.0**	**m_c = 13.8**	**3n**	C is optical.
9350 = A 1871		83.318	305.7	1.71	dm = 0.0	2 + 2	
14381–414N5150–24		83.320	306.4	1.84	dm = 0.0	2 + 2	
8.0–8.0		83.413	308.5	1.75	dm = 0.0	2 + 2	The angle has decreased by 24° since 1829.
		83.350	**306.9**	**1.77**	**dm = 0.0**	**3n**	
9425 = 0Σ 288		83.416	174.3	1.39	8.0–9.0	1 + 2	Heintz, 1950: + 4°.6, + 0″.21
14487–534N1567–43							
6.9–7.6							
9497 = β 119		82.422	278.5	1.96	dm = 0.7	1 + 1	The angle has decreased by 35° since 1875.
15002–055S0638–61							
8.0–8.5	AB						

Table I (Continued)

ADS α δ m	Disc. 1900–2000 Mults.	Epoch 1900+	θ	ρ	m	Weight	Notes
9599 = Ho 62		82.422	279°.5	1".31	–	1 + 1	No certain change.
15169–207N3521–00							
9.9–9.9							
9626 = Σ 1938		83.471	16.1	2.12	8.5–9.2	3 + 2	Baize, 1951: + 1°.1, – 0".07
15207–245N3742–21							
7.2–7.8	BC						
9639 = OΣ 296		82.373	279.5	1.81	7.0–8.5	1 + 2	
15230–265N4421–00		82.376	279.0	1.78	dm = 1.2	1 + 2	
7.6–9.2	AB	82.414	283.3	1.84	7.5–8.5	3 + 2	
		82.392	**281.1**	**1.82**	**dm = 1.5**	**3n**	The angle has decreased by 47° since 1845.
7.4–12.5	AC	82.373	313.5	75.9	m_c = 13.5	1 + 2	
		82.376	313.4	–	m_c = 14.0	1 + 2	
		82.414	313.9	76.0	m_c = 13.5	3 + 2	The distance has increasec by 11" since 1911.
		82.392	**313.6**	**76.0**	**m_c = 13.6**	**3/2n**	The pair probably optical.
9880 = OΣ 303		82.422	169.7	1.40	dm = 0.1	1 + 1	
15562–609N1333–15		82.441	172.4	1.39	dm = 0.4	1 + 1	
7.5–8.0		82.652	166.2	1.25	dm = 0.2	2 + 2	The angle has increased by 58° since 1846.
		82.542	**168.6**	**1.32**	**dm = 0.2**	**3n**	An optical pair.
– GP 1		83.413	179.8	2.65	10.0–13.0	2 + 2	
16235–271N3432–18		83.471	182.7	2.05	11.0–12.0	3 + 2	
10.1–12.0 (9n)	AB	**83.445**	**181.4**	**2.32**	**10.6–12.4**	**2n**	GP 1 = BD + 34°2788 (9^m.5)
10070 = Σ 2049		82.376	196.2	1.00	8.0– 8.5	1 + 1	
16238–280N2572–59		82.414	199.0	1.21	6.5– 7.5	2 + 2	
7.1–8.1		82.417	196.9	1.16	dm = 0.7	1 + 2	
		82.407	**197.7**	**1.15**	**dm = 0.8**	**3n**	The angle has decreased by 17° since 1829.
10036 = VBs –		82.417	35.0	0.82	9.0–10.0	2 + 2	
16198–226N3335–21		82.652	37.5	0.90	8.5– 9.5	2 + 2	
9.6–9.7–9.9	AB×C	**82.534**	**36.2**	**0.86**	**8.8– 9.8**	**2n**	The angle has decreased by 21° since 1879.
10312 = Σ 2114		82.422	187.6	1.38	dm = 1.0	1 + 1	
16572–619N0836–27		82.652	188.0	1.27	6.8– 7.5	2 + 2	
6.5–7.7		82.682	187.4	1.26	dm = 1.0	1 + 1	
		82.602	**187.8**	**1.30**	**dm = 0.8**	**3n**	The angle has increased by 52° since 1830.
– GP 131		83.413	136.0	3.73	10.0–11.0	2 + 1	
17123–153N4446–40		83.471	137.3	3.21	12.0–12.7	2 + 2	
10.6–11.2 (4n)	AB	**83.446**	**136.7**	**3.43**	**11.0–11.8**	**2n**	
m_c = 11.1 (3n)	AC	83.413	322.5	28.0	10.0–11.0	1 + 1	
		83.471	322.5	28.0	12.0–12.0	2 + 1	
		83.448	**322.5**	**28.0**	**11.3–11.7**	**2n**	
	AP	83.471	105.8	19.9	12.0–14.0	1 + 1	
10460 = Σ 2153							
17154–180N4925–19		82.376	250.8	1.68	dm = 0.3	1 + 1	
9.3–9.8		82.414	253.3	1.48	9.0– 9.3	2 + 2	
		82.417	252.2	1.62	–	3 + 2	
		82.420	255.1	1.57	dm = 0.3	1 + 1	
		82.410	**252.8**	**1.58**	**dm = 0.3**	**4n**	The angle has decreased by 29° since 1831.
11432 = OΣ 354		83.413	195.1	0.66	8.5– 9.0	2 + 1	
18272–321N0643–47		83.471	199.4	0.65	8.5– 9.0	3 + 2	
7.7–8.5		**83.449**	**197.8**	**0.65**	**8.5– 9.0**	**2n**	The angle has increased by 44° since 1846.

Table I (Continued)

ADS α, δ m	Disc. 1900–2000 Mults.	Epoch 1900+	θ	ρ	m	Weight	Notes
11451 = J 463		82.417	216°.4	1".37	–	1 + 1	
18292–334N2256–61		82.614	218.5	1.50	10.0–10.0	1 + 2	
11.3–11.3	AB	82.652	222.4	1.61	dm = 0.1	1 + 2	
		82.677	222.1	1.57	dm = 0.0	1 + 1	
		82.599	**220.0**	**1.52**	**dm = 0.0**	**4n**	Unchanged.
11488 = Es 1422		82.682	77.0	3.42	9.5–11.0	1 + 1	
18322–352N4309–14		83.471	80.7	3.71	10.0–11.2	2 + 1	
10.3–11.0		**83.155**	**79.2**	**3.59**	**9.8–11.1**	**2n**	
13012 = J 124		83.471	227.8	12.8	m_B = 14.0	2 + 1	Orbital?
19462–510N1010–25							
5.2–13.5	AB						
5.2–13.7	AC	83.471	222.5	22.2	m_C = 13.5	2 + 2	Unchanged in 73 years.
	AD	82.494	121.1	58.8	m_D = 13.3	1 + 1	
		82.499	119.6	58.8	–	1 + 1	
		82.496	**120.4**	**58.8**	**m_D = 13.3**	**2n**	
	AE	82.494	144.7	90.2	m_E = 13.0	1 + 1	
		82.499	145.3	89.4	-	1 + 2	
		82.497	**145.1**	**89.7**	**m_E = 13.0**	**2n**	
13050 = 0Σ 388		82.611	136.3	3.53	dm = 0.0	2 + 2	Unchanged.
19482–524N2536–52							
8.2–8.2	AB						
7.7–8.9	AC	82.611	130.7	31.6	dm = 1.5	2 + 2	Unchanged.
13186 = 0Σ 392		82.611	287.1	2.57	-	1 + 1	C probably belong to the system. The distance closing in.
19546–579N4159–75							
6.7–8.5–9.0	ABxC						
13277 = 0Σ 395		82.652	116.4	0.80	dm = 0.3	2 + 2	The angle has increased by 37° since 1844.
19578–618N2439–56							
5.9–6.3							
13312 = Σ 2624		82.668	175.9	1.64	7.0–7.8	1 + 2	
19598–635N3545–62		82.677	175.0	1.83	dm = 0.5	1 + 1	
7.2–7.8	AB	82.682	170.6	1.84	dm = 0.5	1 + 1	
		82.675	**174.1**	**1.75**	**dm = 0.6**	**3n**	Very slow retrograde motion.
6.8–9.1	AC	82.668	327.1	42.2	7.0–9.0	1 + 2	
		82.677	326.5	42.5	m_C = 9.0	1 + 2	
		82.672	**326.8**	**42.4**	**m_C = 9.0**	**2n**	
6.7–11.0	AD	82.668	170.4	29.2	7.0–12.0	1 + 2	
14286 = β 364		82.669	238.3	0.87	dm = 0.0	2 + 2	
20427–470N2503–25		82.677	240.8	0.88	dm = 0.2	1 + 2	
8.9–9.1		**82.672**	**239.4**	**0.87**	**dm = 0.1**	**2n**	The angle has increased by 20° since 1876.
BD + 41°4049		82.652	269.3	55.5	9.0–9.5	2 + 2	In had not found the star BD + 41°4054 (9^m5) in the expected place. Mayby the component B is BD + 41°4054. In that case the star BD + 41°4054 would have p.m. ~3".5.
21109N4118 (1900)		82.819	269.7	55.0	–	1 + 1	
9.1–		**82.708**	**269.4**	**55.3**	**9.0–9.5**	**2n**	
14805 = Es 1582		82.652	131.6	3.27	9.0–12.0	1 + 1	
21123–161N4159–84							
9.9–11.2							

Table I (Continued)

ADS α, δ m	Disc. 1900–2000 Mults.	Epoch 1900+	θ	ρ	m	Weight	Notes
–	GP 49	82.830	210°.0	6″.00	dm = 0.1	1 + 2	Direct motion.
21220–261N3503–29							
11.6–11.8 (4n)							
15007 =	Σ 2799	82.611	265.4	1.60	–	2 + 2	
21240–289N1039–65		82.614	266.5	1.57	7.0–7.0	2 + 2	
7.5–7.5	AB	82.669	266.6	1.50	dm = 0.0	1 + 1	
		82.688	267.3	1.55	dm = 0.0	1 + 1	
		82.634	**266.3**	**1.56**	**dm = 0.0**	**4n**	The angle has decreased by 67° since 1831.
15176 =	β 1212	82.682	166.8	36.3	$m_c \sim 12$	1 + 1	
21344–395S0030–03							The angle has increased by 26° since 1891.
7.3 7.8–10.9	AB×C						C probably belong to the system.
15215 =	0Σ 448	82.669	200.8	0.41	dm = 1.0	2 + 1	
21366–410N2853–81		82.677	200.2	0.44	dm = 0.7	2 + 1	
8.4–9.4		82.898	198.4	0.56	dm = 0.7	2 + 2	
		82.763	**199.7**	**0.48**	**dm = 0.8**	**3n**	The angle has decreased by 48° since 1845.
15251 =	β 688	82.669	208.2	0.32	dm = 0.0	2 + 1	Unchanged.
21385–426N4035–63							
8.3–8.3	AB						
–	GP 88	82.898	241.4	2.80	12.5–13.0	2 + 1	
21510–553N3410–38							
11.7–12.6 (4n)							
–	GP 145	82.898	101.7	2.06	10.0–10.2	1 + 1	
22002–041N4604–32							
10.0–10.5 (4n)	AB						
10.3–10.6 (4n)	CD	82.898	23.0	1.78	10.0–10.5	1 + 1	
15735 =	Hu 978	82.611	208.7	1.09	dm = 0.5	1 + 1	
22079–127N1325–55		82.614	208.8	0.99	9.0–9.6	2 + 2	
9.1–9.6		**82.613**	**208.8**	**1.02**	**dm = 0.6**	**2n**	The angle has decreased by 17° since 1901.
15769 =	Σ 2881	82.682	80.5	1.18	dm = 0.3	1 + 1	
22100–145N2905–35							The angle has decreased by 31° somce 1830
7.6–8.1							
16116 =	Hu 391	82.614	211.3	0.62	dm = 1.2	2 + 2	The angle has increased by 44° since 1901.
22327–374N2325–56							
9.8–11.1	AB						
9.5–12.9	AC	82.614	191.5	–	$m_c = 13$	2 + 2	
16317 =	Σ 2950	82.830	286.2	1.30	dm = 0.8	1 + 1	
22474–513N6109–41		82.893	285.9	1.50	dm = 1.0	1 + 2	
6.1–7.4	AB	**82.868**	**286.0**	**1.42**	**dm = 0.9**	**2n**	The angle has decreased by 33° since 1832.
16435 =	Hn 56	82.669	95.9	1.05	dm = 0.0	2 + 2	
22551–597N4117–49		82.677	94.8	1.04	dm = 0.1	2 + 2	
9.3–9.4		**82.673**	**95.4**	**1.04**	**dm = 0.1**	**2n**	The angle has decreased by 30° since 1881.
16561 =	β 385	82.677	89.5	0.58	dm = 0.5	2 + 2	
23055–103N3156–88							The angle has decreased by 46° since 1876.
7.3–8.1	AB						

Table I (Conti

ADS α, δ m	Disc. 1900–2000 Mults.	Epoch 1900+	θ	ρ	m	Weight	Notes
16602 = Σ 2990 23084–134N2132–65 9.6–9.6		82.669	56°.3	2''.20	dm = – 0.1	1 + 2	
		82.677	56.6	2.30	dm = 0.0	2 + 1	
		82.824	54.6	2.16	–	1 + 1	
		82.893	58.4	2.33	10.0–10.0	1 + 2	
		82.920	54.5	2.37	dm = – 0.1	1 + 2	
		82.795	**56.2**	**2.28**	**dm = 0.0**	**5n**	The angle has decreased by 13° since 1831.
16649 = β 79 23125–176S0164–31 8.4–10.0	AB	82.677	22.5	1.63	dm = 1.5	1 + 1	Heintz, 1959: – 0°.8, 0''.11
– GP 3 23224–272N2941–74 12.5–12.5 (12n)		82.898	116.9	4.20	12.0–12.0	1 + 1	
17149 = Σ 3050 23544–595N3310–43 6.6–6.6	AB	82.669	312.0	1.55	dm = 0.0	1 + 2	Heintz, 1973: – 0°.8, – 0''.02

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MICROMETER MEASURES OF DOUBLE STARS

(Series 38)

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(Received July 30, 1983)

SUMMARY: Presented here are 262 measures of 107 double stars made with the 65/1055 cm refractor of Belgrade Observatory.

The present series of measures is the continuation of the observations published in Number 133, of the Bull.Obs. Astron. Belgrade of the series 36. The measures I made with the 65/1055 cm refractor of Belgrade Observatory between 1982 February 15 and 1983 July 27. In the Table of Measures the columns give: ADS or DM number, double star designation, position for 1900 (IDS), mutiple, epoch omitting the century, position angle, separation, estimated magnitudes, number of nights and notes. In the Notes are given comparosons have been made with the latest available orbits. In the present work the distribution of 262 measures of distances is as follows:

Distances	Measures
to 0.50	2
0.50 to 1.00	94
1.01 to 1.50	100
1.51 to 2.00	32
2.01 or greater	34

ADS DM	DISC. IDS	Mult.	Epoch 1900+	p	ρ	Est. mag.	n	Notes
61	STF 3062 00010N5753		82.740	295°.2	1″.36	6.4–7.5	1	Baize, 1957: + 2°.0,–0″.08.
207	STF 13 00106N7624		82.740	58.9	0.87	6.7–7.2	1	Heintz, 1960: + 2°.6, 0″.00
283	HJ 1018 00154N6707		82.740	87.0	1.29	8.6–9.2	1	Muller, 1957: + 0°.7, – 0″.18.
1254	STF 138 01308N0708		82.896	55.0	1.61	7.4–7.7	1	The angle has chauged by 34 since 1830.
1370	D 3 01384N5637		82.740	334.4	2.63	9.7–11.2	1	No change after 106 years.
1371	BU 453 01384N5641		82.740	71.3	0.44	10.0–10.5	1	Baize, 1973: + 9°7, + 0″04. Zulević, 1981: +0°.9,–0″.05.
1538	STF 186 01507N0121		82.740	52.4	1.29	7.0–7.0	1	Cid Palacios, 1952: + 0°.5, + 0″.06
			82.896	56.9	1.15		1	
			82.818	**54.6**	**1.22**		**2**	
2612	STF 400 03268N5942	AB	82.926	257.5	1.21	6.9–7.9	1	Baize, 1952: 1°.8, – 0″.10. Scardia, 1980: – 4°.3, – 0″.03.
2995	STT 531 04009N3749	AB	82.893	10.4	1.51	7.3–9.0	1	
			82.921	9.6	1.46		1	
			82.926	7.7	1.45		1	
			82.913	**9.2**	**1.47**		**3**	Rabe, 1961: + 9°.1, – 0″.04.
3169	STT 82 04171N1449		82.893	352.8	1.30	8.0–8.0	1	
			82.921	356.5	1.38		1	
			82.907	**354.7**	**1.34**		**2**	Heintz, 1969: – 2°.4, – 0″.06.

(Continued)

ADS DM	DISC. IDS	Mult.	Epoch 1900+	p	ρ	Est. mag.	n	Notes
3264	STF 544		82.921	20°.9	1″.73	5.8–8.3	1	
	04244N1525		82.926	18.5	1.71		1	Kuiper, 1937: +3°.3, −0″.07.
			82.923	**19.7**	**1.72**		**2**	Baize, 1977: + 1°.2, −0″.05.
3390	STF 577		82.126	20.0	1.08	8.6–8.6	1	Hock, 1968: −0°.2, −0″.03.
	04355N3719							
3956	STF 677		82.893	155.8	0.95	7.9–8.0	1	Heintz, 1962: + 0°.9, −0″.10.
	05153N6317							
4200	STF 742		82.921	272.5	3.89	7.2–7.8	1	Hopmann, 1973:+ 1°.0, −0″.11.
	05304N2156							
5197	STF 932		82.921	313.1	1.68	8.1–8.2	1	Hopmann, 1960: + 2°.5, −0″.08.
	06286N1449							
5290	STH —		83.169	284.3	0.77	8.3–8.3	1	Very slow change in both coordinates.
	06337N0944							
5871	STF 1037	AB	82.126	321.8	1.15	7.2–7.2	1	
	07066N2742		82.170	321.5	1.22		1	
			82.187	320.2	1.23		1	
			83.169	319.6	1.25		1	Karmel, 1939: + 1°.0, −0″.10.
			82.414	**320.8**	**1.21**		**4**	Scardia, 1982: +0°.8, −0″.002
6117	STF 1093		82.170	185.0	0.67	8.8–8.8	1	
	07227N4971		82.208	185.4	0.75		1	
			82.189	**185.2**	**0.71**		**2**	Baize, 1958: −5°.6, −0″.05.
6650	STF 1196	AB	82.170	254.1	0.87	5.6–6.3	1	
	08065N1757		82.208	260.1	0.83		1	
			82.189	**257.1**	**0.85**		**2**	Gasteyer, 1954: −7°.2, + 0″.10.
		AB–C	82.208	80.0	5.48		1	Gasteyer, 1954: −0°.3, −0″.43.
7007	ES 294		83.315	161.9	1.86	9.0–9.2	1	Unchanged.
	08428N3631							
7067	STF 1280	AB	82.208	127.6	1.18	9.3–9.4	1	
	08460N7071		82.261	124.1	1.14		1	
			82.234	**125.8**	**1.16**		**2**	Heintz, 1973: −0°.5, −0″.02.
7307	STF 1338		82.187	259.6	0.99	6.6–6.8	1	
	09147N3837		83.315	258.7	0.98		1	
			82.751	**259.1**	**0.98**		**2**	Starikova, 1966: −3°.1, + 0″.11.
7704	STT 215		82.187	183.6	1.29	7.3–7.5	1	
	10108N1774		82.348	182.4	1.24		1	
			83.315	184.7	1.38		1	
			83.342	183.5	1.32		1	Wierzbinski, 1956: + 0°.9, −0″.09
			82.798	**183.5**	**1.31**		**4**	Zarea, 1957: + 3°.2, −0″.08.
7721	STF 1423		83.184	9.9	0.95	9.3–10.0	1	Heintz, 1960: + 2°.2, −0″.10.
	10137N2064							
8119	STF 1523	AB	83.315	95.7	2.80	4.4–4.9	1	
	11128N3166		83.394	96.1	2.91		1	
			83.413	95.8	2.83		1	
			83.374	**95.9**	**2.85**		**3**	Heintz, 1967: −0°.2, + 0″.16.

(Continued)

ADS DM	DISC. IDS	Mult.	Epoch 1900+	p	ρ	Est. mag.	n	Notes
8539	STF 1639		82.376	322°3	1"47	6.7–7.9	1	
	12194N2568		83.401	323.7	1.46		1	
			83.315	327.0	1.43		1	
			83.383	327.3	1.48		1	
			83.386	324.8	1.46		1	
			83.389	324.2	1.48		1	
			83.405	325.6	1.39		1	
			83.408	324.8	1.39		1	
			83.245	**325.0**	**1.45**		**8**	Aller, 1951: + 0°1, −0"07.
8553	STF 1643		82.187	12.4	2.48	9.2–9.5	1	
	12222N2735		83.315	12.9	2.63		1	
			83.383	13.7	2.56		1	
			83.386	14.1	2.54		1	
			83.389	14.1	2.56		1	
			83.408	14.0	2.56		1	
			83.178	**13.5**	**2.56**		**6**	Hopmann, 1964: + 2°1, + 0"27.
8569	STT 251		83.383	51.5	0.56	8.3–10.0	1	
	12242N3157		83.413	54.1	0.65		1	
			83.416	51.5	0.68		1	
			83.403	**53.4**	**0.63**		**3**	Baize, 1957: − 0°7, +0"02.
8575	STF 1647		83.301	240.5	1.31	8.5–8.8	1	
	12255N3157		83.413	241.2	1.35		1	
			83.427	240.4	1.26		1	
			83.380	**240.7**	**1.31**		**3**	Hopmann, 1964: −2°1, −0"01.
8680	HU 640		83.416	151.0	0.55	10.1–10.1	1	Baize, 1973: + 8°2, − 0"19.
	12458N2065							
8887	HO 260		82.444	71.0	0.92	9.6–9.8	1	
	13189N2945		83.383	76.0	0.98		1	
			83.386	77.0	0.97		1	
			83.389	77.0	0.97		1	
			83.405	72.9	0.97		1	
			83.408	74.1	0.98		1	
			83.427	73.9	0.98		1	
			83.263	**74.6**	**0.97**		**7**	Ambruster, 1978: + 0°7, − 0"12.
8949	STF 1757		83.383	115.1	2.39	7.7–8.8	1	
	13292N0012		83.394	115.7	2.41		1	
			83.388	**115.4**	**2.40**		**2**	Heintz, 1956: − 1°3, + 0"30.
8974	STF 1768	AB	82.417	102.6	1.45	5.0–7.0	1	
	13330N3648		82.455	105.5	1.51		1	
			82.436	**104.0**	**1.48**		**2**	Wierzbinski, 1958: + 0°7, − 0"35.
9031	STF 1785	AB	82.387	162.3	3.36	7.9–8.2	1	
	13445N2689		83.394	162.8	3.19		1	
			83.400	160.7	3.28		1	
			83.408	161.1	3.23		1	
			83.416	159.8	3.28		1	
			83.400	**161.3**	**3.27**		**5**	Strand, 1955: − 0°6, − 0"14
9071	A 1614		83.405	133.2	1.17	9.4–9.5	1	
	13539N5229		83.413	133.0	1.17		1	
			83.416	133.6	1.16		1	
			83.411	**133.3**	**1.17**		**3**	Mourao, 1963: + 1°0, − 0"14.

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ADS DM	DISC. IDS	Mult.	Epoch 1900+	p	ρ	Est. mag.	n	Notes
9177	STF 1817		82.428	348°3	0″53	8.0–8.5	1	
	14097N2670		83.482	349.0	0.62		1	
			82.955	**348.7**	**0.57**		**2**	
9174	STF 1816		83.419	91.2	0.88	7.0–7.1	1	
	14095N2934		83.471	89.2	0.75		1	
			83.445	**90.2**	**0.81**		**2**	
9182	STF 1819		83.383	233.7	1.01	7.7–7.8	1	
	14103N0336		83.400	229.9	1.01		1	
			83.391	**231.8**	**1.01**		**2**	Baize, 1973: + 0°7, + 0″19.
9211	BU 1272	AB	83.413	135.0	1.16	10.3–10.6	1	
	14141N4873		83.416	135.3	1.35		1	
			83.427	134.9	1.19		1	
			83.419	**135.1**	**1.23**		**3**	No certain change after 91 years.
9229	STF 1834		82.439	102.4	1.18	7.9–8.0	1	
	14166N4858		82.455	104.2	1.31		1	
			83.383	102.8	1.20		1	
			83.394	102.1	1.22		1	
			83.400	106.1	1.21		1	
			83.416	103.2	1.29		1	
			83.427	102.7	1.25		1	
			83.131	**103.4**	**1.24**		**7**	Bos, 1936: – 0°5, – 0″02.
9324	A 347		83.482	270.0	0.60	8.7–8.5	1	Güntzel–Lingner, 1955: – 4°7, – 0″
	14334N4839							
9343	STF 1865	AB	83.482	306.8	1.10	4.4–4.6	1	Wierzbinski, 1953: + 2°7, + 0″06.
	14364N1369							
9380	STF 1837	AB	83.383	89.6	1.60	7.5–8.4	1	
	14414N0965		83.400	89.7	1.52		1	
			83.416	90.6	1.48		1	
			83.399	**90.0**	**1.53**		**3**	Wierzbinski, 1956: + 0°9, + 0″01.
9418	STT 287		82.428	346.1	1.00	7.5–7.6	1	
	14478N4480		82.924	347.8	0.97		1	
			83.548	346.0	1.01		1	
			83.307	**346.6**	**0.99**		**3**	Heintz, 1962: + 0°1, – 0″10.
9425	STT 288		82.428	169.0	1.40	6.9–7.5	1	
	14487N1567		83.400	169.7	1.35		1	
			83.416	171.5	1.25		1	
			83.424	173.4	1.32		1	
			83.167	**170.9**	**1.33**		**4**	Heintz, 1956: + 1°1, + 0″14.
9530	A 1116		83.548	48.0	0.67	8.5–8.5	1	Change 27° in 78 years.
	15068N1030							
9578	STF 1932	AB	83.383	252.0	1.43	7.1–7.6	1	
	15140N2672		83.400	254.4	1.41		1	
			83.419	257.9	1.38		1	
			83.471	253.9	1.40		1	
			83.418	**254.5**	**1.41**		**4**	Heintz, 1965: + 2°4, – 0″03.
9617	STF 1937	AB	83.545	357.6	0.66	5.6–5.9	1	Danjon, 1938: – 0°5, – 0″02.
	15191N3039							
9626	STF 1938	BC	82.439	13.9	1.99	7.2–7.8	1	
	15207N3742		83.383	18.1	2.04		1	
			83.419	16.3	2.12		1	
			83.471	14.1	2.04		1	
			83.178	**15.6**	**2.05**		**4**	Baize, 1952: + 0°5, – 0″14.

(Continued)

ADS DM	DISC. IDS	Mult.	Epoch 1900+	p	ρ	Est. mag.	n	Notes
9641	A 82 15228N2376		83.558	349°0	0″78	10.0–11.0	1	Change 27° since 1900.
9716	STT 298 15325N3968	AB	83.424	229.2	0.72	7.4–7.7	1	
			83.471	227.5	0.69		1	
			83.482	228.8	0.71		1	
			83.499	227.9	0.59		1	
			83.543	227.0	0.61		1	
			83.488	**228.1**	**0.67**		**5**	Couteau, 1966: + 1°6, + 0″15.
9756	STF 1969 15394N6018		83.556	20.6	0.49	8.9–9.6	1	Heintz, 1974: + 0°7, + 0″01.
9769	STF 1989 15451N7977		83.482	31.7	0.65	8.0–8.5	1	
			83.499	34.0	0.67		1	
			83.490	**32.8**	**0.66**		**2**	Giannuzzi, 1954: 6°7, + 0″06.
9809	A 2078 15464N1929		83.558	155.2	0.89	8.5–9.0	1	Unchanged
9925	BU 812 16026N1670		83.569	107.4	0.60	9.2–9.3	1	The orbital motion.
9952	A 1799 16069N1523		83.548	127.6	0.58	9.2–9.3	1	Change 44° in 75 years.
10071	BU 813 16239N2646		83.558	170.7	0.92	8.4–8.4	1	
			83.564	170.8	0.99		1	
			83.569	171.4	0.98		1	
			83.564	**171.0**	**0.96**		**3**	Unchanged.
10075	STF 2052 16245N1837	AB	82.428	133.7	1.47	7.5–7.5	1	
			82.439	134.8	1.50		1	
			82.510	133.5	1.47		1	
			82.459	**134.0**	**1.48**		**3**	Siegrist, 1952: 0°0, – 0″01.
			83.384	133.5	1.49		1	
			83.419	133.5	1.54		1	
			83.499	134.3	1.49		1	
			83.433	**133.8**	**1.51**		**3**	Siegrist, 1952: + 1°5, – 0″01.
10111	STT 313 16292N4019		83.558	133.2	0.91	7.7–8.3	1	
			83.564	132.7	0.91		1	
			83.561	**132.9**	**0.91**		**2**	Change 30° in 136 years
10188	D 15 16408N4340		83.419	141.9	1.21	9.1–9.1	1	
			83.425	142.1	1.16		1	
			83.485	140.2	1.17		1	
			83.443	**141.4**	**1.18**		**3**	Wierzbinski, 1955: + 2°3, + 0″07.
10229	STF 2106 16464N0935		83.545	178.7	0.53	7.0–8.0	1	
			83.556	178.8	0.59		1	
			83.551	**178.8**	**0.56**		**2**	Heintz, 1962: – 0°1, – 0″01.
10235	STF 2107 16479N2850	AB	82.439	87.8	1.22	6.7–8.2	1	
			83.384	90.1	1.35		1	
			83.419	90.4	1.27		1	
			83.081	**89.5**	**1.28**		**3**	Rabe, 1927: 0°0, – 0″10.
10279	STF 2118 16559N6511		82.428	69.0	1.19	6.4–6.9	1	
			83.425	69.7	1.21		1	
			83.499	69.8	1.28		1	
			83.117	**69.5**	**1.23**		**3**	Gainnuzzi, 1956: + 1°1, – 0″07.

(Continued)

ADS DM	DISC. IDS	Mult.	Epoch 1900+	p	ρ	Est.mag.	n	Notes
10312	STF 2114		83.548	189°0	1″19	6.5–7.7	1	
	16572N0836		83.553	188.9	1.19		1	
			83.556	188.7	1.17		1	
			83.552	**188.9**	**1.18**		**3**	Change 44° in 153 years.
45°2505	KUI 79	AB	83.499	241.9	1.21	10.2–10.3	1	
	17092N4551		83.543	245.8	1.09		1	
			83.545	246.0	1.08		1	
			83.529	**244.6**	**1.13**		**3**	Baize, 1952: – 2°5, – 0″04.
10540	BU 1250		83.548	105.7	1.74	8.3–9.8	1	
	17210N3049		83.556	105.2	1.77		1	
			83.552	**105.5**	**1.75**		**2**	Slow change.
10646	HU 923		83.569	99.6	0.85	9.2–9.7	1	No change.
	17318N4917							
10815	J 754	AB	82.439	50.1	1.77	9.0–9.4	1	
	17449N2454		83.425	49.7	1.75		1	
			83.485	50.5	1.70		1	
			83.116	**50.1**	**1.74**		**3**	Unchanged in 71 years.
10850	STT 388	AB	83.425	352.5	0.86	6.6–6.9	1	
	17475N1521		83.479	373.1	0.80		1	
			83.452	**352.8**	**0.83**		**2**	Unchanged in 148 years.
11010	BU 1127		83.558	74.8	0.91	7.4–9.3	1	
	17596N4414		83.564	74.8	0.91		1	
			83.561	**74.8**	**0.91**		**2**	Popović, 1970: – 5°1, – 0″17.
11046	STF 2272	AB	82.778	305.3	2.17	4.1–6.3	1	
	18004N0232		83.479	302.6	2.16		1	
			83.128	**303.9**	**2.17**		**2**	Heintz, 1973: + 2°3, – 0″13.
11110	STF 2283		83.558	63.9	0.80	8.1–8.6	1	Change 28° in 151 years.
	18047N0608							
11123	STF 2289		83.543	225.2	1.22	6.5–7.2	1	
	18057N1627		83.545	222.8	1.20		1	
			83.553	223.6	1.20		1	
			83.564	222.8	1.18		1	
			83.554	**223.6**	**1.20**		**4**	Hopmann, 1956: + 3°6, – 0″03.
11128	HU 674		83.548	228.9	0.51	7.5–8.0	1	Change 50° in 79 years.
	18072N5023							
11186	STF 2294		82.739	94.2	0.98	8.5–8.8	1	
	18094N0009		83.479	95.2	1.05		1	
			83.109	**94.7**	**1.01**		**2**	Wilson, 1935: + 1°1, 0″00.
11334	STF 2315		83.425	132.8	0.71	6.6–7.6	1	
	18210N2720		83.479	131.2	0.73		1	
			83.485	131.1	0.70		1	
			83.463	**131.7**	**0.71**		**3**	Heintz, 1960: + 3°5, + 0″01.
11479	STT 359		83.425	12.0	0.69	6.4–6.7	1	
	18314N2331		83.479	10.1	0.74		1	
			83.485	10.7	0.75		1	
			83.463	**10.9**	**0.73**		**3**	Symms, 1964: + 2°0, + 0″11.

(Continued)

ADS DM	DISC. IDS	Mult.	Epoch 1900+	p	ρ	Est.mag.	n	Notes
11483	STT 358	AB	82.428	161°.1	1″.53	7.0–7.2	1	
	18314N1654		82.679	161.5	1.57		1	
			82.734	161.8	1.61		1	
			82.739	164.4	1.64		1	
			83.384	164.0	1.61		1	
			83.543	161.2	1.49		1	
			82.918	**162.3**	**1.57**		**6**	Starikova, 1966: + 3°.1, + 0″.05.
11623	A 253		83.546	121.9	0.78	9.4–10.0	1	
	18400N3135		83.556	123.3	0.78		1	
			83.551	**122.6**	**0.78**		**2**	Muller, 1954: – 0°.1, + 0″.01.
11635	STF 2382	AB	83.543	354.0	2.72	5.0–6.1	1	
	18410N3934		83.556	354.4	2.56		1	Guntzel–Lingner, 1955: 0°.0, – 0″.02.
			83.550	**354.2**	**2.64**		**2**	
11635	STF , 2382	CD	83.543	88.4	2.42	5.2–5.5	1	
	1840N3934		83.556	88.4	2.33		1	Guntzel–Lingner, 1955: + 6°.4, + 0″.03.
			83.550	**88.4**	**2.38**		**2**	
11879	A 260		83.559	245.4	0.88	9.4–9.6	1	
	18538N3201		83.564	245.2	0.87		1	
			83.561	**245.3**	**0.88**		**2**	Unchanged.
11897	STF 2438		82.739	1.1	0.86	6.9–7.4	1	
	18558N5805		83.425	3.4	0.80		1	
			83.485	2.1	0.82		1	
			83.216	**2.2**	**0.83**		**3**	Jastrzebski, 1959: + 0°.5, – 0″.06.
12447	STF 2525		82.679	292.2	1.65	8.5–8.8	1	
	19225N2707		82.740	295.4	1.65		1	
			82.778	294.2	1.61		1	
			83.384	291.5	1.62		1	
			82.895	**293.3**	**1.63**		**4**	Tamburini, 1969: + 0°.7, – 0″.24.
12889	STF 2576	AB	82.655	357.8	1.99	9.3–9.3	1	
	19418N3322		82.679	355.5	1.98		1	
			82.734	354.7	2.01		1	
			82.740	355.6	2.03		1	
			82.778	355.4	2.01		1	
			82.717	**355.8**	**2.00**		**5**	Rabe, 1948: + 1°.8, – 0″.12.
12972	STT 387	AB	83.425	166.0	0.68	6.9–7.9	1	
	19450N3504		83.479	164.4	0.66		1	
			83.485	165.2	0.72		1	
			83.463	**165.2**	**0.69**		**3**	Baize, 1961: + 3°.3, + 0″.08.
13723	STT 406		83.546	115.7	0.58	7.4–8.3	1	
	20166N4503		83.556	115.7	0.59		1	
			83.551	**115.7**	**0.59**		**2**	Heintz, 1975: – 0°.1, + 0″.01.
13885	BU 62	AB	83.559	136.0	1.13	8.6–9.5	1	
	20239N2948		83.564	136.2	1.16		1	
			83.561	**136.1**	**1.15**		**2**	Unchanged.
14286	BU 364		83.559	240.0	1.08	8.9–9.1	1	
	20427N2503		83.564	240.0	1.06		1	
			83.561	**240.0**	**1.07**		**2**	Change 21° in 107 years.
14499	STF 2737	AB	82.679	290.5	0.99	5.8–6.3	1	
	20541N0355		82.734	284.1	0.98		1	
			82.706	**287.3**	**0.98**		**2**	Van den Bos, 1933: + 2°.0, – 0″.06.

(Continued)

ADS DM	DISC. IDS	Mult.	Epoch. 1900+	p	ρ	Est.mag.	n	Notes
14573	STF 2744	AB	82.680	125°9	1″34	7.0–7.5	1	
	20580N0108		82.734	129.8	1.28		1	
			82.740	128.8	1.29		1	
			82.778	128.6	1.20		1	
			82.816	125.8	1.18		1	
			82.853	123.8	1.27		1	
			82.767	**127.1**	**1.26**		**6**	Popović, 1969: + 3°3, 0″00.
14783	HI 48		82.740	260,0	0.69	7.0–7.2	1	
	21117N6400		83.546	253.6	0.59		1	
			83.143	**256.8**	**0.64**		**2**	Baize, 1950: + 4°9, + 0″03.
15270	STF 2822		82.740	296.1	1.72	4.5–6.0	1	
	21397N2817		82.778	298.9	1.85		1	
			82.759	**297.5**	**1.78**		**2**	Heintz, 1966: – 2°6, + 0″01.
15401	HO 171		83.559	161.9	0,80	9.5–9.5	1	Change 17° in 100 years.
	21476N2719							
15525	STF 2850		82.778	264.7	2.72	7.5–10.5	1	
	21552N2328		83.546	262.2	2.97		1	
			83.556	265.2	2.76		1	
			83.293	**264.0**	**2.82**		**3**	No change.
15769	STF 2881		82.778	79.2	1.39	7.6–8.1	1	
	22100N2905		83.546	80.9	1.35		1	
			83.556	81.4	1.28		1	Very slow changed in both
			83. 293	**80.5**	**1.34**		**3**	coordinates since 1930.
15794	HO 180		83.559	240.2	0.72	8.2–8.2	1	Change 18° in 97 years.
	22116N4324							
15971	STF , 2909	AB	82.901	217.0	1.79	4.4–4.6	1	
	22237S0032		83.548	219.2	1.75		1	
			83.224	**218.1**	**1.77**		**2**	Harrington, 1968: – 1°6, – 0″02.
15988	STF 2912		82.740	123.1	0.90	5.8–7.2	1	
	22249N0355		83.548	122.1	0.98		1	
			83.144	**122.6**	**0.94**		**2**	Knipe, 1960: + 5°1, – 0″05.
16185	STF 2934		82.740	69.9	0.94	8.5–9.5	1	
	22370N2054		82.822	67.9	0.98		1	
			82.896	69.5	0.92		1	
			82.901	69.8	0.93		1	
			82.839	**69.2**	**0.94**		**4**	Heintz, 1962: + 1°4, – 0″01.
16326	A 632	AB	82.740	167.0	0.89	8.2–9.0	1	Heintz, 1962: + 0°5, + 0″11.
	22480N5712							
16345	BU 382	AB	82.740	211.0	0.83	5.8–7.8	1	Muller, 1954: + 3°0, – 0″13.
	22492N4413							
16373	HU 987		82.778	88.6	0.69	9.1–9.3	1	
	22508N1515		83.548	87.3	0.63		1	
			83.163	**88.0**	**0.66**		**2**	Heintz, 1966: + 2°9, – 0″01.

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ADS DM	DISC. IDS	Mult.	Epoch 1900+	p	ρ	Est.mag.	n	Notes
16435	HLD 56 22551N4117		83.559	98°3	0"98	9.3–9.4	1	Change 27° in 102 years.
17149	STF 3050 23544N3310	AB	82.740	313.4	1.47	6.6–6.6	1	
			82.778	311.9	1.50		1	
			82.896	310.9	1.53		1	
			82.901	311.2	1.49		1	
			82.829	**311.8**	**1.50**		**4**	Heintz, 1973: – 1°2, – 0"06
17178	HLD 60 23563N3905		82.740	179.6	0.92	9.2–9.6	1	
			82.896	179.7	0.95		1	
			82.818	**179.7**	**0.93**		**2**	Heintz, 1963: – 1°5, – 0"14.

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