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FURTHER BELGRADE RESULTS OF THE LARGE-SCALE PHOTOSPHERIC VELOCITY RESEARCH

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SUMMARY. A series of Doppler shift spectrographic observations in FeI 630.25 nm has been analysed. Solar sidereal equatorial rotational velocity amounting to 2.82 μrad s^{-1} was found. Low space-resolution (3º8 x 3º8 at the solar disk) line-of-sight velocity data show a difference of 12 ms^{-1} between the quiet and by activity contaminated photosphere. The equatorial limb effect out of active regions exhibits at θ = 27º a blue shift with respect to the centre of the solar disk amounting to 46 ms^{-1} while the meridional one amounts to 14 ms^{-1} at θ = 30º. The meridian minus equator limb effect difference (named „meridional excess") would give a poleward horizontal meridional velocity of about 100 ms^{-1}. As such a fast meridional flow is doubtfull, additional explanations of the meridional excess have to be considered.

1. INTRODUCTION

Photospheric large-scale velocities have been observed at Belgrade Astronomical Observatory since 1974. Previous results have been published twice (Kubičela and Karabin, 1977, Karabin and Kubičela, 1979). After certain improvements in the instrument and the reduction procedure, a suitable series of observations has been obtained in 1983.

This observational material has been analysed with the aim to estimate the influence of solar activity in our specific observation approach, to obtain a limb effect curve and to find some parameters of a possible meridional motion.

2. OBSERVATIONS

The observations were done with the equatorial solar spectrograph of Belgrade Astronomical Observatory (Kubičela, 1975). The series contains 13 daily observations from 2. Sept. 1983 till 3. Oct. 1983 (see the first column in Table I). Central meridian and equatorial diameter of the solar disk were covered with a total of 17 observed points located at the sin ϕ (ϕ = heliocentric angle) values: 0.00, 0.25, 0.50, 0.66 and 0.79. In order to filter out to some extent the small–scale velocity fields, the solar image was observed extrafocally hence integrating a square portion of the solar disk of 3.″8 side around each observed point.

Table I: Estimated Presence of Activity at the Observed Radii of the Solar Disk

Date (UT)	Active radius CM	Active radius EQ	Date (UT)	Active radius CM	Active radius EQ
Sept. 2.454	N	–	Sept. 23.375	S	E + W
3.417	none	E	24.375		–
9.362	S	E + W	28.471		E
11.400	S	E + W	29.467		E
14.442	S + N	W	Oct. 2.404	N	none
15.354	S + N	W	3.471	S	–
16.333	S	W			

The measurements were performed with the Belgrade Observatory Doppler measuring machine described by Vince (1983). FeI 630.25 nm spectral line was measured with respect to the two neighbouring telluric lines. Four spectrograms were measured at each observed position of the solar disk. Entrance slits of the measuring machine cover in both wings of the Fe I line intervals of 6.4 pm with a distance between them of 2.8 pm. In the line profile this corresponds to an integration interval from about 40% to 80% of the continuum intensity what defines the measured wavelength as an implicitly averaged line bisector within the same intensity interval.

The measured line shifts were corrected for the Earth's rotation, its orbital motion and the effects of extrafocal observations depending on solar rotation and limb effect fields across the disk and amounting up to ± 8 ms^{-1} (Kubičela et al., 1985). It is known that solar active regions contribute with a predominant red shift in large–scale velocity fields interpreted as a steady downward motion (Howard, 1971 and 1972) or as an effect of radiative transfer in a complex enviroment of magnetic flux tubes (Cavallini et al., 1984). To discern this activity effect in our observation, daily solar maps of Solnechnye Dannye for the corresponding period were used. Any observed solar radius along the central meridian (CM) or along the equatorial diameter of the solar disk (EQ) has been assigned as „active" if it crossed an active region contour in the corresponding activity map or if it was touched by such a contour. Actually, in most cases only a small portion of active radius was contaminated with the photospheric activity. Solar filaments were neglected in this procedure. The observed radii oriented toward N, E, S and W ends of the solar disk are listed in Table I. Here the absence of the velocity observations along an equatorial diameter has been marked with a hyphen.

3. RESULTS AND DISCUSSION

3.1 Rotation

A by–product of the reduction of equatorial distribution of the observed line–of–sight velocities is the sidereal solar equatorial rotation velocity. The linear regression procedure applied to the averaged observed velocity data along the equatorial diameter yielded a slope which after being corrected by the factor sec B_0 (B_0 = heliographic latitude of the Earth) amounted to 1961 ms^{-1} or 2.82×10^{-6} rad s^{-1}. The corresponding values for the quiet and active equatorial radii are 1967 ms^{-1} and 1957 ms^{-1} respectively. As far as the differential solar rotation is concerned the influence of non–zero value of B_0, being about 3.5 ms^{-1}, has been neglected. Also, the synodic and sidereal rotation axes were taken as identical (neglecting 1 ms^{-1}).

The obtained value of 2.82×10^{-6} rad s^{-1} is within the long-term scatter of the observed solar equatorial rotation velocities (e.g. Paterno, 1979). At the same time it is somewhat smaller than some other similar measurements in 1983. Namely, Pierce and Lopresto (1984) using various spectral lines in the period from March till October 1983 found an equatorial velocity of 1986 ms^{-1} (or 1977 ms^{-1} for our spectral line in May and June). Also, the corresponding quantity in Snodgrass (1984) amounts to 2007 ms^{-1}. No corrections for scattered light in the atmosphere or in the instrument have been done in our case. The obtained difference between our quiet and active rotational velocities we do not take as significant – especially having in mind the overall accuracy of the whole material and the small number of the observed quiet equatorial diameters (only 3).

3.2 Activity Contribution

Distribution of the average line–of–sight velocities in 9 observed points along the central meridian (A, B, C, D, S, V, X, Y and Z) is given in Table II. The corresponding velocity distribution along the equator (points RE, T, N, M, S, L, K, U and RW) have been found after subtracting the obtained rotational slope for quiet, active and all equatorial radii separately. All velocities in Table II, except those derived from three or less observations, are accompanied by the r.m.s. errors of the mean values.

The first interesting aspect of these central meridian and equatorial velocity profiles is the difference between the quiet and active radii data. They are shown in Figure 1 for the central meridian and in Figure 2 for the equa-

Table II: Mean Line–of–sight Velocities (in ms^{-1})

$\sin\theta$	0.79	066	0.50	0.25	0.00	0.25	0.50	0.66	0.79
	South				Center				North
CM points	A	B	C	D	S	V	X	Y	Z
Quiet radii	+47 –	+ 1 –	–19 –	– 8 –	–2±4	–1± 8	–15±8	+11± 6	+69± 8
Active radii	+41±5	+12±6	+ 3±13	–11±7	+ 1±4	+ 8±13	+ 3±15	+26±11	+55±18
All radii	+42±4	+10±6	– 2±11	–11±5	0±4	+ 2± 7	– 9±7	+15± 5	+63± 7
	East				Center				West
EQ points	RE	T	N	M	S	L	K	U	RW
Quiet radii	–	+ 7 –	–53 –	–33 –	–0–	–24–	–33–	–16–	–
Active radii	+28 –	+11± 9	–20± 9	–13±11	0±10	–15±14	–20±13	+ 2±20	+43 –
All radii	+31 –	+12±11	–28±10	–16±12	0±10	–18±10	–36±10	– 7±15	+54 –

Fig. 1. Observed line–of–sight velocities along the central meridian. Full line: quiet photosphere; dashed line: active photosphere.

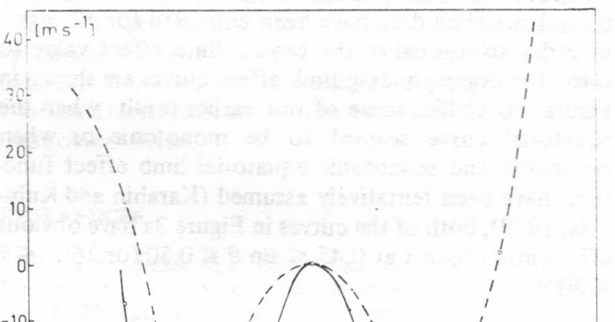

Fig. 2. Observed line–of–sight velocities along the solar equator. Full line: quiet photosphere; dashed line: active photosphere.

tor as full–line curves in the case of quiet photosphere and as dashed lines in the case of active regions partly covering the observed radii of the solar disk.

All the curves follow in general the expected form where the limb effect shape dominantes, but the active velocity profiles are in most points red–shifted with respect to the quiet ones. This is in accordance with the mentioned prevailing red shift in active regions. Somewhat more complex shape of the active central meridian velocity profile is probably due to non–uniform activity distribution or even to the presence of some possible localized blue–shifted region (Howard, 1971). The most striking red–shifted activity contribution was found in the central meridian velocity distribution on 28. September when a sunspot group entered the observed area around the point C. The line–of–sight velocity difference between the 28. September data and the mean value was +98 ms^{-1} contributing to the mean active velocity profile at C with about 9 ms^{-1}. Activity along the equator was not very frequent but was more evenly distributed than along the central meridian. The equatorial active velocity profile is also red–shifted with respect to the quiet one.

It is found that the mean difference between the active and the quiet line–of–sight velocity profiles for the seven central observed point (points B to Y at the central meridian and T to U at the equatorial diameter) amounts to 12 ms^{-1}. It is not clear whether the opposite sign of this difference at the peripheral points of the central meridian (A and Z) is a systematic effect. The same quantity for the equator has not ben derived as the points RE and RW in the quiet photosphere were not observed.

3.3 Limb Effect

As far as the limb effect is concerned, it is supposed that both central meridian and equatorial line shift distributions are symmetric with respect to the centre of the solar disk. The values of the observed quiet photosphere line–of–sight velocities averaged in such a way are given in Table III (column L_m for the central meridian and L_e for the equator). Here the photospheric data disturbed by activity have not been used and all the central meridian data have been corrected for +2 ms^{-1} in order to normalize the central limb effect value to zero. The corresponding limb effect curves are shown in Figure 3a. Unlike some of our earlier results when the equatorial curve seemed to be monotonic or when symmetric and monotonic equatorial limb effect functions have been tentatively assumed (Karabin and Kubičela, 1979), both of the curves in Figure 3a have obvious off–centre minima at $0.45 \leqslant \sin\theta \leqslant 0.50$ (or $26^o \leqslant \theta \leqslant 30^o$).

Table III: Limb Effect and Meridional Excess in the Quiet Photosphere (in ms^{-1})

$\sin\theta$	Central meridian	L_m	Equatorial diameter	L_e	ME
0.00	S	0	S	0	0
0.25	D, V	− 1	M, L	−28	+27
0.50	C, X	−14	N, K	−43	+29
0.66	B, Y	+ 10	T, U	− 5	+15
0.79	A, Z	+ 65	RE, RW	−	−

Though less complete, the equatorial curve L_e, presumably free from large–scale stationary flows, has to be taken as more representative for the limb effect itself. It can be represented in a $\cos\theta$ polynomial form

$$-7035 + 26742\cos\theta - 33511\cos^2\theta + 13804\cos^3\theta. \quad (1)$$

Expression (1) satisfies the obtained limb effect values with an error less than 1 ms^{-1} but it is severely limited to the interval $0.00 \leqslant \sin\theta \leqslant 0.66$ what makes it meaningless at the extreme limb. The curve has a minimum of −47 ms^{-1} at $\theta = 27^o$. A tendency of increasing the red shift toward the limb is also present. Such a shape could be expected having in mind the integrated effect of unresolved granular motions (Beckers and Nelson, 1978), though some minor contribution can be allowed for interatomic collisional processes too (Beckers and Vegvar, 1978). The effect is highly line–dependent and even the off–centre blueshift is not always observed in a given spectral line. Perhaps that can also depend on the observational approach. Among recent results, for example, Balthasar (1984) found for 59 FeI lines (including FeI 630.25 nm) a mean blue shift of 42 ms^{-1} and 73 ms^{-1} along the equatorial radii, but only 0 ms^{-1} and 5 ms^{-1} along the polar ones. Cavallini et al., (1985) found the off–centre minimum in FeI 629.78 nm but in FeI 630.15 and 630.25 they did not detect it. In our case the central meridian off–centre minimum in FeI 630.25 nm has been so far observed three times and the equatorial one once.

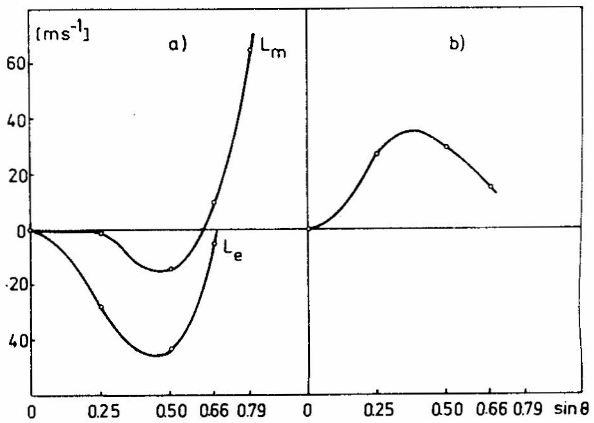

Fig. 3. a) Limb effect in quiet solar photosphere. L_m: along the central meridian; L_e: along the equator. b) Meridional excess ($ME = L_m - L_e$)

3.4 Meridional Excess

The term meridional excess refers to the difference of meridional and equatorial spectral line shift distribution (whether it is symmetrical with respect to the centre of the solar disk or not) expressed in wavelenght or velocity units. It was almost routinelly interpreted as a line–of–sight component of a horizontal meridional motion. Within the appearance of some alternative views (e.g. Cavallini et al., 1984 and 1985), such a term allowing different interpretations of the observed phenomenon might be useful.

The result of our evaluation of meridional excess, ME, in the sense $ME = L_m - L_e$ is given in the last column of the Table III and shown in Figure 3b. It is qualitatively different from the earlier situations when we compared a similar meridional velocity distribution with monotonic equatorial curves. Now, meridional excess is positive throughout the observed interval $0.00 \leqslant \sin\theta \leqslant 0.66$. The meridional excess reaches maximum of 34 ms^{-1} at $\theta = 21^o$. Interpreted as a horizontal meridional motion, this line–of–sight velocity distribution would yield a high horizontal velocity of 108 ms^{-1} at about $\theta = 15^o$ (and 95 ms^{-1} at $\theta = 21^o$) quickly decreasing toward the centre of the solar disk (where the measurability of horizontal velocities decreases linearly) and toward the higher θ–values where it would suggest a decelleration of the meridional flow.

The obtained line–of–sight velocity distribution has a somewhat higher maximum located at a lower heliocentric angle than in some other observations. Consequently, our derived horizontal meridional velocity is higher than found before. For example, Duvall (1979) found a poleward flow of 20 ms^{-1}, Beckers (1979) published 42 ms^{-1} in the same direction, Howard (1979) agreed with Duvall, and LaBonte and Howard (1982) measured 16 ms^{-1}. Perez–Garde et al. (1981) obtained an equatorward flow of 20 ms^{-1}. The highest value of 70 ms^{-1} was published by Beckers and Taylor (1980). However, if Balthasar's (1984) limb effect functions from his Table 6 are re–reduced in the sense ME = 0.5 (N + S – E – W), one can (besides the published 45 ms^{-1}) obtain line–of–sight components of about 130 ms^{-1} at $\sin\theta = 0.8$ or horizontal velocities of even more than 160 ms^{-1} at $\sin\theta = 0.75$.

4. CONCLUSION

Our equatorial sidereal solar rotation velocity of 1961 ms^{-1} fits into the well known picture where the scatter of various observations exceeds the inner errors of any particular series of observations. There is, however, a possibility that correction of the influence of scattered light (instrumental or atmospheric) might improve the situation. Perhaps it would be usefull to introduce some kind of standardization in this field.

The direction in which the activity contamination changes the observed line–of–sight velocities is expected at least for $\sin\theta \leqslant 0.66$. The obtained mean amount of +12 ms^{-1} reflects the actual strength and distribution of active regions along the observed solar diameters as well as our specific way of extrafocal aver aging of radiation in square areas around each observed point. With such an out–of–focussed solar image one can not decide upon reality of the opposite signe of the effect closer to the limb (beyond $\theta = 52^o$).

The choice of equatorial radii of the solar disk in quiet photosphere for representation of the limb effect (free of a priori expected large–scale stationary flow along the polar meridian) in our material based on a moderate number of observations, resulted in a somewhat smaller weight of our limb effect curve. Its extension in $\sin\theta$ is also limited as well as the applicability of the expression (1). We, nevertheless, belive in reality of the blue shifted minimum (at medium $\sin\theta$ values) of the limb effect curve with respect to the centre of the solar disk. The relation (1) can then be used for good representation of our data within the mentioned interval $\sin\theta \leqslant 0.66$.

The unique explanation of the meridional excess as a steady horizontal meridional flow is doubtfull. Some other not yet fully elaborated effects, as those suggested by Cavallini et al. (1984 and 1985), probably contribute considerably. Some room must be also left for possible individual instrumental or observational effects of various observations.

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VARIATIONS OF THE LINEAR OPTICAL POLARIZATION OF κ DRACONIS

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ABSTRACT. It is demonstrated that there were present in the star κ Dra, in the period 1979 to 1984, slow–going variations in the linear intrinsinc polarization in the spectral band V. The variations were developing within approximately 0.13 and 0.61 polarization percent, the minimum having taken place during 1980, between 5° and 22° position angle. As of 1981 the polarization percent is continuously increasing while the position angle ever since 1982 is keeping constant. It might well be that the minimum of the polarization percent has been occasioned by the emission from the shell which is largely unpolarized.

1. INTRODUCTION

Slow variations in the intrinsinc optical polarization of the Be star radiation in the course of time are generally well known. It is considered as firmly established that the polarization arises inside an extended, spherically asymmetric enlarged atmosphere, i.e. in the stellar shell. Coyne (1976a) and Coyne and McLean (1982) in their review papers described the basic features of polarization of Be star radiation. However, few are stars in which variations in the intrinsinc polarization have been pursued over longer time intervals, e.g. several years. Not in a single star yet has the behaviour of the polarization parameters P and Q been scrutinized in the course of shell phases or outside these phases, nor their connection with photometric and spectral characteristics over year-long intervals, apart from some double systems. One of the principal reasons is the non–availability of an entirely dependable method for removing, from the observed polarization, the interstellar component, i.e. for accurate determination of the intrinsinc polarization of particular stars.

Concerning the star κ Dra there have been some sporadic observations of its optical polarization: Hall (1958), Behr (1959) and Coyn and Kruszewski (1969). Coyne and Kruszewski established the polarization to be probably variable and that, having regard to the polarization percent dependence on wavelength, the conclusion was to be drawn that it incorporated an interstellar component. Poeckert and Marlborough (1976), from their measurements in H–alpha line and neighbouring continuum, evaluated the interstellr polarization component in the direction of κ Dra considerably diverging from the one given by McLean and Brown (1978). Another measuring in the H–beta and Ca II K lines was performed by Clarke and Brooks (1983), who found in the Ca II K line's centre, at variance with the H–beta line, an increase of the linear polarization percent with respect to the polarization value in the continuum around the line. This, according to the literature at our disposal would be about all hitherto achieved concerning this star's polarization.

Since 1979 started at the Belgrade Observatory, within an enlarged programme of investigation of long–term polarization variations of bright star radiation, polarimetric observations of the star κ Dra in the visual spectral region. The work has been undertaken with the purpose of pursuing over several years the variations in the polarization parameters and studying possible relationships with other physical parameters. The present paper is first result of this programme.

2. OBSERVATIONAL RESULTS

The observations have been carried out with the Zeiss equatorial having a lens of 65 cm aperture, in the visual spectral domain V, using the Belgrade Observatory's polarimeter. Any individual measure is a result of a 8–minute integration of the photoelectrical signal modulated by a continuously rotating polaroid, its full turn taking 1 minute. The observations encompass the period 1979 to 1984. On the basis of an appreciable number of stars with known polarization and the zero–polarization stars, the characteristics of the instrument and the polarimeter were pursued in the course of the entire interval, as were the instrumental polarization and the zero–direction of measuring the polarization position angle. In the course of a night's run one accomplished from 1 to 6 eigth–minute measures from which were determined mean daily values of the observed polarization parameters p_o and θ_o, as well as the Stoks parameters Q_o and U_o. These observed values are listed in Table 1, wherein, in addition to the entered parameters and the number n of the corresponding individual measurements, are given also the rms errors of the quantities Q_o and

Table 1. Daily means of the polarization parameter of κ Dra in the spectral region V

J.D 2440+ 000+	Qo%	σ_Q	Uo%	σ_U	Po%	θ_o^o	Qs%	Us%	Ps%	θ_s^o	n
3927	0.27	±0.06	0.11	±0.03	0.28	11	0.34	0.01	0.34	1	4
3993	0.19	–	0.20	–	0.27	23	0.26	0.11	0.28	11	1
4340	0.02	–	0.28	–	0.27	42	0.09	0.18	0.20	31	1
4342	0.01	0.03	0.13	0.01	0.13	44	0.08	0.13	0.09	11	2
4343	0.03	0.02	0.13	0.02	0.13	38	0.10	0.03	0.10	9	2
4344	0.09	0.01	0.15	0.02	0.17	31	0.16	0.15	0.16	9	2
4346	0.04	0.03	0.14	0.03	0.15	37	0.11	0.04	0.12	10	4
4371	0.11	0.01	0.17	0.02	0.20	29	0.18	0.07	0.19	11	2
4401	0.02	0.01	0.23	0.07	0.23	43	0.09	0.13	0.16	28	2
4403	0.05	0.02	0.16	0.05	0.16	36	0.12	0.06	0.13	13	3
4637	0.09	0.03	0.22	0.07	0.23	33	0.16	0.12	0.20	19	2
4644	0.13	0.04	0.19	0.02	0.23	29	0.20	0.09	0.22	12	2
4670	0.14	0.02	0.20	0.02	0.24	27	0.21	0.10	0.23	13	4
4701	0.09	0.02	0.17	0.03	0.18	31	0.16	0.07	0.18	12	4
4702	0.10	–	0.21	–	0.23	32	0.17	0.11	0.20	17	1
4753	0.07	0.07	0.20	0.07	0.20	35	0.14	0.10	0.17	18	2
4755	0.20	0.02	0.19	0.01	0.27	22	0.27	0.09	0.28	9	2
4756	0.16	0.04	0.16	0.09	0.22	23	0.23	0.06	0.24	7	2
4757	0.10	0.02	0.24	0.02	0.25	34	0.17	0.14	0.22	20	2
4758	0.08	0.01	0.23	0.01	0.24	35	0.15	0.13	0.20	20	2
5083	0.13	–	0.21	–	0.24	29	0.20	0.11	0.23	15	1
5107	0.29	0.03	0.48	0.08	0.56	29	0.36	0.38	0.52	23	2
5111	0.18	–	0.39	–	0.42	32	0.25	0.29	0.38	25	1
5344	0.34	–	0.44	–	0.55	26	0.41	0.34	0.53	20	1
5346	0.22	0.03	0.40	0.03	0.46	31	0.29	0.30	0.42	23	5
5354	0.33	0.04	0.37	0.07	0.49	24	0.40	0.27	0.48	17	4
5402	0.25	0.01	0.36	0.02	0.43	28	0.32	0.26	0.41	20	4
5403	0.30	0.01	0.59	0.03	0.66	31	0.37	0.49	0.61	27	2
5405	0.24	0.06	0.47	0.03	0.53	31	0.31	0.37	0.48	25	4
5406	0.20	0.08	0.34	0.05	0.39	29	0.27	0.24	0.36	21	2
5407	0.30	0.02	0.47	0.04	0.55	29	0.37	0.37	0.52	23	4
5408	0.31	0.02	0.36	0.03	0.47	25	0.31	0.26	0.41	20	6
5409	0.28	0.02	0.41	0.04	0.49	28	0.35	0.31	0.46	21	6
5410	0.24	0.07	0.45	0.04	0.50	31	0.31	0.35	0.47	24	2
5411	0.28	0.05	0.39	0.01	0.47	27	0.35	0.29	0.46	20	2
5433	0.34	–	0.46	–	0.57	27	0.41	0.36	0.55	21	1
5434	0.33	0.06	0.43	0.09	0.54	26	0.40	0.33	0.52	20	2
5461	0.17	0.08	0.50	0.10	0.56	36	0.24	0.40	0.47	30	3
5469	0.29	0.03	0.46	0.03	0.54	29	0.36	0.36	0.51	23	4
5470	0.34	0.05	0.42	0.08	0.53	25	0.41	0.32	0.52	19	3
5520	0.12	0.01	0.27	0.06	0.29	33	0.19	0.17	0.32	21	3
5758	0.41	0.03	0.48	0.04	0.62	25	0.48	0.38	0.61	19	2
5786	0.39	0.01	0.60	0.02	0.71	28	0.46	0.50	0.68	24	2
5787	0.33	–	0.52	–	0.61	29	0.40	0.42	0.58	23	1
5797	0.32	0.03	0.57	0.02	0.65	30	0.39	0.47	0.61	25	3
5818	0.38	0.02	0.49	0.03	0.62	26	0.45	0.39	0.60	21	4

U_o, σ_q and σ_u. The polarization percent p_o and the position angle θ_o from Table 1 are plotted in Fig. 1 versus time. In Fig. 2 are displayed the Stoks parameters Q_o and U_o. It is readily recognized in both Figs. that variations were present in the observed polarization parameters, significant ones in the polarization percent and lesser ones in the position angle. These variations are an unmistakable indication of the existence of variations in the intrinsinc polarization of the κ Dra radiation. However, to judge on the magnitude and the character of the variations in the intrinsic polarization from the measured polarization parameters is not possible as there are indications, referred to previously, of the presence in this star of an interstellar polarization component that can-

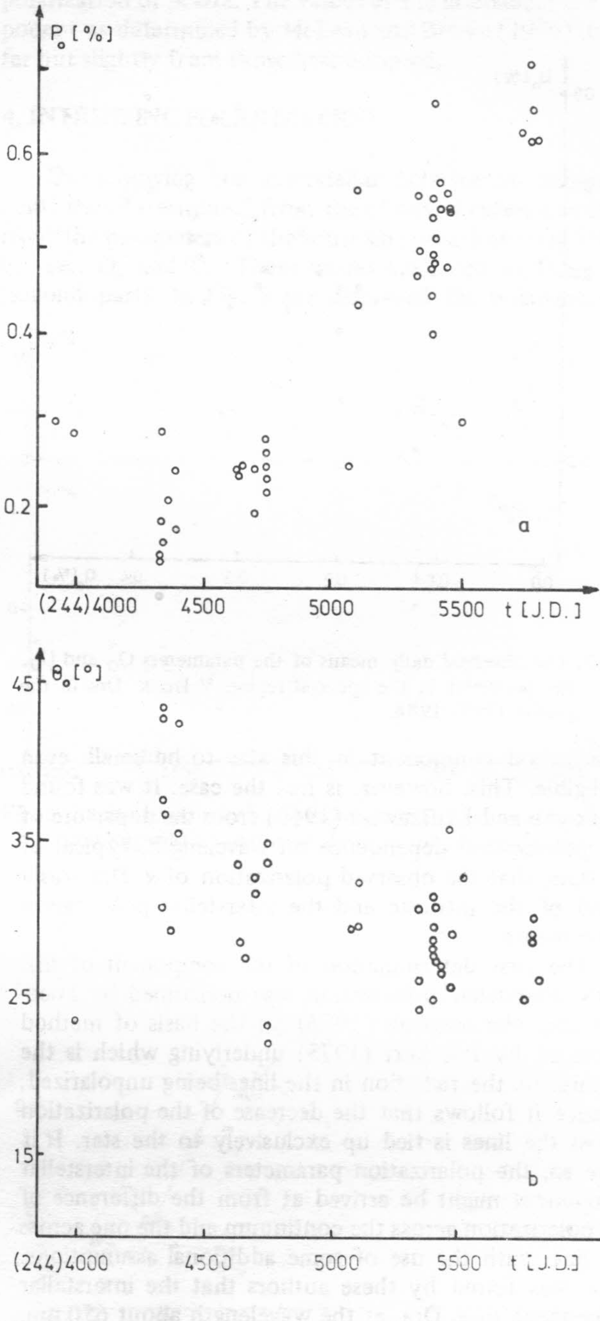

Fig. 1. Daily means of the observed polarization parameters of κ Dra in the spectral region V in the course of time. a) Polarization percentage P_O, b) Position angle θ_O.

not be neglected. It appears therefore indispensable to have this component, considered constant in time, removed from the observed value.

3. INTERSTELLAR COMPONENT

Having regard to high galactic latitude of κ Dra there would be some ground for assuming the interstellar

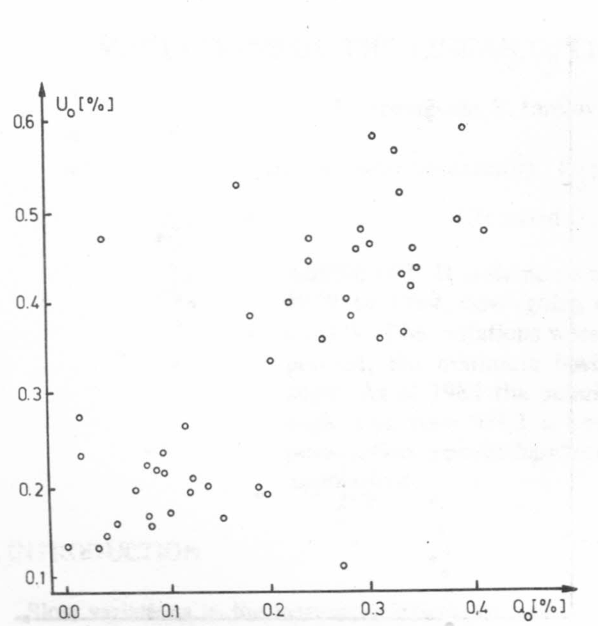

Fig. 2. The observed daily means of the parameters Q_0 and U_0. (in percents) in the spectral region V fro κ Dra in the period 1979–1984.

polarization component in this star to be small, even negligible. This, however, is not the case. It was found by Coyne and Kruszewski (1969) from the departure of the polarization dependence on wavelength, typical of Be stars, that the observed polarization of κ Dra was a blend of the intrinsic and the interstellar polarization components.

The first determination of the component of this star's interstellar polarization was performed by Poeckert and Marlborough (1976) on the basis of method advanced by Poeckert (1975) underlying which is the premise of the radiation in the lines being unpolarized, whence it follows that the decrease of the polarization across the lines is tied up exclusively to the star. If it were so, the polarization parameters of the interstellar component might be arrived at from the difference of the polarization across the continuum and the one across the line, with the use of some additional assumptions. Thus was found by these authors that the interstellar component of κ Dra, at the wavelength about 650 nm, was having the following polarization parameters: $p_i = 0.138$ % and $\theta_i = 30^\circ\!.37$. It turned out, however, that a fraction of the radiation in the lines may, none the less, be polarized, making it not always certain that the method will yield true value of the interstellar polarization. Besides, the nature of the polarization in the lines and the continuum is not sufficiently understood, while the variations in time are so large as to invite the question of the justifiability of deriving mean values of the observed polarization parameters from which it is parted in this procedure of separating the polarization components. These probably are the reasons why the next attempt at deriving the intrinsinc polarization of κ Dra, made by Poeckert and al. (1979), failed to furnish any results.

McLean and Brown (1978) approached the problem in a more sophisticated way. By analysing polarization of the surrounding stars, the variations in polarization in the course of time as well as polarization variations along the emission lines, they inferred that the interstellar polarization component in the direction of κ Dra likely had the values: $p_i = 0.10$ % and $\theta = 60^\circ$.

Having regard to the complexity of the method of determination of the interstellar polarization component and also the inconsistency in the evaluated values, we deemed it useful to reconsider the problem of the interstellar component in κ Dra on the basis of evidence on polarization of the neighbouring stars.

There are in the neighbourhood of the star κ Dra (between 39° and 62° galactic latitude and 79° and 100° galactic longitude) 10 stars with measured polarization (Behr, 1959). The positions of κ Dra and the rest of stars in the field are illustrated in Fig. 3 (in galactic coordinates). Being given that the polarization parameters do not differ as much as it often happens, we considered it admissible to assume the field relatively homogenous and that it made sense deducing the mean value of the polarization. The mean value of the polarization parameters resulting from all the 10 stars is $p = 0.09$ % and $\theta = 66^\circ$. However, as apparent from Fig. 3 κ Dra is situated between the stars HD 108907 (4 Dra) and HD 113092 (9 Dra), possessing highly similar polarizations, and in both parameters at that. The mean value of the polarization parameters of these two stars is $p_i = 0.12$% and $\theta = 62^\circ$. Note here that the Behr's measures were performed in the spectral region 0.462 nm effective

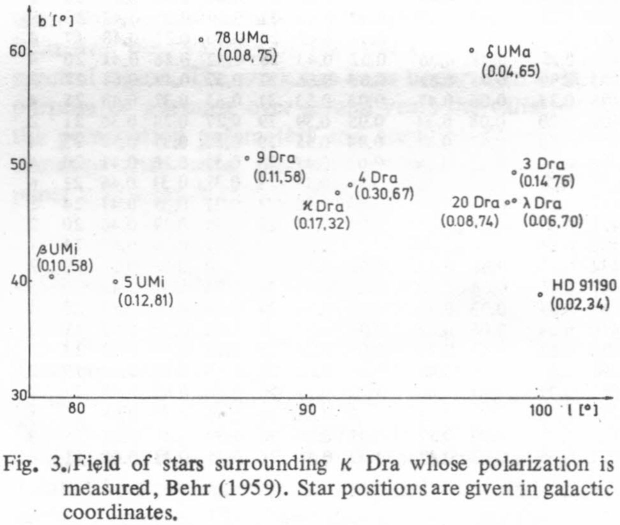

Fig. 3. Field of stars surrounding κ Dra whose polarization is measured, Behr (1959). Star positions are given in galactic coordinates.

wavelength, but the corrections involved by the transition to the visual spectral region, provided one employs the known dependence of interstellar polarization on the wavelength given by Serkowski (1971), are less than errors commited by meaning the polarization values for different stars.

As an illustration of how much do the parameters of the observed polarization of κ Dra, incorporating also parameters of the intrinsinc polarization, deviate from the polarization parameters of the neighbouring stars, likely possess only interstellar component, may serve Fig. 4, in which the parameters are plotted in the (p,θ) system.

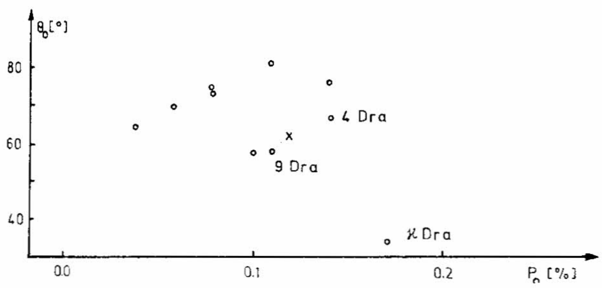

Fig. 4. Polarization parameters of stars surrounding κ Dra plotted in the p, θ plane.

To decide confidently which one of the values of the interstellar polarization component was to be adopted one would know the distances of all the stars in the field, which unfortunately is not the case. Yet, something may be said. Namely, seven stars out of 10 present in the field, are of the lumunosity class III and the magnitudes from 2.2 to 5.5. The star κ Dra has a 3.9 magnitude. We rate it little likely that κ Dra, possessing a 3.9 magnitude and a luminosity class III – IV, may substantially be farther away than these luminosity class III stars or, more precisely, we consider it likely that κ Dra is situated somewhere at the mid–distance of the rest of stars in the field. When it comes to the mid–distance it seems as the most likely that it is comwhere in the middle between two nearest stars in the field, i.e., 4 Dra and 9 Dra. This because 4 Dra is a dwarf star and 9 Dra of the luminosity class III, both having nearly the same magnitude 5.4 which is perhaps suggestive of their different distances. Taking in consideration their similar polarizations one may well assume the error, involved by the not accurately known distance of κ Dra, not to be large.

Thus was how, in consideration of all the above stated, one adopted for the parameters of the interstellar polarization component of κ Dra the values: Pi = 0.12 % and Qi = 62° (mean values of the polarization parameters of two nearest stars in the field). The error committed by adopting these values is certainly not large and will not substantially affect the behaviour of the intinsinc polarization of κ Dra. The values of the interstellar component as determined by McLean and Brown (1979) differ but slightly from those here adopted.

4. INTRINSINC POLARIZATION

On removing the interstellar polarization component, thus determined, from the observed values one derived the parameters of the intrinsinc polarization p_s and θ_s, i.e., Q_s and U_s. These values are listed in Table 1 (second part). In Fig. 5 are displayed the polarization

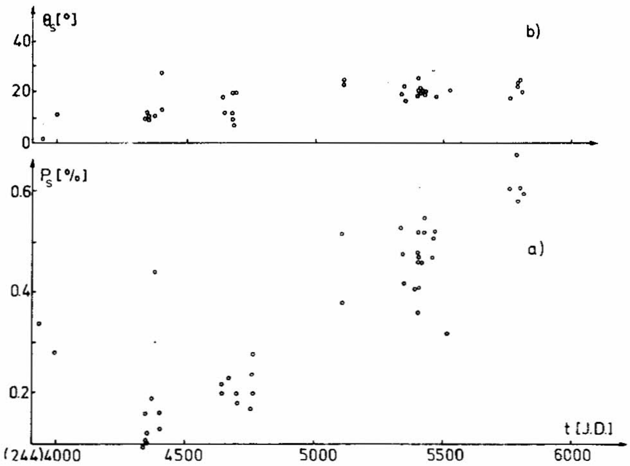

Fig. 5. Intrinsinc polarization percent of κ Dra (a) and the position angle(b) on terms of time in the period 1979–1984

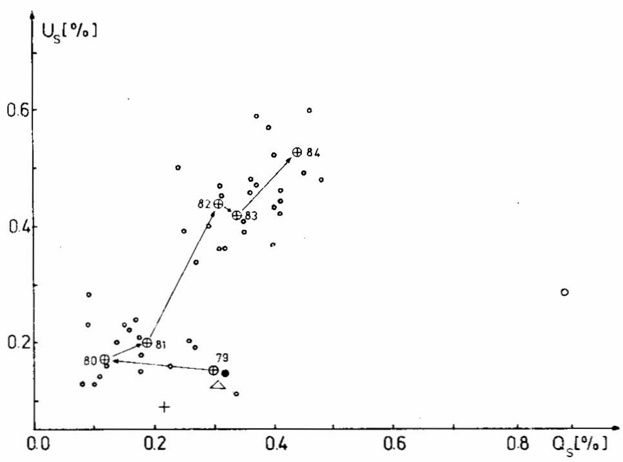

Fig. 6. The plot illustrating Stoks parameters of the intrinsinc polarization of κ Dra in the spectral region V in the period 1979–1984. Annual means are marked by circlets with corresponding years indicated.

The observations performed by other authors are labeled in the following way:

○ 1949–1950, Hall (1958)
\+ 1956–1958, Behr (1959)
△ 1967–1968, Coyne and Kruszewski (1969)
● 1982, September, Clarke and Brooks (1983), measured within narrow spectral intervals around the H_β line.

percent (5a) and the position angle (5b) as a function of time. In Fig. 6 are illustrated the Stoks parameters Q_s and U_s in terms of percent as well as the values of these parameters as determined by other authors. On comparing the latter plots with the one of the observed polarization, one at once recognizes that the features of the polarization percent variations did not markedly change. The percent of the intrinsinc polarization (and of the observed one) varies continuously in the course of time. The minimum percent value is about 0.13 %, as measured in 1980. Following 1980 the polarization percent grows steadily up to the close of the observing period. The variations of the polarization position angle, though slight, upon removing the interstellar component, acquired new features which becomes clearly recognizable on comparing Figs. 1b and 5b exhibiting respectively the position angles of the observed and the intrinsinc polarization. The position angle of the intrinsinc polarization increased from about 5° during 1979 to about 22° as obtained in 1984.

In the (Q, U) plane, Fig. 6, the variations of both parameters are clearly recognized. Namely, starting in 1980, the polarization percent is steadily increasing (distance from the coordinate origin) with the position angle keeping practically constant, so that the anual means Q_s and U_s, whose values are summarized in Table 2, plotted in graphs by circlets, lie virtually on straight line. However, the parameter values measured in 1979 deviate from the straight line along which lie all other values measured over the period 1980 to 1984. The measurements by other authors (indications given in the figure subscript) are also plotted in the graphs. Hall's (1958) measurement is the only one departing considerably from the rest. The turnover in the star seems to have taken place in the period around 1980, bringing down the polarization percent to the extremely low value, seconded by a change in the position angle of about 10°. The next event occured apparently during 1982. With an unsignificant change in the position angle of about 6° the percent increased by about 0.2%. Therafter the polarization keeps increasing without the position angle having changed.

There are in the (Q, U) graph roughly three areas whithin which the points are converging. The first area is patterned by points measured in 1979, including some measurements by other authors in the preceding years. The second area is the one containing points from 1980 and 1981, distinguished by low polarization value. Finally, the third area of higher polarization values encloses all points from 1982, 1983 and 1984. It may well be that this separation had resulted from the scarcity of observations in 1979 and 1982. Nevertheless, we believe the cause to be in the star itself, mainly because the polarization position angles in all three areas are differing (see annual means in Table 2), comparatively slightly true, but having regard to the agreement within the groups containing more measurements, probably real as well.

Table 2. Annual means of the parameters of the intrinsinc polarization of κDra

Godina	Qs%	Us%	Ps%	θs	n
1979	0.30±0.04	0.06±0.05	0.30	5	5
1980	0.12 0.01	0.07 .02	0.14	16	18
1981	0.19 .01	0.10 .01	0.21	14	23
1982	0.31 .05	0.34 .08	0.45	24	3
1983	0.34 .02	0.32 .02	0.47	22	48
1984	0.44 .02	0.43 .02	0.43	22	12

The growing of the polarization percent is ongoing uninterruptedly ever since 1981, while the position angle stabilized in 1982. Abiding to the already accepted notions concerning the origin of polarization in Be stars, we assume that during 1981 a global process of shell forming has set in involving an augmentation of the number of free electrons in the shell, whose asphericity is growing or, rather, is getting changed.

Obviously, the ways of interpreting these observed polarization changes within one spectral region, without an insight into other relevant physical parameters, are practically limitless, being mostly dependent on an author's imagination. It is certainly hoped that there is a great deal of spectral observations of κ Dra, along with polarimetric ones, not yet published, to render possible a more complex analysis. It is equally hoped that these polarimetric results will give an impetus to researches into other physical characteristics of κ Dra in the period 1979–1984.

An interesting fact is perhaps still to be mentioned at this point. Namely, Andrillat and Fehrenbach (1982) found in 1980 for κ Dra the maximum values of the equivalent width of the emission line H_α, after 1977, when the polarization increase did set in. Providing this live emission is attended by the emission in the continuum, and, that it is generated in the shell, and is mainly unpolarized, one might assume it as being responsible for the polarization percent decreasing i.e. for the 1980 minimum. In other words, the increase of the unpolarized component of the star's radiation in the total stars's flux had led to the diminishing of the polarization percentage. With plausible assumptions on this emission's location, the position angle might be accounted for as well. The possibility of the polarisation percent decreasing on account of the emission in the continuum increasing, was pointed out by Brown and McLean (1977), but it failed so far to be observationally established in any star.

5. CONCLUSION

First systematic measurements of the linear optical polarization of the star κ Dra in the spectral region V enabled some interesting results to be arrived at.

Determined, rather dependably, were the parameters of the interstellar polarization component in the direction of

κ Dra: $P_i = 0.12\,\%$, $Q_i = 62^{\circ}$.

The star's intrinsinc polarization was determined and its changes pursued over the period 1979 to 1984. The minimum of the polarization percent was observed in 1980. Since 1981 the polarization percent has steadily increased the process probably not having terminated by 1984. Since 1982 the polarization position angle changed from about 5° to about 22°.

The polarization percent minimum in 1980 is assumed to have been occasioned by an extra unpolarized emission from the star's shell across the continuum and the lines.

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COLLISION BROADENING AND MICROTURBULENCE SENSITIVITY OF SOME NaI NON–RESONANT LINES

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SUMMARY: Profiles of six weak and moderate weak NaI lines in the centre and on the limb of the solar disk have been synthetized using the Smirnov–Roueff potential. The sensitivity has quantitatively been examined of a variety of parameters of the spectral line profiles (equivalent width, central intensity, half–width and line shape parameter) to microturbulent velocity variations. The results are displayed both numerically and graphically. Inadequate knowledge of the collision broadening can lead to the value of the microturbulence velocity, obtained from these spectral lines being significantly distorted.

1. INTRODUCTION

Inadequate knowledge of the spectral line collision broadening may turn up an origin of errors in determining the microturbulent velocity (see e.g. Gray, 1976; Gurtovenko, 1979). This is particularly true if the broadening due to collisions with the neutral perturbers in typified as the van der Waals broadening as then both the enhancement factor and the microturbulent velocity (hereafter denoted by ξ) become virtually free „best–fit" parameters.

We quantitatively investigated the sensitivity to the quantity ξ changes of a variety of profile parameters of several weak and moderate weak lines in the solar spectrum, and by this very fact the possible uncertainty of its deriving from these lines. The calculations have been performed using the results of the current collision broadening theories (see Section 2).

It is well known that the weak line sensitivity to changes in ξ is not a strong one and this fact, together with the simplicity of calculations under LTE conditions, is one among reasons of their being particularly suitable for determination of the chemical elements abundance (Blackwell et al., 1972) as well as for exploration of other conditions in the solar photosphere. Accurate quantitative evaluation of the weak and moderate weak line sensitivity to changes in ξ can prove useful at clearing this sort of problems.

The lines have been selected in such a way as to satisfy the following demands:

1) The uncertainty in the knowledge of all other parameters, viz.: transition probabilities, the abundance of the absorbing element in the solar atmosphere, the broadening due to collisions with the neutral and electrically changed particles, to be as small as only possible;
2) The NLTE effects to be as little pronounced as possible;
3) The existence of high resolution spectrograms.

Particularly suitable in terms of all these points proved the moderate weak and weak lines of neutral sodium.

In earlier analogous investigations (Blackwell et al., 1972; Sheminova, 1977) the FeI lines were those used. The van der Waals broadening was anticipated and the sensitivity of the equivalent line width alone was investigated.

2. COLLISION BROADENING PARAMETERS, ATOMIC AND OBSERVATIONAL DATA

The preponderant agent of the spectral line collision broadening is constituted by interactions with the neutral perturbers, chiefly with hydrogen atoms. This broadening mechanism's contribution was computed from the semi–empirical Smirnov–Roueff exchange potential (Smirnov, 1967; Roueff, 1970), employing the approach (Roueff, 1975) adjusted to the p–s transitions of the neutral sodium.

For the case of broadening due to collisions with the electrically charged particles (mainly electrons) use was made of the results (Dimitrijević & Sahal–Brechot, 1985), acquired by the semi–classical approach to the Stark broadening (Sahal–Brechot, 1969 a, b). For all the lines under consideration the ratio of the broadening by collisions with the hydrogen atoms to the one due to collisions with the electrons amounts to 10.1 approximately. Thence it follows that only excessive errors in the knowledge of the Stark broadening could have materially affected this paper's results.

Table 1. Line profile parameters calculated from data of Pierce & Slaughter (1982). The upper index indicates cos θ (θ is the heliocentric angle)

	Laboratory wavelength (nm)	$EW^{1.0}_{obs}$ (pm)	$I^{1.0}_{c\,obs}$	$FW^{1.0}_{obs}$ (pm)	$LSP^{1.0}_{obs}$	$EW^{1.0}_{obs}$ (pm)	$I^{0.2}_{c\,obs}$	$FW^{0.2}_{obs}$ (pm)	$LSP^{0.2}_{obs}$
$3p^2P^o-5s^2S$	616.07470	6.06	.558	11.9	.623	6.34	.594	14.3	.643
$3p^2P^o-5s^2S$	615.42253	3.76	.704	10.8	.618	4.37	.707	13.2	.639
$3p^2P^o-6s^2S$	514.88381	1.30	.868	8.92	.628	1.63	.848	9.98	.638
$3p^2P^o-7s^2S$	475.18218	1.29	.865	8.43	.627	1.77	.842	10.4	.626
$4p^2P^o-6s^2S$	1638.885	2.08	.940	29.5	.624	4.00	.906	38.4	.630
$4p^2P^o-7s^2S$	1290.794	.192	.992	20.5	.619	.367	.987	27.4	.629

Natural broadening was calculated using the simple quantum-mechanical method (relation 11.22 in Gray, 1976). The broadening of both upper and lower levels was calculated. The contribution of this sort of broadening is almost negligible in comparison with the collision broadening.

The transition probabilities and the oscillator strengths are borrowed from Wiese et al. (1969).

The value $A_{Na} = 6.32$ taken from Lambert & Luck (1978) has been adopted for the sodium abundance in the solar photoshere.

The calculating results were compared with the recently published high resolution observations (Pierce & Slaughter, 1982) made with the Kitt Peak large and infrared spectrographs.

Table 1 shows our line selection as well as the parameters of the observed profiles in the centre of the solar disk (cos θ = 1) and on its limb (cos θ = 0.2) where θ is the heliocentric position angle.

3. METHOD OF ANALYSIS

The spectral lines were syntetized using the SUNLINE program, developed by these authors at the Belgrade Observatory. Pure absorption and absence of NLTE effects are implied. The HSRA solar atmospheric model was used (Gingerich et al., 1971). Each line's profile in the solar disk centre (cos θ = 1) as well as on its limb (cos θ = 0.2) was synthetized for five different values of ξ (ξ = 0, 0.5, 1.0, 1.5 and 2.0 km/s). Gaussian, homogeneous and isotropic turbulence model was assumed. (Possible changes of ξ with optical depth have not been considered since previous inquiry revealed that such changes, within the photospheric layer within which weak and moderate weak lines are formed, are too slight for their effect on the spectral lines to be reliably registered).

The sensitivity to variations of ξ of the following parameters of the spectral line profiles was investigated: equivalent width within the frequency range corresponding to the observed one (EW), relative intensity in the line centre (I_c), full width at half-maximum (FW) and the line shape parameter (LSP) specified by the ratio of the 3/4 width to the 1/2 width (Slettebak, 1956). The amounts of these parameters as obtained from the observed profiles are listed in Table 1.

In order to allow a quantitative comparison of the sensitivity of individual lines and parameters we normalized all the values obtained from the synthetized profiles to those deduced observationally.

The Figures 1 through 12 illustrate the variations of the normalized parameters of the synthetized spectral lines depending on the ξ variations.

Calculated were also the gradients

$$\frac{\partial EW^{norm}}{\partial \xi}, \quad \frac{\partial I_c^{norm}}{\partial \xi}, \quad \frac{\partial FW^{norm}}{\partial \xi}, \quad \frac{\partial LSP^{norm}}{\partial \xi}$$

$$\text{where } A^{norm} = \frac{A^{calc}}{A^{obs}}, \quad (A = EW, I_c, FW, LSP).$$

Provided in this form they are rendered directly comparable with each other. Their summarization is found in Table 2. The same Table contains also the effective depths of individual lines (τ^{5000}_{eff}) furnished by the emission contribution function, weighted according to the line depths at particular points of the calculated profiles.

4. RESULTS AND DISCUSSION

Theoretical consideration of microturbulence effects on profiles of the moderate and weak lines (see e.g. Section 18 in Gray, 1976) made us expect a weak sensitivity of the equivalent width and the central intensity and a somewhat stronger sensitivity of the half-width and the line shape parameter.

Table 2 shows that from all the selected parameters most sensitive to the ξ variations is the FW.

The line shape parameter recomended by Evans et al. (1975) also exhibits expectedly a relatively high sensitivity though less intensive than the one displayed

Table 2. The microturbulence sensitivities of the different line profile parameters. The second line indicates cos θ. The Roman numerals indicate number of points taken into account (for the unmarked cases the number is V)

Wavelength (nm)	τ_{eff}^{5000}		$\frac{\partial EW^{norm}}{\partial \xi}$		$\frac{\partial Ic^{norm}}{\partial \xi}$		$\frac{\partial LSP^{norm}}{\partial \xi}$		$\frac{\partial FW^{norm}}{\partial \xi}$	
	1.0	0.2	1.0	0.2	1.0	0.2	1.0	0.2	1.0	0.2
616.1	.44	.052	.052	.063	.057	.037	.11	.12^{IV}	.10	.079
615.4	.60	.076	.038	.054	.046	.037	.10	.12	.15	.12
514.9	1.0	.15	.006	.019	.018	.025	.045^{IV}	.075^{IV}	.13	.11
475.2	1.1	.18	.000	.006	.010	.021	.034^{III}	.087^{IV}	.15	.096
1638.9	1.3	.34	.000	.000	.003	.004	.044	.087	.18	.13
1290.8	.95	.20	.000	.000	.000	.001	.049	.14	.19	.16
			.016	.024	.022	.021	.064	.10	.15	.12
Averaged values			.020		.022		.082		.14	

$$A^{norm} = \frac{A^{calc}}{A^{obs}}$$

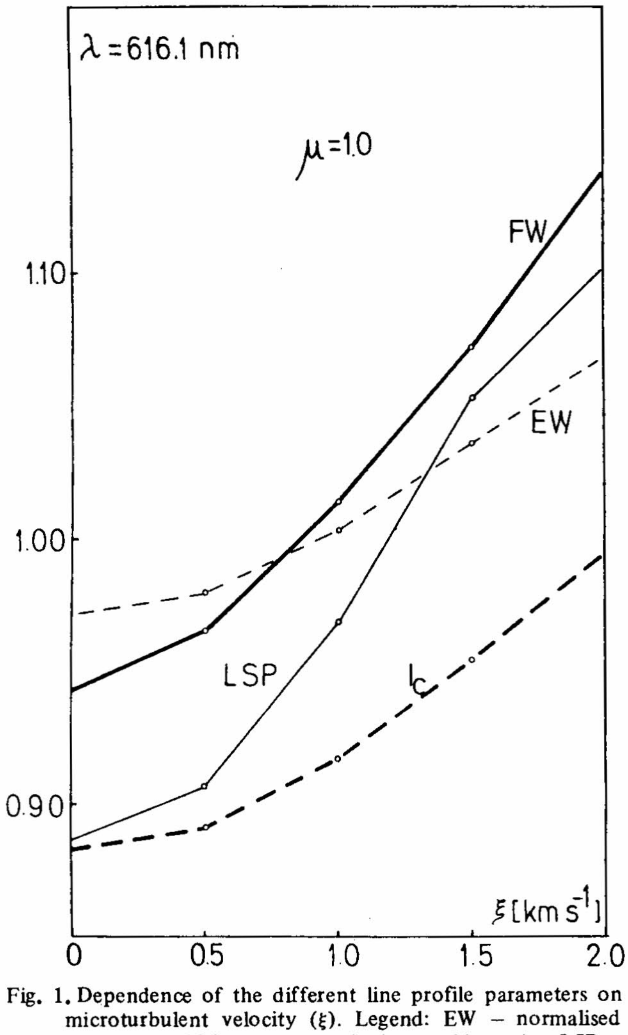

Fig. 1. Dependence of the different line profile parameters on microturbulent velocity (ξ). Legend: EW – normalised equivalent width; I_c – normalised central intensity; LSP – normalised line shape parameter; FW – normalised full width at the half maximum

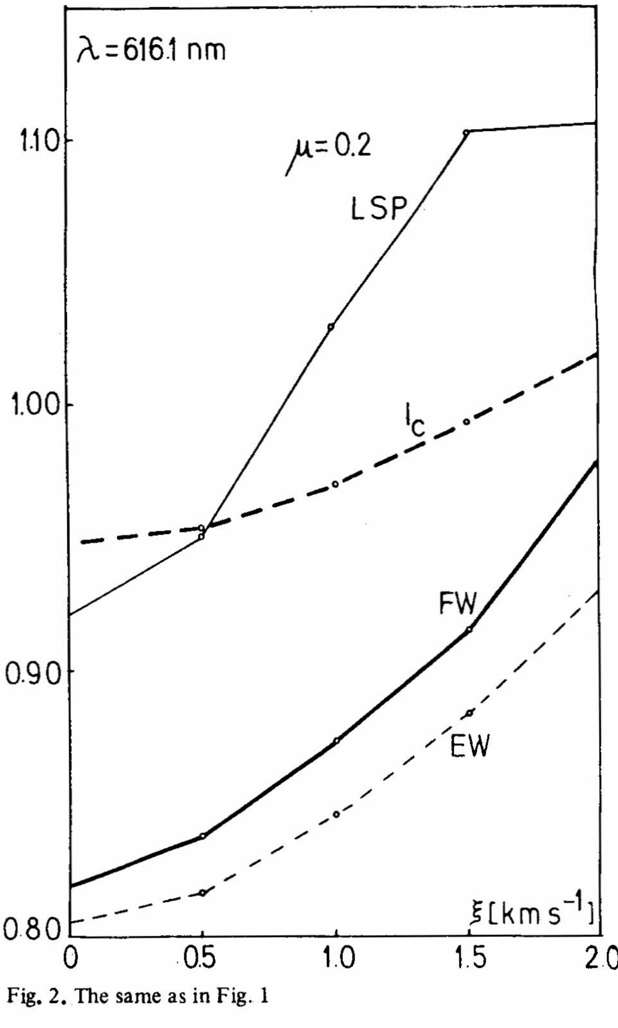

Fig. 2. The same as in Fig. 1

by the FW. With the weak lines it is conspicuously lower. For some of the lines, however, (Figures 2, 5, 6, 7

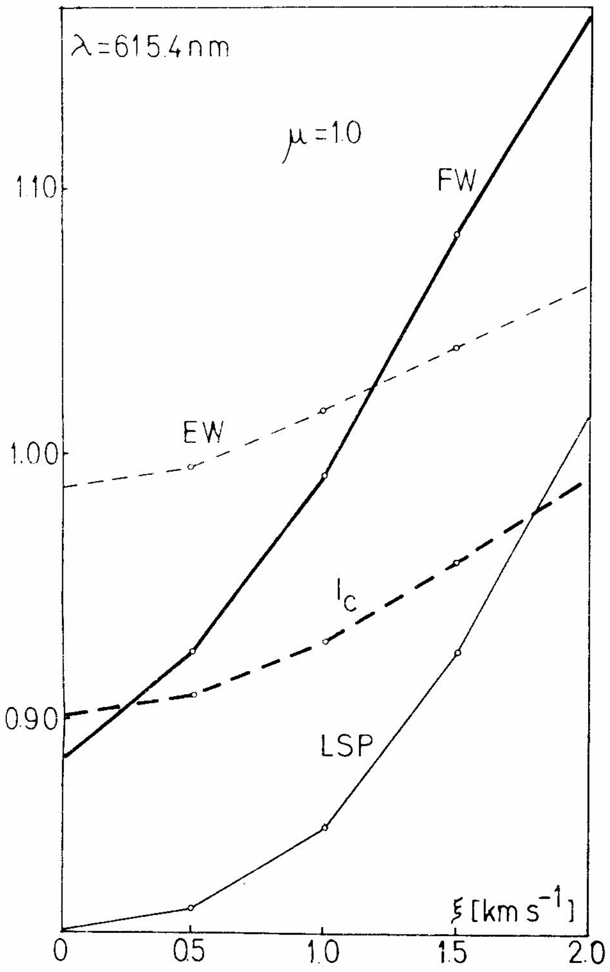

Fig. 3. The same as in Fig. 1

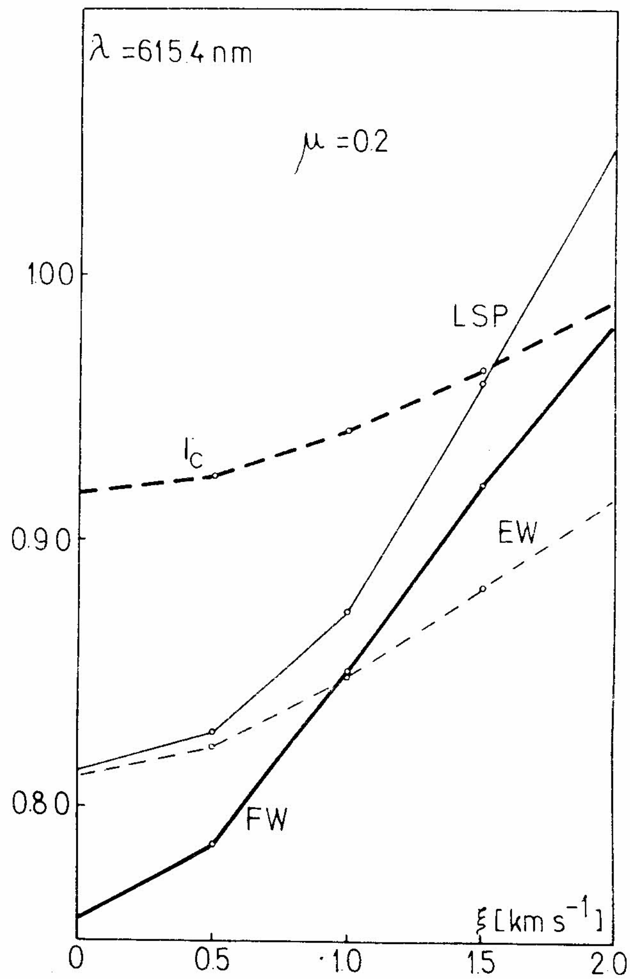

Fig. 4 The same as in Fig. 1

and 8) the irregularity in the LSP behaviour conditioned the gradients to be calculated from fewer points, i.e. from 4 and 3, respectively, instead of from 5, which in Table 2 is specially indicated. This irregularity, emerging for high values of ξ, can be accounted for by the Doppler core being significantly extended, approaching the line wing, thus producing a decrease in the 3/4 width sensitivity. This suggests caution at using the LSP parameter.

The I_c displays a comparatively weak sensitivity to the ξ variations, but a strong regularity of its behaviour.

The EW parameter, linked with the definition of the microturbulence notion, displays convincingly the weakest sensitivity, making it actually the least suitable for the determination of ξ.

The quantitative analysis of Table 2 data points to an extremely feeble sensitivity of the investigated lines to the ξ changes. It transpires that, using the ξ values in the solar photosphere acquired in recent years (1 km/s or less), the omission of ξ from the calculation of these lines might affect the EW and I_c parameters by no more than a percent, which is on the very limit of the observing accuracy, and the FW and LSP parameters by about 10%, which must not be neglected. However, a change of about 10% in ξ generates changes that are below the observing accuracy for the parameters EW and I_c, and the ones at its very limit for the FW and LSP parameters.

The results shown in Figures 1 through 12 and in Table 2 lead one to several more conclusions.

The $3p^2\,P^o - 5s^2\,S$ lines are probably experiencing a macroturbulence influence as well, which harmonizes with the findings of Evans et al. (1975) for the moderate lines.

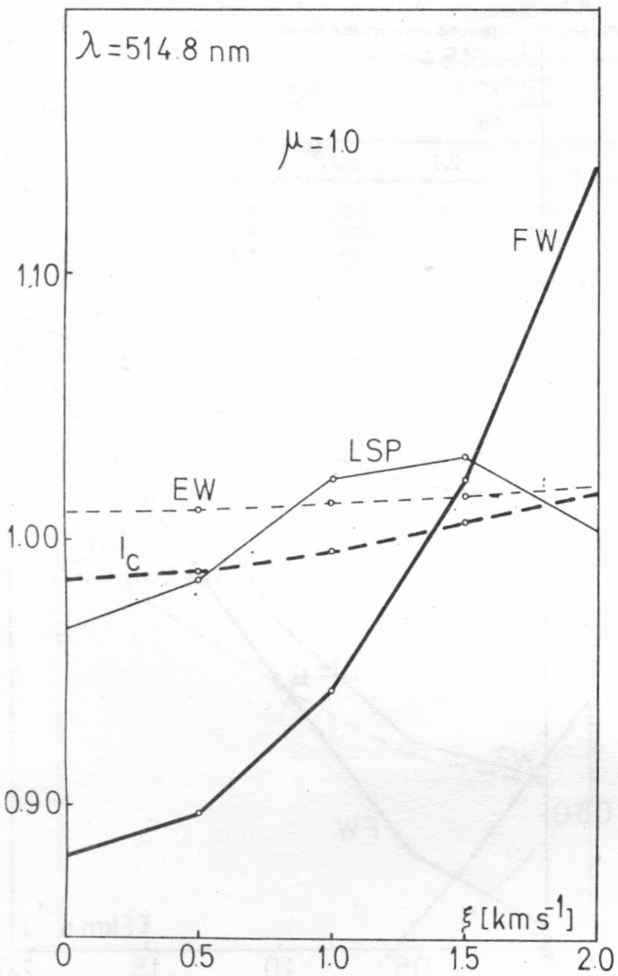

Fig. 5. The same as in Fig. 1

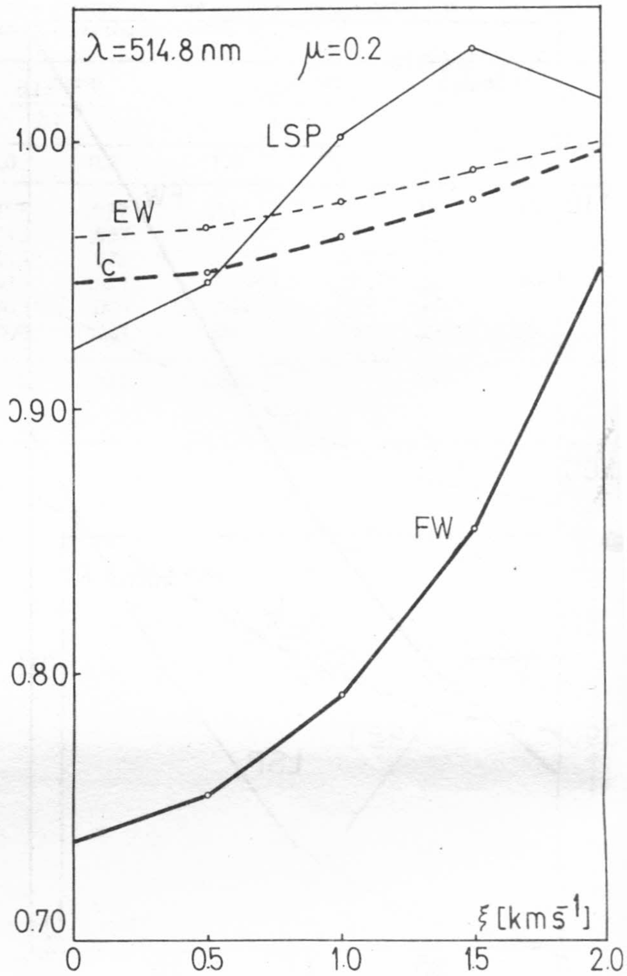

Fig. 6. The same as in Fig. 1

A stronger sensitivity of the half–width at the centre of the solar disk than on its limb is a consequence of the adopted normalization, i.e. of the poorer accordance of the synthetized and the observed profiles on the limb. The reasons of this are to be looked for above all in the disparity of the adopted model (pure absorption, LTE) from the physical reality in the given case, having regard to the considerably lower effective depths of the line forming on the limb (apparent also from Table 2).

A number of reasons might be induced (which might be at work in combination) for the distinct divergence of the profile parameters of the two lines from the 4p–ns series and the observed ones, such as: too large theoretical value of the collision broadening for this series, to low abundance value for the sodium (no attempts have so far been undertaken to check this value in conformity with the knowledge of the exchange potential, which these authors are intent of doing) and, in view of the extremely low depth and enormous width of these lines, not to be ruled out is the possibility of an error in the continuum level of these lines.

We tried to establish possible uncertainty in the providing of ξ from the investigated lines for the case of unsufficient accuracy of the collision broadening. The estimation was performed for the instance of 3p–7s line (475,2 nm), considered representative of this line selection. This line's profile was synthetized using different values of the factor by which the broadening due to collision with the hydrogen atoms was miltiplied. The factor values were varied from 0 to 2. For each one of the profiles parameters were calculated whose sensitivity was scrutinized. The results are shown in Figure 13. The diminuation of EW is a consequence of its having invariably been determined within the same frequency range while the far wings have been neglected.

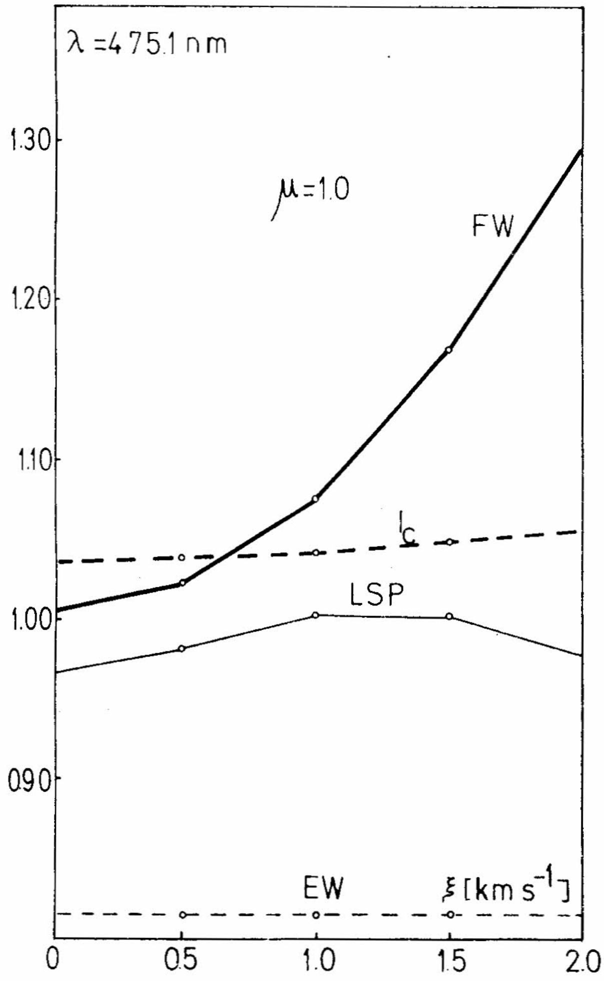

Fig. 7. The same as in Fig. 1

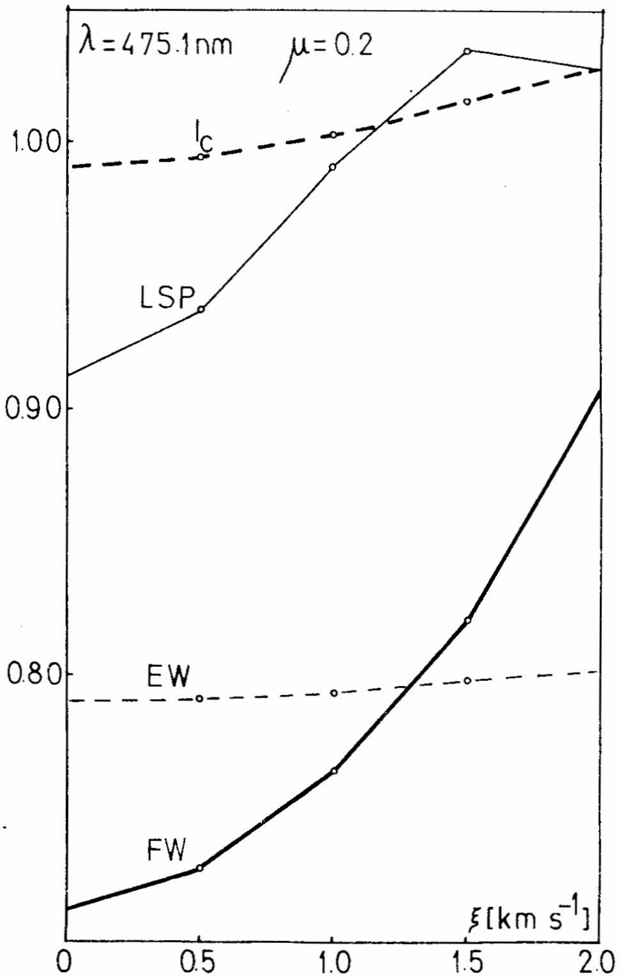

Fig. 8. The same as in Fig. 1

The profile parameters changes due to the enhancement factor changes disclose trends similar to those due to the ξ changes. Mutual relations of the parameters in terms of their sensitivity are also similar. However, with the value of the collision broadening used in this paper, the parameters disclose stronger sensitivity to its changes than to the variations in ξ.

It can be brought out by comparing the variations of the most sensitive parameter, FW, visualized in Figure 7 and 13, that a 30% change in the collision broadening can occasionally produce an effect analogous to the one brought about by a 1 km/s change in ξ.

5. CONCLUSIONS

The unsuitability of the weak and moderate weak lines for the determination of ξ has quantitatively been confirmed. This, however, makes them simultaneously suitable for such investigations, as for instance the investigation of the element abundance, in which the unsufficiently accurate knowledge of ξ may prove a handicap.

The line profile parameters whose sensitivity was investigated have all been used in the literature for the determination of ξ (see e.g. Gray, 1978). Our analysis points to the unpracticability for this purpose of the EW and I_c parameters in the case of weak and moderate weak lines, even though this is occasionally done (e.g. Sheminova & Gurtovenko, 1979; Sheminova, 1984).

Inadequate knowledge of the collision broadening (not unfrequent even in the present–day calculations) can significantly affect the quantity ξ deduced from the weak and moderate weak lines.

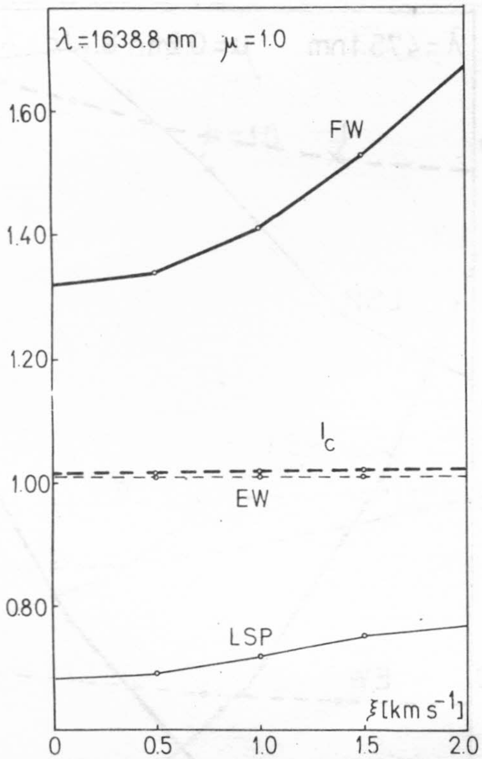

Fig. 9. The same as in Fig. 1

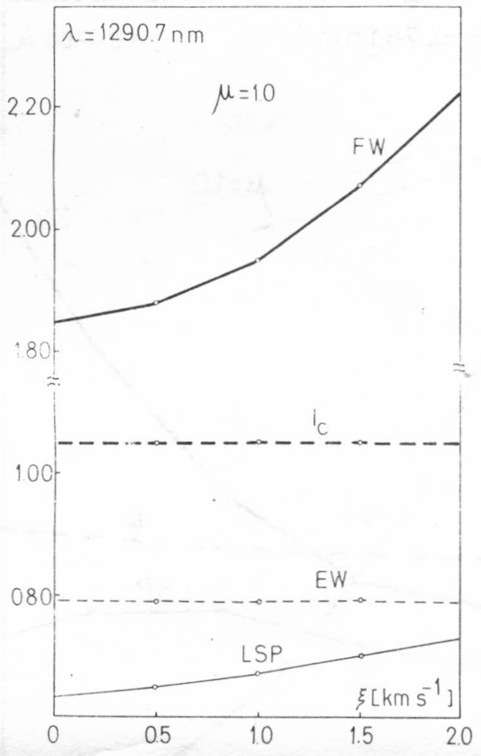

Fig. 11. The same as in Fig. 1

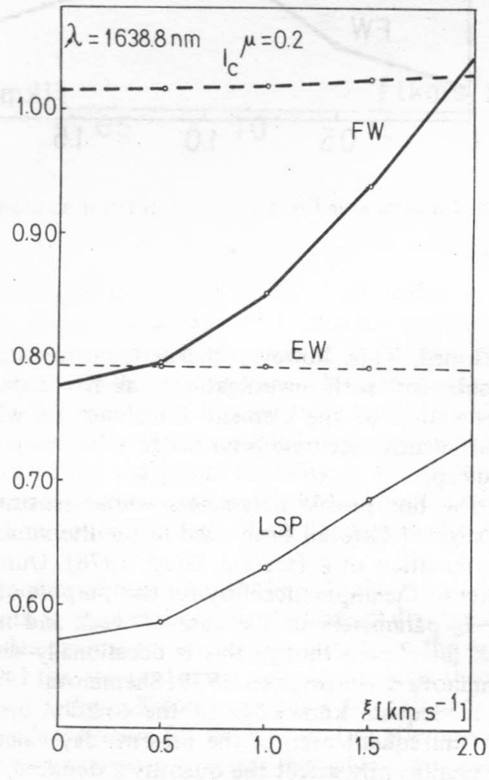

Fig. 10. The same as in Fig. 1

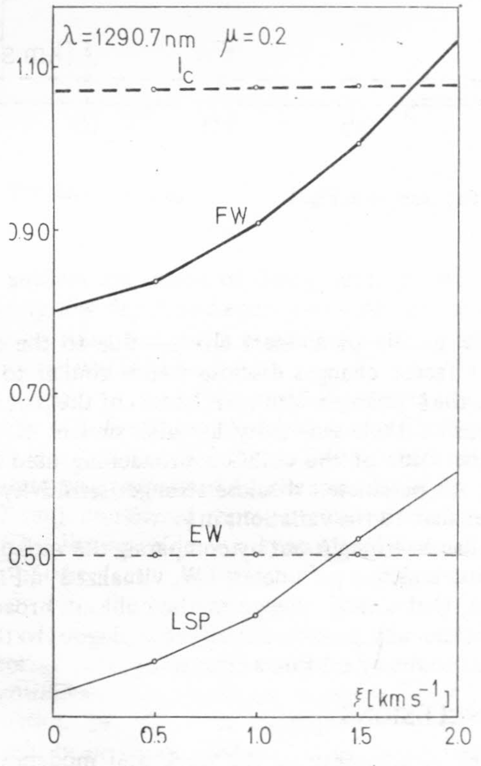

Fig. 12. The same as in Fig. 1

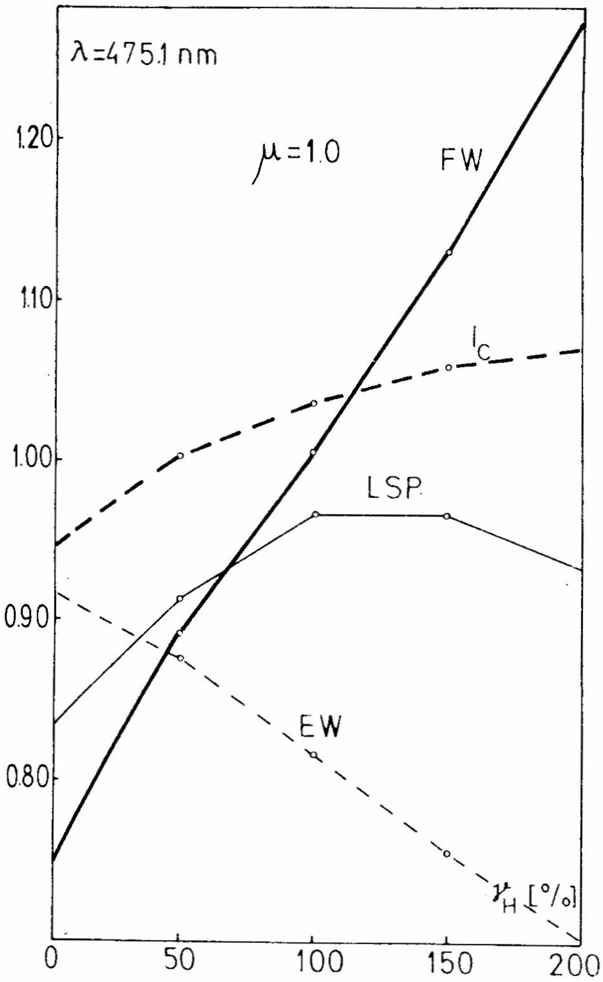

Fig. 13. Dependence of the line profile parameters on changes in broadening due to collisions with H–atoms (γ_H). All symbols have the same meaning as in previous figures.

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ON THE PROBLEM OF CLASSIFYING MODERN METHODS FOR THE RIGHT ASCENSION DETERMINATION

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SUMMARY. At comparing different methods of reduction of the star coordinates and of compilation of a fundamental catalogue it is important to know 1) In what was do the derived values of coordinates depend on the initial (source) catalogue and 2) How accurate is the method in terms of the observational errors (systematic and accidental).

Several methods, intended for the improvement of the right ascension (R.A.) system of the FK4 are discussed, among them those analysed by Strelkova and the author (1985). The derived R.A.s are shown to deviate from their absolute values not by only a constant, as implied by the absolute method, but by a quantity $C + C_1 f(\delta)$ where C and C_1 are dependent on the R.A. values in different δ–zones of the FK4 (or of the initial catalogue).

Two methods are in use nowadays for the absolute azimuth determination. The one–from both, upper and lower, culminations of the circumpolar stars. It this case the clock correction Δu is determined from the observations of equatorial stars in the closing stage of the reduction.

The second method is based on the determination of Δu from the zenith stars in the opening stage of the reduction and the subsequent derivation of the absolute azimuth from both, upper and lower, culminations of the zenith stars. The optimum conditions are shown to be different for the two methods. Their systematic errors are of different origin.

To overcome the existing difficulties: the deficiency of the methods and the divergence in terminology, a conformity should be achieved in planning and in solving of both problems: the choice of the methods of reduction and the procedure of compiling the star catalogues.

1. INTRODUCTION

„There is no king's way in the modern astrometry" states Eichhorn (1974). The classification of modern methods for the reduction of catalogue observation would help achieving better planning and cooperation in the positional astrometry, as voiced by G. Teleki at the IAU Symposium No. 109 „Astrometric Techniques" (1986).

Some aspects of the problem concerning the right ascension (R.A.) determination will be considered in this paper.

2. CLASSIFYING THE METHODS OF R.A. DETERMI-NATION

We distinguish two methods for the determination of the star coordinates. The purpose of the differential method is to reproduce the system of the reference catalogue by extending it over uncatalogued stars. The purpose of the absolute (or fundamental) method is the establishment of a system of positions independent of the source catalogue.

As far as the R.A.s are concerned it is only absolute differences $\alpha_i - \alpha_k$ that can be obtained from the observation of stars. However, as coordinates, not their differences, is what is required, an equation of condition must be subjoined in order to solve the set of equations and determine, in the initial stage, the sums α_i + C, where C is constant throughout the celestial sphere.

Absolute values of α_i are unknown until the link to the Sun or the planets is established. The preliminary zero point in α coincides with that of the initial fundamental catalogue if the correction to the R.A. of the fictitious mean equatorial star is assumed to equal zero in this catalogue.

Such was the case in the classical approach. For instance in the Pulkovo method the R.A.s were derived by the equations

$$\Delta a_j \sin z_i \sec \delta_i + \Delta b_j \cos z_i \sec \delta_i + \Delta u_j + \Delta\alpha_i = l_{ij} \quad (1)$$

where the unknowns Δu_j and $\Delta\alpha_i$ cannot be separated or determined simultaneously.

In the Washington method the equations

$$\Delta n_j \mathrm{tg}\, \delta_i + \Delta(u + m)_j + \Delta\alpha_i = l_{ij} \quad (2)$$

are used, whereby the unknowns $\Delta\alpha_i$ and $\Delta(u + m)_j$ are unseparable. In (1) and (2) the subscripts **i** and **j** indicate the star and the series, respectively.

To solve the equations the restriction is adopted for the corrections $\Delta\alpha_i$ to the R.A.s of certain equatorial stars

$$\sum_{i=1}^{N} \Delta\alpha_i = 0 \quad (3)$$

Therefore Δu or $\Delta(u + m)$ are dependent on the initial (fundamental) catalogue. All the other reduction parameters i.e. Δa and Δb in (1) or Δn in (2) have to be determined independently of the initial catalogue i.e. they have to be absolute.

Thus, the absolute method enables to derive the R.A.s deviating from the absolute ones by only a constant. Such is the implication of the method.

2.1. The methods used by Høg (1974), Zverev (Anguita et al., 1971) and Bykov (1977) were analysed by Strelkova and the author (1985). We showed that even though the three authors just mentioned used different equations for the reduction, their methods are similar in one respect: the derived R.A.s differ from the absolute values by

$$C + C_1 f(\delta)$$

i.e. not by only a constant but also by a variable – function of star declinations. The unknown constants C and C_1 depend on the errors in R.A.s in different δ zones of the fundamental (FK4) catalogue.

2.2. The author and Popov (1986) analysed N.N. Pavlov's method for the R.A. determination from observations with the small transit instrument (T.I.) as used in the time services.

If the T.I. is reversed during the observation of a star the error Δb (lateral flexure) is removed in (1). Hence (1) becomes for the zenit stars

$$\Delta u_j + \Delta\alpha_i = l_{ij} \quad (4)$$

with the weight $P = \cos^2 \delta_i$.

Using the chain method for the reduction of observations of several years duration Pavlov obtained for the zenith stars the sums $\alpha_i + C$, where C is dependent on the error $\Delta\alpha_{\delta=\varphi}$ in the initial (fundamental) catalogue, imposing the restriction (3) for the **zenith** stars in order to solve the equations (4).

Further, from the observation of the lower culminations of the same zenith stars one obtains

$$\Delta a_k \sin z_z \cos \delta_z + \Delta u_k + \Delta\alpha_z = l_{zk} \quad (5)$$

which weight is $P = \cos^2 \delta_z$.

Assuming the sums $\alpha_z + C$ to be known one may write (4) and (5) for z and i zenith stars

$$\left.\begin{aligned} \text{u.c.}\quad & \Delta u_j = l_{ij} - \Delta\alpha_i - C \\ \text{l.c.}\quad & \Delta a_j \sin z_z \cos \delta_z + \Delta u_j = \\ & = l_{zj} - \Delta\alpha - C \end{aligned}\right\} \; p = \cos^2 \delta \quad (6)$$

The determinant

$$\begin{vmatrix} C\,[\sin z \cos \delta] & [\sin z \cos \delta] \\ Cn & n \end{vmatrix} = 0$$

whence it follows that the value of Δa_j derived from (6) is independent of C, i.e. it is absolute one, only C on the right-hand side of the equations (6) being dependent on the catalogue positions.

C enters fully into Δu_j as

$$\frac{\begin{vmatrix} [\sin^2 z \cos^2 \delta] & C\,[\sin z \cos \delta] \\ [\sin z \cos \delta] & Cn \end{vmatrix}}{\begin{vmatrix} [\sin^2 z \cos^2 \delta] & [\sin z \cos \delta] \\ [\sin z \cos \delta] & n \end{vmatrix}} = C$$

Thus the Pavlov's method is available if two parameters Δa and Δu enter the equation. It is absolute one. The derived R.A.s deflect from the α–absolute by a constant, the latter being dependent – not on the error $\Delta\alpha_{\delta=0}$ in the fundamental catalogue as is the case in the classical method but – on $\Delta\alpha_{\delta} = \varphi$.

2.3. The stumbling–block to many authors has been presented by the problem of absolute azimuth determination (Tolchenikova–Murri, 1980). For instance in Nemiro (1973) the method is discussed in which the instrumental parameters a and b depart from the absolute ones by constants, say C_1 and C_2, respectively. In such a case we shall have for $\Delta\alpha$ derived from (1)

$$\Delta\alpha = l - C_1 \sin z \cos \delta - C_2 \cos z \cos \delta - C$$

If Bessel's equations (2) are used and the derived values of n deviate from the absolute ones by a constant C_1, then

$$\Delta\alpha = l - C_1 \operatorname{tg} \delta - C$$

In either case the obtained R.A.s depart from the absolute ones by a quantity

$$C + f(\delta)$$

Accordingly, the methods do not satisfy the definition of an absolute one.

2.4. At comparing different methods of right ascension determination it is important to know 1) in what way do the derived values of the coordinates depend on the initial catalogue and 2) how accurate is the method in terms of the observational errors (systematic and accidental).

In the foregoing it was the first point that was considered. Turning now on the second point let us compare the classical and the Pavlov's methods.

Suppose the weight of the equations (1) and (2) is

$$p = \cos^2 \delta$$

Here the decreasing of p with the zenith distance is neglected in order to come by analytical formulae for the dependence of the weights of the unknown quantities on the local latitude.

From the four equations (1), i.e. from the observations of both transits of a star with $\delta \approx 90^\circ$ in two clamp (CE and CW) positions of the instrument one obtains the corrections Δa and Δb with the weights

$$\begin{aligned} p(\Delta a) &= 4 \cos^2 \varphi \\ p(\Delta b) &= 4 \sin^2 \varphi \end{aligned} \qquad (7)$$

Adopting the values of Δa and Δb with their weights (7) one obtains the correction Δu from the observation of N equatorial stars with $\delta = 0$ (2N equations for CE and CW). The inverse weight of Δu is

$$\frac{1}{p(\Delta u)} = \frac{1}{2N} + \frac{1}{4} \operatorname{tg}^2 \varphi \qquad (7')$$

Using (7) and (7') one finds for the weights of the unknown corections $\Delta\alpha_i$ (see Kreinin, Tolchelnikova–Murri, 1982):

$$\frac{1}{p(\Delta\alpha_i \cos \delta_i)} = \frac{1}{2} + \frac{1}{4} \sin^2 \delta_i + \frac{1}{2N} \cos^2 \delta_i \qquad (7'')$$

From (7'') it is clear that the weight of $\Delta\alpha_i$ is independent of the observatory's latitude.

On proceeding from the equations (2) we shall find the same formulae (7'') for $p(\Delta\alpha_i \cos \delta_i)$.

The systematic errors associated with the observations of the polar star at low altitudes from low φ, or those associated with the observations of the equatorial stars from high φ, narrow the range of latitudes suitable for the method.

At deriving (7) – (7'') we had to assume the azimuth of the meridian marks of T.I. constant for at least 12 hours (longer in practice).

In Pavlov's method the steadiness of the instrumental azimuth for several hours is required, in principle the period might be reduced to the fractions of an hour. Ignoring the systematic errors in R.A. of the zenith stars, arising from the chain method of reduction, which is a concession from the strictness, we can derive

$$p(\Delta a) = 2k \sin^2 \varphi \cos^2 \varphi \qquad (8)$$

$$\frac{1}{p(\Delta u)} = \frac{1}{k \cos^2 \varphi} \qquad (8')$$

$$\frac{1}{p(\Delta\alpha_i \cos^2 \delta_i)} = 1 + \frac{\sin^2 \delta_i}{2k \sin^2 \varphi} + \frac{\cos^2 \delta_i}{2k \cos^2 \varphi} \qquad (8'')$$

In (8) through (8'') k denotes the number of the zenith stars observed at both culminations.

For precise observations of the zenith stars at the lower culmination it is necessary that the latitude $\varphi \geqslant 55^\circ$. From (8'') one obtains $p(\Delta\alpha)$ is maximum when $\varphi = 45^\circ$, diminishing with φ growing.

Therefore, the Pavlov's method is efficient for instance at Pulkovo ($\varphi \approx 60^\circ$) but is hardly suitable for $\varphi > 75^\circ$.

At high latitudes the effect of the last terms in (8'') on $p(\Delta\alpha)$ could be reduced by augmenting k. However, the nearer an observatory is to the pole, the less is the number of its zenith stars.

In this connection a remark, bearing on the R.A. observations made at high latitudes, might be added.

According to Petrov (1981) the variations of the instrumental parameter n were carefully controlled at Spitsbergen. Note that

$$n = b \sin \varphi - a \cos \varphi$$

becomes

$$n = 0.78\, b - 0.21\, a \qquad (9)$$

for $\varphi = 78^{\circ}$.

As stated on page 15 (Petrov, 1981) the horizontal axis of the T.I. was reversed at each star's observation. Accordingly, the effect of b on the derived values of n should have been removed. Thus, as it results from (9), the azimuth variations might be 5 times as large as those in n, revealed by the Spitsbergen observers.

Consequently, the formal approach is unsufficient and the physical meaning of the parameters is to be clearly understood at studying the accuracy of observations (Teleki, 1986).

2.5. Methodical defficiency makes itself felt by the disparity in terminology.

For instance, in Polozhentsev (1977) the errors $\Delta\alpha_\delta$ of the FK4 system were derived by the calculation of the weighted means from the right ascensions in 8 catalogues. Two among them were termed absolute and six – quasiabsolute ones. However, the methods of reduction of the six catalogues were different.

Namely, in the A S – 1 (astrolabe) the R.A. s deviate from the absolute values by a constant in the same way as they do in the PBPI–1 or 2 if the Washington method is used for the reduction.

As shown by Strelkova (1985) the R.A.s in PB catalogue (Høg, 1974) could be reduced to the absolute system if corrections

$$C + C_1 f(\delta) = C + C_1 \sin(\delta - \varphi) \sec \delta \qquad (10)$$

$$\varphi = 33^{\circ}$$

had been found, C and C_1 being dependent on the R.A. in the FK4 zone -90° to $+40^{\circ}$. The A.R.s in the SPF–1 or 2 catalogues (Anguita et al., 1971) are shown to deviate from the absolute ones by

$$C + C_1 \operatorname{tg} \delta \qquad (11)$$

C and C_1 being dependent on the R.A. in the FK 4 zone -40° to $+40^{\circ}$.

Methods used for the reduction of the SPZ and MP catalogues were also of different kind.

In fact only 6 independent catalogues were used by Polozhentsev (1977), PBPI–1 and 2, as well as SPF – 1 and 2, being two versions of the results of nearly the same observations.

Individual catalogues should be reduced to an absolute system **before** being used for the compilation of a fundamental (general) catalogue, i.e. prior to the calculation of the mean values from individual coordinates. Such was the traditional (classical) requirement. To comply with it the ones and the same stars were used (Maskelyne or other common stars in the equatorial zone) for the determination of the zero point of the absolute catalogues. Hence the differences $\alpha_{ik} - \alpha_{is}$ for the same stars observed at k and s observatories were due to the errors of observation only.

If the methods used at the observatories are absolute, but the reference zones for Δu or $\Delta(u + m)$ determination are different, the quantities $\alpha_{ik} - \alpha_{is}$ will consist of two components: the observational errors and the differences $\Delta\alpha_\delta$ in R.A. in the initial catalogue. The latter are systematic, their mathematical expectation M being constant. The situation gets worse if the R.A. s of the catalogue deviate from the absolute ones by quantities expressible by (10) and (11).

In this case $M = f(\delta)$ even in the total absence of the systematic observational errors, which is never the case. In practice, the systematic errors of both kinds, those having their origin in the initial catalogue and those involved by observations, are mixed. Using the accidental field theory there is no possibility of separating these errors neither is it possible to remove them from the obtained mean values of coordinates.

3. CONCLUSION

It is clear from the above stated that the two problems: the choice of the method of reduction of star coordinates and that of the method of compilation of a fundamental catalogue are closely interconnected.

The rigorous classical solution, yielding an accuracy level formerly considered sufficient, is almost discarded in the current practice. The modern approach calling for efficiency, implies conformity in planning and solution of both problems.

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THE DETERMINATION OF THE BELGRADE LONGITUDE FOR THE PERIOD 1964–1984

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1. THE DATA CHARACTERISTICS; GROUP CORRECTIONS

In this paper we are dealing with an analysis of residuals RT of the Belgrade system of UT1–UTC with respect to the system of UTI–UTC of BIH (Bureau International de l'Heure).

The initial Belgrade longitude in the international terrestrial system of reference „BIH 1968" (Rapport Annuel du BIH pour 1969), used for the computation of RT, is:

$$\lambda_o = 1^h 22^m 3\overset{s}{.}233 \text{ (East)}$$

For the years 1964 and 1965 the BIH has published the monthly means of RT, while for 1966 and 1967 the means for each 1/20 yr. Since 1978.0 onwards we dispose of RT for each group of observation.

In the Time Service of the Belgrade Observatory UTO has been computed from the observation of groups of 10 stars ($-10^o \leqslant \delta \leqslant 70^o$; mean $\delta = 39^o 3$),dedicated to time measurement and 1 „supplement" star, observed in lower transit for the absolute azimut computation. The instrument was a Transit instrument BAMBERG, D = 10 cm, F = 100 cm. Every night 2 to 5 successive groups were observed by the same observer. The synchronisation of quartz clock with UTC signals has been performed with a precision of 0.1 to 0.3 ms. Having in mind that the standard deviation of UTO is larger for approximately, two orders of magnitude, in the following discussions the errors of UTO–UTC will be attributed to UTO.

The standard deviation of RT, estimated from internal incoherence of results (with respect to the mean UTO of the group) is

$$\sigma = \pm 12 \text{ ms}$$

The average number of „clock" stars effectively observed by one group is 9.0.

As the observations were made by the chain method, we have had the possibility to determine the group corrections and, after their removal, the Allan pair variance (on the differences of corrected results of successive groups, observed during the same night by the same observer). We find

$$\sigma' = \pm 13 \text{ ms}$$

As $\sigma' \approx \sigma$ we can consider that during observation of two successive groups (~ 2 hours) contribution of the change of meteorological conditi is negligible. However, their seasonal variation is v important. Because of them and because of ot periodical errors ($\Delta\alpha_\alpha$ of the catalogue), the stand deviation of RT with respect to the annual mean (R amounts to

$$\sigma'' = \pm 25 \text{ ms}$$

In Table 1 the RTa values, their standard deviati σ_a and the number of observed groups (Ng) presented.

Table 1

Year	RTa		Ng	Year	RTa		N
1968	8.2 ±	1.2 ms	246	1977	5.5 ±	1.6 ms	2
1969	10.2	1.0	369	1978	– 8.5	2.3	1
1970	15.2	1.1	283	1979	–11.3	2.1	1
1971	4.6	1.2	280	1980	–15.2	2.2	1
1972	8.5	2.1	208	1981	– 7.9	2.0	1
1973	32.6	1.7	217	1982	– 6.5	1.7	1
1974	40.2	1.8	204	1983	– 6.6	2.2	1
1975	30.3	1.6	221	1984	9.4	2.3	1
1976	15.8	2.1	184	mean	7.3	1.7	2

The mean density of the observation nights is times less than Ng.

From RTa we note that the local system UT1–UTC has a large quasi–periodical variation wi characteristic period P= 15 yrs. It will be discussed l

Besides errors depending on time of observat there exist errors depending on the compositior groups: errors of catalogue, instrumental errors dep ing on the zenithal distance, etc. They generate an e known as the group correction, or, with the opp sign, group error.

The group corrections Δ_i computed by the c smoothing of observations for the period 1969–1 are presented in the Table 2. Before 1969, an anc programme was observed and the number of o vations was insufficient for the computation of Δ_i.

Table 2.

Group No	Δ_i	Group No	Δ_i
1	– 1.2 ± 4.3 ms	15	–2.4 ± 4.3 ms
2	– 8.3	16	–1.4
3	0.2	17	5.2
4	3.2	18	5.1
5	– 3.0	18	4.6
6	– 4.2	20	12.2
7	– 3.7	21	10.6
8	– 4.5	22	14.2
9	– 3.2	23	14.1
10	– 9.4	24	0.5
11	–18.3	25	0.7
12	– 8.6	26	5.2
13	– 7.9	27	5.0
14	– 4.9		

The mean standard deviation of Δ_i is $\sigma_\Delta = \pm 4.3$ ms. It was computed by the formula (Nemiro 1963):

$$\sigma_\Delta^2 = \frac{(N-1)^2-1}{12(N-1)} \quad \sigma_d^2 \qquad (1)$$

where N represents the number of groups in the chain (N=27), σ_d – the mean standard deviation of difference of UTO of successive groups ($\sigma_d = \pm 2.9$ ms).

It seems from Table 2 that the corrections Δ_i are realistic.

The corrections Δ_i are applied for the following computations.

2. THE DRIFT AND THE PERIODICAL VARIATIONS OF RT

After a preliminary analysis of RTa we have assumed that the polynomial term does not exist. On the contrary, there were some indications for the existence of a periodical variation with a period between 10 and 20 years (see Fig. 1). To make it more evident, the 1/10 or means have been smoothed by the Wittaker–Robinson–Vondrak (WRV) method with a parameter $\epsilon = 10^{-14}$. By this smoothing the seasonal variation, whose amplitude is the largest one (see the Table 3 and Fig. 2), was efficiently eliminated. The smoothed residuals (RC) are presented in Fig. 1a.

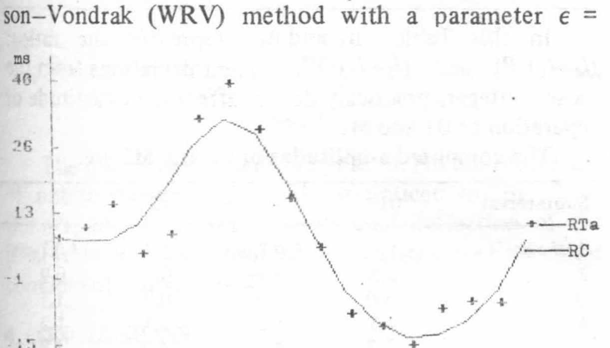

Fig. 1

Table 3.

P	A		α	
123 days	2.4 ±	0.6 ms	,75° ±	21°
183	4.8	.6	330	11
248	2.4	.6	207	21
265	8.3	.6	124	6
504	2.4	.6	158	21
780	2.6	.6	81	21

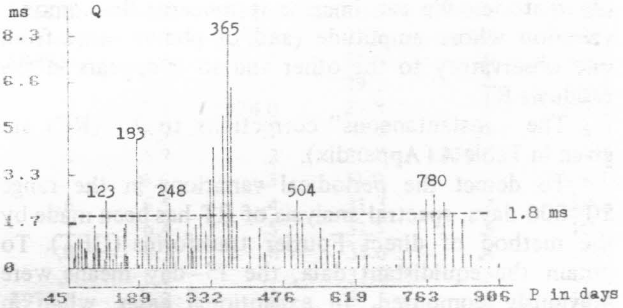

Fig. 2

By the least squares (LS) method the set of equations:

$$RTa = a + b \sin \omega t + c \cos \omega t = a + A \sin(\omega t + \alpha) \qquad (2)$$

has been solved.

By a 0.5 yr step and for values of the period ranging from 10 to 20 yrs we searched for the minimum of the standard deviation of residuals (σ_r). In this way we have found the following results:

P = 15.0 yrs
a = Δλ = 8.1 ± 2.2 ms
A = 19.6 ± 2.0 ms (1968–1984)
α = 201° ± 9°, for 1976.0
σ_r = 9.0 ms

and :

P = 15.0 yrs
a = 2.8 ± 2.3 ms
A = 24.9 ± 2.1 ms (1964–1984)
α = 258° ± 7°, for 1976.0
σ_r = 10.2 ms

The observation period is given in the brackets. Since the former sample of results is based on homogeneous data series, it will be adopted as „definite".

The longitude:

$$\lambda_m = \lambda_o + \Delta'\lambda = 1^h\ 22^m\ 3^s225 \pm 0^s002 \text{ (East)}$$

will be termed the mean longitude.

Here we note that the classical Orlov method (see, for example, Kulikov 1962) gives results practicaly equal to RC. Therefore, the above term „mean longitude" is not equivalent to the known Orlov's definition of the mean latitude. We have followed the logic that the expression „mean' should represent the information that the result has no periodical variation, at least, the variation already identified.

Having in mind the order of the amplitude A, it would be interesting to see whether the variation with a period P=10–20 yrs exists in RT series of other observatories. We can imagine it concerns the comon variation whose amplitude (and/or phase) varies from one observatory to the other and so it appears in the residuals RT.

The „instantaneous" corrections to λ_o (RC) are given in Table A (Appendix).

To detect the periodical variations in the range 50–800 days, spectral analysis of RT has been made by the method of direct Fourier transforms (DFT). To obtain the equidistant data, the 15–day means were previously computed. In exceptional cases, when in 15–day subinterval the observations were missed, the RT was computed by the linear interpolation.

In Fig. 2, where the variable $Q = (s^2 + c^2)^{1/2}$ (s–the amplitude of sinus, c–the amplitude of cosinus transform) is presented in function of the period P, we can remark several peaks which could be due to the real periodical variations of RT. At first, two highest peaks (over 365 and 183 days) are due to the known seasonal variation of the local meteorological parameters. Beside them, there exist over the limit σ_o = 1.8 ms, equal to three times standard deviation of Q, the peaks over 123, 248, 504 and 780 days. As we do not know geophysical phenomena having the same period, it is easy to assume that they are pseudo–pekas, „generated" by the computation technique, or that they are due to an interference of accidental errors.

The 123–day variation has been earlier detected in universal time scales UT1 and UT2 (Djurović 1974, 1983), in geomagnetic index AP and zonal atmospheric circulation (Djurović 1983, Belmont et al. 1974), in Doppler observations of the apparent height of a TRANET station (Déhant and Pâquet 1983). Its appearance in RT could indicate that there exists a difference between the amplitudes (and/or phases) of the local and global effect on UT.

The 248–day peak was noted in spectra RT and RF (RF–the residuals of latitude observations) on several tenths of instruments (Djurović 1978), but it is not explained.

Therefore, the continuation of researches of the origin of above mentioned peaks could reveal unknown phenomena whose contribution in real RT variations is important.

The numerical values of the period P, the amplitude Q and phase ϕ of 6 pronounced peaks from Fig. 2 are given in Table 3.

3. THE LOCAL GRAVITATIONAL ANOMALY

The lunar tides 01 and M2 could be present in RT if there existed the anomalous deflection of the vertical of the observation station. For the investigation of this phenomenon the following methods were applied:

a) The residuals RT are smoothed by the WRV method with $\epsilon = 10^{-7}$. Consequently, the sinusoidal terms whose P $\leqslant$ 40 days are removed (see Feissel and Lewandowski 1984). Therefore, in the second order residuals dRT=RT–RT' they are saved, practicaly free of periodical terms discussed in the previous paragraph. After that, for six subintervals, defined below, we have solved by LS method six systems of equations:

$$dRT = Ao + \sum_{i=1}^{2} (Ai \sin \omega_i t + Bi \cos \omega_i t),$$

where:

$$\omega_1 = 2\pi/P1$$
$$\omega_2 = 2\pi/P2$$
$$P1 = 14.192 \text{ days}$$
$$P2 = 14.765 \text{ days}$$

The length of subintervals was chosen according to the principle of commensurability. The Julian dates of their limits are:

No	l_1	l_2	n_1	n_2
	2439000+			
1	860	1923	74.9	72.0
2	1923	2985	74,8	71,9
3	2985	4049	75,0	72.1
4	4049	5109	74.7	71.8
5	5109	6172	74.9	72.0
6	5933	7054	79.0	75.9

In this Table n_1 and n_2 represent the ratios: $(l_2 - l_1)/P1$ and $(l_2 - l_1)/P2$. Their deviations from the closest integers practicaly do not affect the exactitude of separation of 01 and M2.

The computed amplitudes of 01 and M2 are:

Subinterval	01		M2	
1	1.4	± 0.7 ms	1.7	± 0.7 ms
2	2.5	0.9	0.9	0.9
3	3.0	1.1	0.9	1.1
4	4.1	1.2	3.7	1.2
5	2.2	1.2	4.0	1.2
6	0.6	1.1	1.7	1.1
mean	2.3		2.2	

The mean phases for 1976.0 are: 246° ± 31° (01) and −16° ± 53° (M2).

Evidently, the above results are not sufficient for any serious conclusion on existence of the local anomaly of gravity. As the amplitudes from the above Table are somewhat over the standard deviations we have still made a further attempt to detect the residual deflection of the vertical.

b) Let:

$f1 = \tau_1 - \mathrm{INT}(\tau_1)$

$f2 = \tau_2 - \mathrm{INT}(\tau_2)$

$\tau_1 = (t - to)/P1$

$\tau_2 = (t - to)/P2.$

The operator INT means the integer part of the argument, t–the Julian date of observation, to = 2439860.0.

The residuals dRT have been organised in increasing order of fi (i = 1,2) and their means (dRTm) for each 0.02 of fi have been computed (the number of dRT in one subinterval of fi is ~ 40).

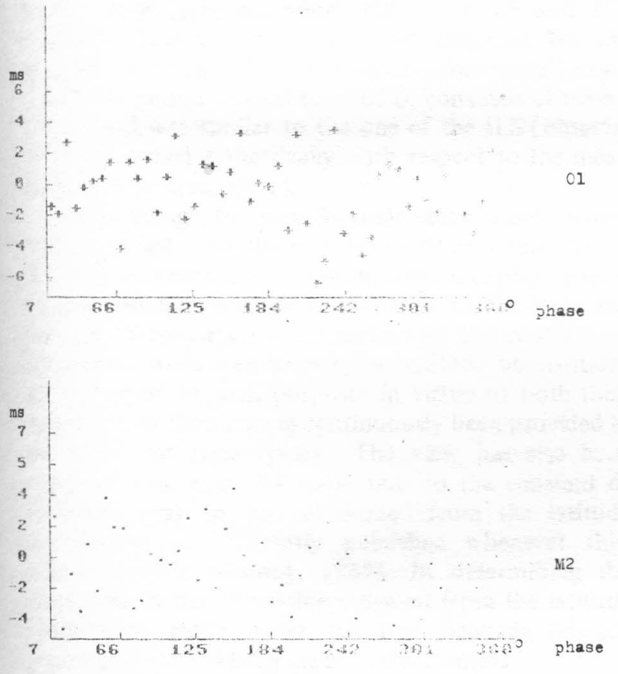

Fig. 3

The dRTm are presented in Fig. 3. No concentration of points tracing a sinusoide is noticed in Fig. 3. It follows, therefore, that the residual deflection of the local vertical is not identified. If it existed, its East–West component is under 3–4 ms.

4. CONCLUSIONS

1. The mean Belgrade longitude in the „BIH 1968" system computed from the observations of about 34000 transits of FK 4 stars, is:

$$\lambda_m = 1^h\,22^m\,3^s225 \pm 0^s002 \text{ East.}$$

2. It seems that the drift of the residuals RT does not exist. On the contrary, a large quasi–periodical variation of 15–yrs, with an amplitude A ≈ 20 ms, is dominant.
3. The amplitudes of seasonal terms are typical for the class of instrument used in Belgrade.

Appendix
Table A

Epoch	RC	Epoch	RC	Epoch	RC
1968.8	7.4 ms	1973.6	27.1 ms	1978.4	-4.1 ms
.9	7.9	.7	27.9	.5	−4.9
1969.0	7.6	.8	28.6	.6	−5.8
.1	7.3	.9	29.3	.7	−6.4
.2	7.1	1974.0	29.8	.8	−7.3
.3	6.9	.1	30.4	.9	−8.0
.4	6.7	.2	30.7	1979.0	−9.0
.5	6.6	.3	31.0	.1	−9.7
.6	6.5	.4	31.3	.2	−10.2
.7	6.4	.5	31.5	.3	−10.7
.8	6.3	.6	31.6	.4	−11.1
.9	6.2	.7	31.6	.5	−11.7
1970.0	6.2	.8	31.5	.6	−12.2
.1	6.2	.9	31.3	.7	−12.7
.2	6.2	1975.0	31.0	.8	−13.0
.3	6.2	.1	30.8	.9	−13.3
.4	6.3	.2	30.4	1980.0	−13.7
.5	6.4	.3	29.8	.1	−13.9
.6	6.6	.4	29.2	.2	−14.1
.7	6.8	.5	28.6	.3	−14.3
.8	7.0	.6	27.9	.4	−14.5
.9	7.2	.7	26.8	.5	−14.6
1971.0	7.5	.8	26.3	.6	−14.7
.1	7.9	.9	25.4	.7	−14.7
.2	8.2	1976.0	24.2	.8	−14.7
.3	8.7	.1	23.5	.9	−14.7
.4	9.1	.2	22.1	1981.0	−14.7
.5	9.6	.3	20.9	.1	−14.6
.6	10.1	.4	19.4	.2	−14.6
.7	10.7	.5	18.5	.3	−14.5
.8	11.5	.6	17.4	.4	−14.4
.9	12.1	.7	16.1	.5	−14.2
1972.0	13.0	.8	14.9	.6	−14.1
.1	13.7	.9	13.6	.7	−13.8
.2	14.6	1977.0	12.4	.8	−13.7
.3	15.2	.1	11.1	.9	−13.4
.4	16.3	.2	9.5	1982.0	−13.3
.5	17.1	.3	8.9	.1	−13.0
.6	18.2	.4	7.5	.2	−12.6
.7	19.0	.5	6.2	.3	−12.3
.8	19.7	.6	4.8	.4	−11.9
.9	20.8	.7	3.6	.5	−11.5
1973.0	21.9	.8	2.5	.6	−11.1
.1	21.5	.9	1.6	.7	−10.5
.2	23.2	1978.0	0.4	.8	−10.2
.3	24.7	.1	−0.6	.9	-9.6
.4	25.7	.2	−1.7	1983.0	-9.0
.5	26.4	.3	−2.9	.1	-8.4

4. The residual (anomalous) deflection of the vertical, if it exists, is under 3–4 ms.

Table A

Epoch	RC
1983.2	−7.6 ms
.3	−7.3
.4	−6.4
.5	−5.7
.6	−5.0
.7	−3.7
.8	−2.8
.9	−1.8
1984.0	−0.3
.1	0.7
.2	1.7
.3	2.8

5. In the spectrum of RT some of the peaks, particularly that of 123 days, could be assumed as realistic.

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CONSTANT OF ABERRATION FROM THE LATITUDE OBSERVATIONS WITH THE BELGRADE ZENITH–TELESCOPE

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SUMMARY: Values of the constant of aberration are determined from the latitude observed under the new Belgrade latitude programme and compared with those derived from observations under the old programme as well as with the results obtained at other observatories.

The observations with the Belgrade zenith–telescope under the new programme, incorporating six groups (twelve subgroups) started in 1960. The prime purpose of this programme was to allow sufficiently long observing runs (at least a full nutation cycle) which implied the inclusion into it two groups (II and V) whose mean right ascensions fall within 6^h and 18^h (Ševarlić, Teleki, 1959). The old Belgrade latitude programme, under which the observations were carried out in the period 1949.0 to 1961.0, consisted of twelve groups and was similar to the one of the ILS (observations performed symetrically with respect to the mean midnight (Ševarlić, 1961).

Even though the new Belgrade latitude programme was composed with the purpose of determining correction to the constant of nutation, besides exploring local factors, attempt is made herewith to derive, from the latitudes obtained by it, correction to the constant of aberration. As is well known the latitude observations are employed to such purposes in virtue of both their accuracy and their having continuously been provided in the course of time (years). The view has also been complied with that the correction to the constant of aberration was to be determined from the latitude observations and promptly published whenever this proves possible (Guinot, 1965). In determining the correction to the aberration constant from the latitude observations made under the new Belgrade latitude programme use has been made of the formula:

$$\Delta k = -R/\Sigma(m_a - m_b)$$

here R – the closing error and

$$m = -[(\sin\epsilon \cos\delta - \cos\epsilon \sin\alpha \sin\delta) \cos L_\odot + \sin L_\odot \cos\alpha \sin\delta]$$

The subcripts a, b denote, respectively, the first and the second subgroup of particular group in the new programme, ϵ – obliquity of the ecliptic, α – mean right ascension, δ – mean declination of the given subgroup of the Talcott pairs and $L_\odot$ – the longitude of the Sun.

The observational material used for the derivation of the correction to the constant of aberration was one collected in the period 1960.0 to 1980.0. Account has thereby been taken of the modifications implemented in the Belgrade Latitude Service early in 1969 (Milovanović et al., 1981) as well as the change of the constant of aberration introduced in 1965 following the respective resolution of the IAU 12 th General Assembly.

So the above related observing period was divided in the way displayed in Table 1, containing the results of the constant of aberration determination from the Belgrade observations.

Table 1. Constant of aberration determined from the Belgrade latitude observations

Period	R	Δk	k	n	$\Sigma(m_a - m_b)$
1. 1960.0–1965.0	+ 0.″015	−0.″004	20.″466	4105	−3.851
2. 1965.0–1969.0	+ 0.039	−0.011	20.485	2970	−3.631
3. 1969.0–1980.0	−0.114	+ 0.031	20.527	10085	−3.691

Notations in Table 1 are as follows: R – closing error; Δk – correction to the constant of aberration; k – constant of aberration; n – number of observations of Talcott pairs and; $\Sigma(m_a - m_b)$ – coefficient of the correction to the constant of aberration.

It is apparent from Table 1 that during the two first periods a tendency made itself felt of the closing error getting biger as the constant of aberration grew larger (Kulikov, 1954).

The constant of aberration value obtained in the third observational period is close to the one obtained from the observations under the old Belgrade programme in the period 1949.0 to 1957.0. The value concerned is 20.″528, being derived from the material embracing observations of 7088 Talcott pairs (Ševarlić, 1959). The mean value of the constant of aberration resulting from the data in Table 1 is 20.″492, and is close to the one adopted by the IAU 12. General Assembly (20.″496).

In the year 1982 the new Belgrade programme was complemented by eight groups of Talcott pairs formed in such a way as to fill this programme's gaps. The new Belgrade programme thus enlarged fills out the whole of 24 hours in right ascension. One is therefore well entitled to assume the latitude differences of the neighbouring groups of Talcott pairs as unaffected by the daily latitude variations. The material collected on the basis of latitude programme thus enlarged in the period 1983.0 to 1985.0 served to derive yet another correction to the constant of aberration. The results of this determination is presented in Table 2.

Table 2. Results of constant of aberration determination from the Belgrade latitude observations under the enlarged programme

Period	R	Δk	k	n	$\Sigma(m_a-m_b)$
1. 1983.0–1985.0	–0.105	+0.032	20.528	1773	–3.249

Notations in Table 2 are identical to those in Table 1.

Note that the costant of aberration from Table 2 is identical to the one obtained from observations under the old Belgrade programme in the period 1949.0 to 1957.0 (Ševarlić, 1959), as well as very close to the value 3 in Table 1.

The values 1 and 2 in Table 1 were compared with the values obtained at Pulkowo and Engelgardt observatories. The value obtained at Pulkovo observatory in the period 1953 to 1964 was 20".4998 (Bahrah, 1971), and at Engelgardt observatory in the period 1957 to 1968 were obtained the values 20".495 and 20".497 (Jusupov, 1976). All these values are closer to the IAU adopted value (20".496) than corresponding values in Table 1.

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PLATE REDUCTION AS THE DETERMINATION OF A BIJECTION IN MODERN ALGEBRA. PURE MATRICAL SOLUTION. ERROR EFFECT AND THEOREM OF THE MINIMUM. THE TEST–STARS METHOD APPLIED TO DETERMINATE ACCURACY ON GPO–LA SILLA–ESO PLATES.

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**SUMMARY. - This work begins with a new definition of the plate reduction in language of Modern Algebra. We introduce the important ideas of the basis subset and test subset and of the reduction of a rectangular system to a quadratic one. One term of the quadratic matrice is the scalar product of two columns of the rectangular matrice.
The main object of the following point is the study of accuracy by means of test subset. The Theorem of the minimum of the error–effect is reminded. Finally, results obtained at the Grand Prisme Objectif (GPO) of La Silla are given.**

1. INTRODUCTION. SETS. MAPPINGS. BIJECTIONS.

The plate reduction in language of Modern Algebra consits in the determination of mappings or maps from S (set of celestial points) into (onto) P (set of their images on the photographic plate). A mapping is an assignment of a unique element of P to each element of S. For the most part we shall denote mappings by lower case Greek letters. If β is a mapping from S to P, we shall express this fact more briefly by writing $\beta : S \rightarrow P$; this is read „β is a mapping from S into P". We call S the „domain" and P the „codomain" of β (Baumslag et al., 1968).

Suppose that $\beta : S \rightarrow P$. If α assigns to s in S ($s \in S$) the element p in T, we write $\beta : s \rightarrow p$ and read as „β sends s into p". We call p the image of s (under β) and write $s\beta = p$, $s^{\alpha} = p$ or $\beta(s) = p$ for this image; we call s a preimage of p. We say β is a mapping from S onto P if every element in P has at least one preimage in S, i.e. if for every $p \in P$ there is at least one element $\in S$ for which $s\beta = p$; in this case we call β an „onto mapping" (Baumslag et al., 1968).

On the other hand we say β is „one–to–one" if $s\beta = s'\beta$ implies $s = s'$, i.e. distinct elements of S have distinct images in P (under β). Finally, we say β is a „matching of S and P" or that „β matches S with P" or **„β is a bijection" if β is both „onto and one–to–one"**. Two sets, S and P, are termed „equipotent or of the same cardinality" if there exists a matching of the one with the other (Baumslag et al., 1968).

Thus, a bijection is a mapping (transformation) of sky „onto" plate and its returnback (inverse transformation or mapping from plate to sky).

2. REDUCTION IN MODERN ALGEBRA LANGUAGE.

In old or classical language, the bijection is identical to the plate constants (that, we use reluctantly) which are the coefficients of the bijection or the coefficients a_{ij}, b_{ij}, of the equations between X, Y (standard coordinates or, in modern algebra language, the rectilinear celestial coordinates of a point in the sky, i.e. the celestial–set) and x, y (measurements or, in modern algebra language, the rectilinear plate coordinates of a point in the plate–set):

$$X = \sum_{i+j=k=o}^{n} a_{ij}\, x^i y^j \quad (1), \qquad Y = \sum_{i+j=k=o}^{n} b_{ij}\, x^i y^j \quad (2),$$

$i \downarrow$, $j \uparrow$ in $i + j = k = 1, \ldots n$, n being the degree of the bijection; for instance, k = 2 gives the the quadratic terms (only a part of the bijection) written in the order

$$a_{20}\, x^2 + a_{11}\, xy + a_{02}\, y^2 ,$$

where i = 2, 1, 0 and j = 0, 1, 2 with i + j = k = 2.

The number NU of a_{ij} is equal to (or less than) **(n + 1) (n + 2)/2**; NU = number of unknowns. In order to compute a_{ij} (b_{ij}), or the bijection, we take a subset (g) in the celestial–set S (i.e. N stars = X_L, Y_L, L = 1, . . ., N) and the corresponding one (g') on the plate (i.e. the N stellar images: x_L, y_L, L = 1, . . ., N). We write N equations like (1) (and like (2)).

From experience and various computational studies we have to take $N \geqslant 2$. NU (two times the number of a_{ij}). Thus we must solve a rectangular system of which the dimensions are N (vertically) and NU (horizontally). The rectangular matrice of (x^i y^j) is defined by the measurements. The independant terms (vertical vector (X_L)) is computed from the catalogue by means of spherical trigonometry. When multiplying the equations system (equations of condition in classical language) by the inverse matrice $(x^i y^i)^{-1}$, we obtain a quadratic system

$$(x^j y^i)^{-1} (x^i y^j) (a_{ij}) = (x^i y^j)^{-1} (X_L) \qquad (3)$$

A coefficient in the quadratic system is the scalar product of two columns of coefficients in the rectangular one. The order numbers of these two columns are the order numbers of the two rows of the term in the quadratic system (normal equations in classical language).

3. ACCURACY. TEST STARS SUBSETS.

After determination of a_{ij} (and b_{ij}), i.e. the bijection β, we shall control the accuracy of β by means of

1° the „return back" on the basis stars subset, $B \in S$, (in modern algebra language), or the computation of residuals on reference or comparison stars (referential) in classical language;
2° a chosen test stars subset, $T \in S$.

The „defect of return back' on the points of the basis subset (mean of the absolute values of residuals on the reference stars in classical language) is the **„internal accuracy"**.

The „defect of return back" on the points of the test subset (means of the absolute values of residuals on the test–stars, Debehogne, 1970, in classical language) is the **„external accuracy"**.

The „internal accuracy" could be without any meaning: for instance, if N (number $|B|$ of points in the basis subset B or number of reference stars) is taken equal to NU (number of unknowns, number of coefficients to constitute the bijection, number of „plate constants"), the „internal accuracy" will be perfect (residuals $\equiv 0$) but the „external accuracy" will be bad.

When external and internal accuracies will remain constant (or become equal) by increasing the basis subset B ($|B| = N \uparrow$):

1° the choice of N is good and N is the minimum of the basis (reference) stars for a good reduction.
2° the mean (or the common value) of both accuracies (internal and external) gives a general accuracy on the position of the points of both sets S (catalogue) and P (measurements). But, in the case of a focal length greater or equal to 2 or 3 m and a measurement instrument such as an Ascorecord (Uccle, last figure: 0.1 micron) or the Optronics (Garching–ESO, last figure: 1 micron) the basis subset on the plate, $B' \in P$, is more accurate than the basis subset on the sky, $B \in S$: this is due to not well known proper motions or positions in our catalogues.

4. ERROR–EFFECT. THEOREM OF THE MINIMUM.

If, when increasing $|B| = N$, the position of a new basis star is not accurate, the „internal accuracy" increases by a value equal to about

(|residual| = |error – error effect|)/N;

the error–effect could be small following the localisation of the reference erroneous star and the value of $N = |B|$ (Debehogne, 1972).

At the same moment, for same reasons, the „external accuracy" could remain constant. Thus

1° we gain nothing by increasing $N = |B|$;
2° the error–effect is very faint on the whole plate (if we are not sure, we can devide the plate in concentrical circles, Debehogne, 1974).

When performing a plate reduction **by means of a simulation method** we can deduce the error–effect (Debehogne, 1972) and the connection between this error–effect and the residual:

error = residual + error–effect.

The error-ffect can be studied at the alone erroneous point itself or on the whole plate.

In the first case, when changing the degree of the bijection we can see that(theorem of the minimum): **for odd degrees only**, the error–effect at the erroneous point (i.e. where the error is acting) is minimum at the center of the basis subset; there, we have a local maximum for even degrees (Debehogne, 1972).

5. RESULTS AT THE GRAND PRISME OBJECTIF (GPO) – LA SILLA.

Celestial coordinates of the center (plate n°: 6378, date: 1983 sept. 10.0; focal length: 4 m; diameter: 40 cm; plate size: 16 cm x 16 cm):

SAO nr : 227481, $\alpha_{1950} = 16^h53^m\!.5$, $\delta_{1950} = -42°50'$.

Chosen bijections: n = 1 (3 terms), n = 2 (6 terms), n = 3 (10 terms).

Basis subsets B used:

N = | B | = 3, 5, . . . , 22 stars, for n = 1,

N = | B | = 7, . . . , 22 stars, for n = 2,

N = | B | = 11, . . . , 22 stars, for n = 3.

In the graphs, N is on the horizontal axis and the arithmetical mean of the absolute values of residuals on the vertical axis:

a) for points (reference stars) of basis subset, B,
b) for points (test stars) of test subset, T,

in α, n = 1 (fig. 1), n = 2 (fig. 3), n = 3 (fig. 5),
in δ, n = 1 (fig. 2), n = 2 (fig. 4), n = 3 (fig. 6).

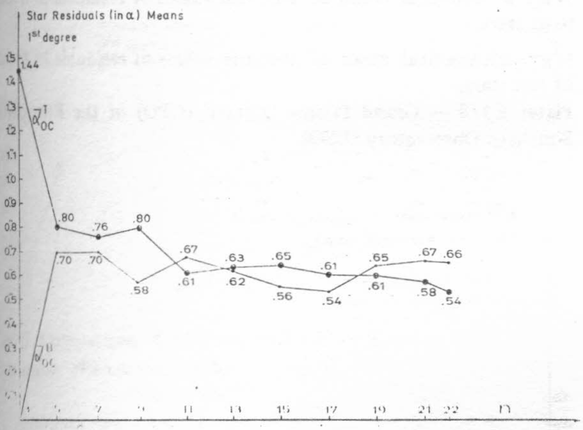


Fig. 1. Precision on Reductions in α by the 1st degree bijection. Bijection between sky and plate: $X = a_{00} + a_{10}x + a_{01}y$, $Y = b_{00} + b_{10}x + b_{01}y$. n: number of basis stars (reference stars).

α^{B}_{OC} : arithmetical mean of absolute values of residuals in α on basis stars.

α^{T}_{OC} : arithmetical mean of absolute values of residuals in α on 9 test stars.
Plate: 6378 – Grand Prisme Objectif (GPO) at the European Southern Observatory (ESO).

Superposition of fig. 1, 3, 5 for
basis subset, B, in α: fig. 7;
test subset, T, in α: fig. 9;

Superposition of fig. 2, 4, 6 for
basis subset, B, in δ : fig. 8;
test subset, T, in δ: fig. 10.

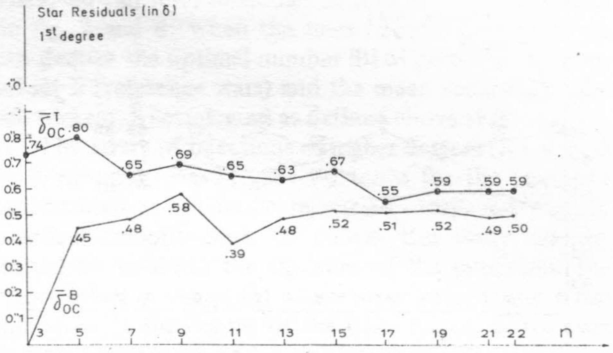


Fig. 2. Precision on Reductions in δ by the 1st degree bijection. Bjection between sky and plate: $X = a_{00} + a_{10}x + a_{01}y$, $Y = b_{00} + b_{10}x + b_{01}y$.
n: number of basis stars (reference stars).

δ^{B}_{OC}: arithmetical mean of absolute values of residuals in δ on basis stars.

δ^{T}_{OC}: arithmetical mean of absolute values of residuals in δ on 19 test stars.
Plate: 6378 – Grand Prisme Objectif (GPO) at the European Southern Observatory (ESO).

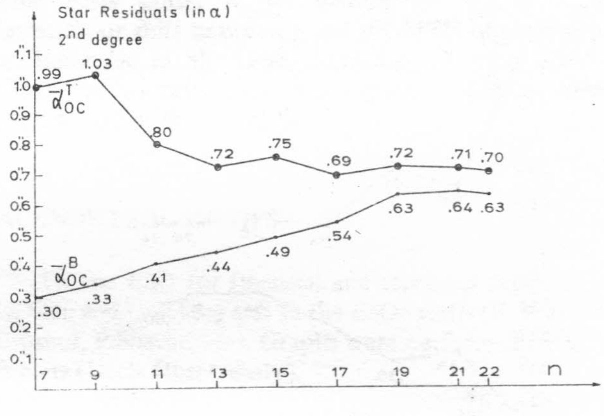
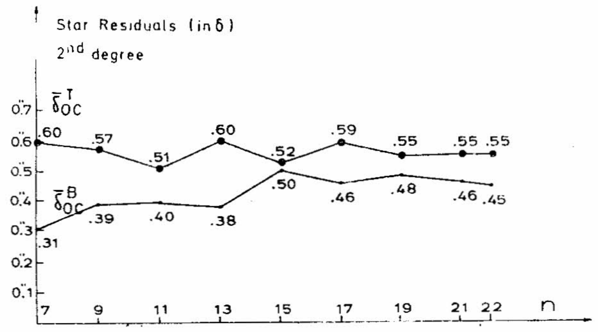


Fig. 3. Precision on Reductions in α by the 2nd degree bijection. Bijection between sky and plate: $X = a_{00} + a_{10}x + a_{01}y + a_{20}x^2 + a_{11}xy + a_{02}y^2$, $y = b_{00} + b_{10}x + b_{01}y + b_{20}x^2 + b_{11}xy + b_{02}y^2$.
n: number of basis stars (reference stars).

α^{B}_{OC}: arithmetical mean of absolute values of residuals in α on basis stars.

α^{T}_{OC}: arithmetical mean of absolute values of residuals in α on 19 test stars.
Plate 6378 – Grand Prisme Objectif (GPO) of the European Southern Observatory (ESO).

Measurements and computations performed on the OPTRONICS machine (Garching–European Southern Observatory – Programs: R. West).



fg. 4. Precision on Reductions in δ by the 2nd degree bijection. Bijection between sky and plate: $X = a_{00} + a_{10}x + a_{01}y + a_{20}x^2 + a_{11}xy + a_{02}y^2$, $y = b_{00} + b_{10}x + b_{01}y + b_{20}x^2 + b_{11}xy + b_{02}y^2$.

n: number of basis stars (reference stars).

δ^B_{OC}: arithmetical mean of absolute values of residuals in δ on basis stars.

δ^T_{OC}: arithmetical mean of absolute values of residuals in δ on 19 test stars.

Plate 6378 – Grand Prisme Objectif (GPO) of the European Southern Observatory (ESO).

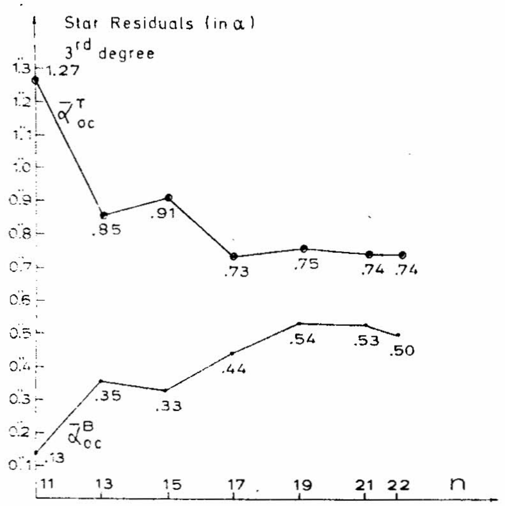


Fig. 5. Precision of Reductions in α by the 3rd degree bijection. Bijection between sky and plate:

$X = a_{00} + a_{10}x + a_{01}y + a_{20}x^2 + a_{11}xy + a_{02}y^2 + a_{30}x^3 + a_{21}x^2y + a_{12}xy^2 + a_{03}y^3$,

$y = b_{00} + b_{10}x + b_{01}y + b_{20}x^2 + b_{11}xy + b_{02}y^2 + b_{30}x^3 + b_{21}x^2y + b_{12}xy^2 + b_{03}y^3$.

n: number of basis stars (reference stars).

α^B_{OC}: arithmetical mean of absolute values of residuals in α on basis stars.

α^T_{OC}: arithmetical mean of absolute values of residuals in α on 19 test stars.

Plate: 6378 – Grand Prisme Objectif (GPO) of the European Southern Observatory (ESO).

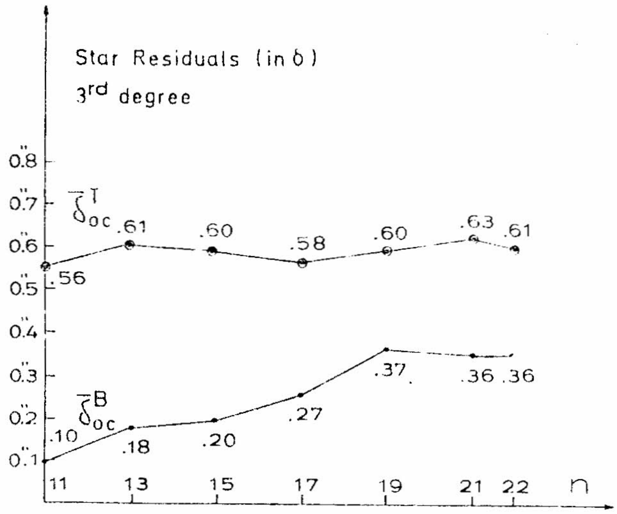


Fig. 6. Precision of Reductions in δ by the 3rd degree bijection. Bijection between sky and plate: see fig. 5.

n: number of basis stars (reference stars).

δ^B_{OC}: arithmetical mean of absolute values of residuals in δ on basis stars.

δ^T_{OC}: arithmetical mean of absolute values of residuals in δ on 19 test stars.

Plate: 6378 – Grand Prisme Objectif (GPO) of the European Southern Observatory (ESO).

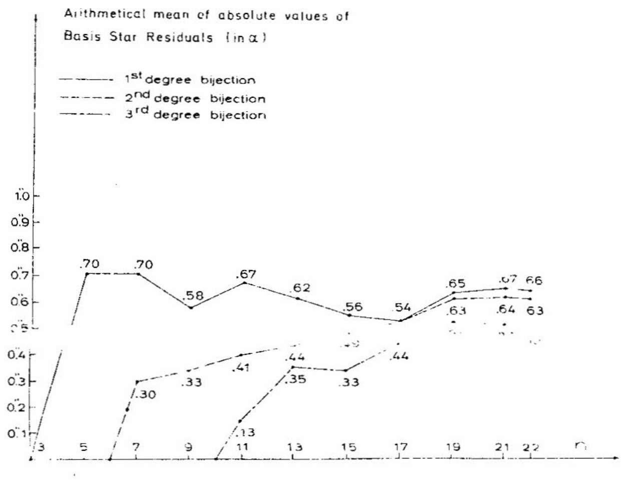


Fig. 7. Comparison of 3 bijections by Basis Stars, in α.

n: number of basis stars (reference stars).

6. CONCLUSION.

When the number of catalogued stars on a plate is small or when we choose a bijection with a great number of coefficients a_{ij} (and b_{ij}) we can not take a sufficient number of test stars (test subset, T, with $|T|$ small).

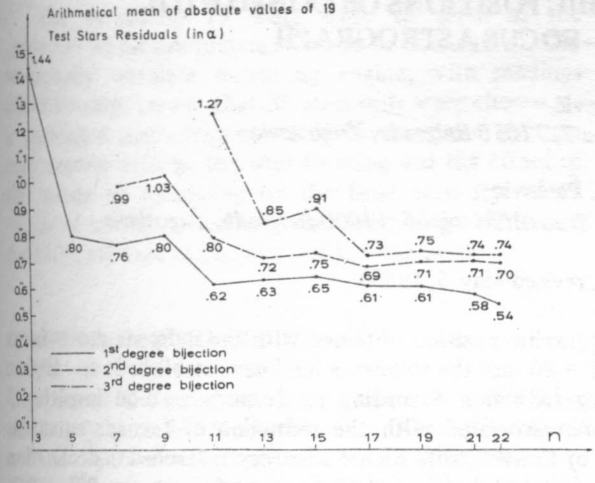


Fig. 8. Comparison of 3 bijections by Test Stars, in α.
n: number of basis stars (reference stars).

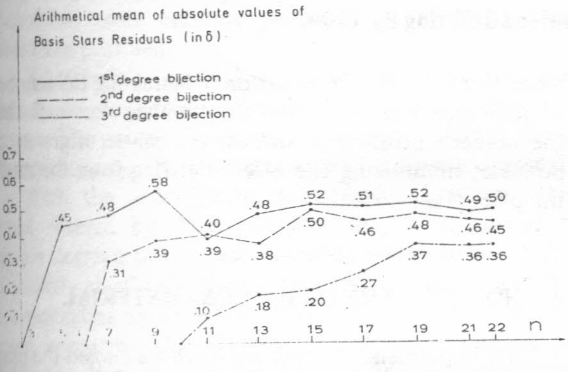


Fig. 9. Comparison of 3 bijections by Basis Stars, in δ.
n: number of basis stars (reference stars).

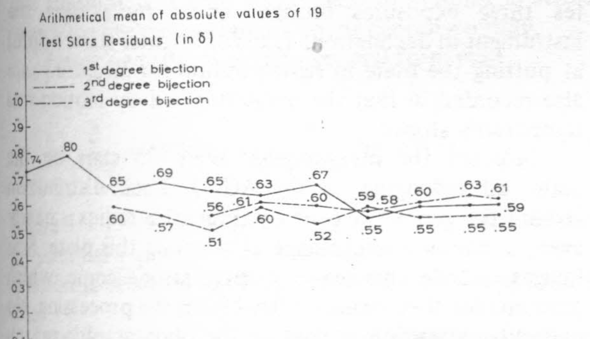


Fig. 10. Comparison of 3 bijections by Test Stars, in δ.
n: number of basis stars (reference stars).

Then, we can refer to studies such as those of the graphs on fig. 7 and 8: when the lines become horizontal we can deduce the optimal number |B| of points in the basis subset B (reference stars) and the mean accuracy of the celestial set, S (catalogue) as defined above (§ 3).

The study of bijections of higher degrees (n= 4, 5, 6 or 7 meaning 15, 21, 28, 36 terms for the complete polynomial) is not to be rejected because not used in practical computations. Of course, this study has permitted to establish the theorem of the minimum: the error–effect at the point where an error is acting is not minimum at the center of the basis subset, B, for even degrees but it is for odd degres bijections. This theorem is available (and to be taken into account and used) for all mathematical and physical problems with rectangular algebraic systems.

In the case of a „well furnished" basis subset, B, if a bijection β is perfect (residuals = 0 or perfect return back by means of β), for bijections β' including β ($\beta \in \beta'$, for example when degrees of β' and β verify $n' > n$) we must notice that β' will reduce to β when using the same B. In other words, the a_{ij} in (1) for β', different of the a_{ij} for β, are identical to zero. It is easily seen in (3).

On the other hand, in the same case (of a perfect bijection β) when applying bijection β' ($\beta' \in \beta$) at the same basis subset B, we deduce the mathematical deviation or shift between β and β' (defect of equivalence, Baumslag et al., 1968), excluding all other error–effect due to catalogue, measurements or geometrical constitution or display of B.

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ACCURACY OF THE ASTROGRAPHIC POSITIONS OBTAINED WITH THE BELGRADE SHORT–FOCUS ASTROGRAPH

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SUMMARY By analyzing astrographic position obtained with the Belgrade short–focus astrograph (Zeiss, D = 16 cm, F = 80 cm) the following has been established: a) Higher accuracy is reached by making reduction according to Terner's method involving 3 coefficients (T(3)) than the one associated with the reduction of Terner's equations involving 6 coefficients (T(6)); b) Considerably higher accuracy is reached in declination $|\Delta\delta| = 0''.3 \pm 0''.3$ in comparison with the one in right ascension $|\Delta\alpha| = 0''.7 \pm 0''.7$, attributable, in the authors' oppinion, to defects in the measuring engine; c) Chief prerequisite for expecting optimum results lies in such a selection of reference stars that the object is placed not beyond 43 arc minute from their gravity centre, and d) The plate ought to be measured in two positions differing by 180°.

1. INTRODUCTION

It is well known that the accuracy of the equatorial coordinates (α and δ) obtained with the short–focus astrographs is substantially inferior to the one associated with coordinates delivered by long–focus astrographs.

Thus, for instance, Chernyk (1970) found from the minor planet 10 Hygiea observations, used for calculating the mass of Jupiter, that the mean erros in the astrographic positions, as furnished by short–focus astrographs ($F \leqslant 100$ cm) at Belgrade, Warsovie, Wurtzburg and Rome observatories, amounted to 2" to 5", those in the positions obtained with the medium–focus instruments (F = 1 m to 2 m) to about 1" and those associated with the long–focus astrographs ($F > 2$ m) to 0".5 in both coordinates.

Belgrade observations used by the above mentioned author were obtained with Zeiss astrograph whose object–glass (Petzwal) has a 16 cm diameter and 80 cm focal length. Reduction was made by Schlesinger method involving three reference stars whose positions were taken from the Yale catalogue.

The astro–plate were measured on a Zeiss, Pulfrich type, measuring engine with 0.001 mm graduation in both coordinates. It is the only measuring engine available at this observatory.

This astrograph, on a suggestion by Orelskaya (1975a, 1975b) was included – in the „Leningrad Programme" aimed at determining corrections to the inertial reference frame (Fricke, 1985).

It was these authors' intention to put under scrutiny whether the accuracy just referred to was to be improved by: choosing more suited method (involving more terms in Terner equations); increasing the number of reference stars; selection of reference stars such that the object's position is an near the centre of gravity as possible; minimizing the effect deriving from the mode the plate is measured.

2. CHOICE OF THE OBSERVING MATERIAL

To implement the task set forth we chosed the plate OL 44/1983 with the centre's coordinates $A = 3^h4^m29^s$ and $D = +23^o6.7$, which were taken in the reduction also as optical centre's coordinates. The plate incorporates three exposures brought about by shifting the instrument in declination. Trails of brighter stars, helpful at putting the plate in right position for measuring, are also recorded in that the instrument's daily motion was temporarily stoped.

Selected for measurement were 35 stars on the plate, all belonging to the AGK 3. Their distribution around the geometric centre within a 1.5 radius is nearly even, a crucial circumstance at selecting this plate. Star images outside this region display strong come, which accounts for their being omitted from the processing. No particular attention is paid to the photographic magnitudes nor to spectral types of the stars at their selection.

From among 35 selected stars 16 were designated to be reference stars. They were formed into systems of 3, 6, 9, 12 and 16 stars, whereby each subsequent system enclosed stars from the preceding one. Care was taken at this selecting that each one of the systems possessed as even a distribution with reference to the plate's centre as only possible.

The remaining 19 stars were to serve as the „objects" whose coordinates were to be determined. The technically obsolete measuring engine, with readings made visually, caused that 35 stars only were chosen, as a prolonged measurement would have entialed stronger temperature effects. In order to bring out the effect of the mode of measuring on the final accuracy, mean values of measures, made at two plate positions differing by 180°, are used at carrying out the reduction.

3. METHODS OF REDUCTION

Instructions dispatched to the participants in the „Leningrad Programme" includes among others the request to use in the reductions 5 to 7 reference stars, Schlesinger method being employed. This method, which in fact is but modified Terner method involving only linear temrs (3 terms), is well suited to ulterior correcting the object's coordinates should it occur that meanwhile more accurate positions of reference stars have been provided.

Schlesinger's method is otherwise used for the reductions of observations made with long–focus astrographs. The polygon featured by reference stars in these observations occupies a small area (1.5 square degrees).

With the short–focus astrographs, however, the areas covered by these polygons may even exceed 6 square degrees. In this case the relationships between the so called „ideal" (standard) coordinates X and Y and the corresponding measured coordinates x and y can become more complex. This is why use is made, instead of Schlesinger's method or the Terner's one involving three coefficients (T(3), ot Terner's equations involving more than 3 coefficients. The extra terms (higher order terms) are aimed at removing all manners of systematic errors which the linear ones cannot do, or cannot do fully.

Terner's equations in their general form read

$$X = \sum_{i+j=o}^{n} a_{ij}\, x^i y^j \quad ; \quad Y = \sum_{i+j=o}^{n} b_{ij}\, x^i y^j \qquad (1)$$

where i + j + k, k = 0, 1, 2, ... , n – 1 denotes the polynomial's power. For instance for n = 1 a linear relation is obtained (T(33)), for n = 2 a quadratic (T(6)) etc.

Having regard to the small number or reference stars, decided on for considerations given above, it was deemed logical to confine ourselves to n = 2, i.e. to compare accuracies of coordinates resulting from the reduction made according to linear (hereafter labeled T(3) and quadratic T(6) Terner's relation).

To evaluate accuracies one calculated quantities $|\Delta\alpha|$ and $|\Delta\delta|$ representing departures of the catalogue values from those calculated for each one of the reductions.

However, submited to analyzis will be the quantities $|\Delta\alpha|$ and $|\Delta\delta|$ specified by the relation (2) calculated for the zones a, b and c. Namely, in order to examine the dependence of the quantities $|\Delta\alpha|$ and $|\Delta\delta|$ on the object's distnace D from the gravity centre of the corresponding system of reference stars (N(RS)) we introduced three zones: zone a – D < 10 mm, zone b – 10 mm ⩽ D < 20 mm, and zone c – D ⩾ 20 mm (10 mm = 43').

$$|\Delta\alpha| = \frac{1}{f} \sum_{i=1}^{m} \sum_{j=1}^{n=3} |\alpha_{oi} - \alpha_{ci}^{j}| \; ;$$
$$|\Delta\delta| = \frac{1}{f} \sum_{i=1}^{m} \sum_{j=1}^{n=3} |\delta_{oi} - \delta_{ci}^{j}| \qquad (2)$$

Here: m – number of objects within the zone; j – ordering number of the exposure; α_{oi} and δ_{oi} catalogue coordinates of the i–th object; α_{ci}^j and δ_{ci}^j – calculated coordinates fo the i–th object in the j–th exposure; f – frequency (f = m x n). (Objects in the present case are having three exposures).

4. RESULTS AND CONCLUSIONS

Results of the performed calculations are summarized in Table 1 and 2. Data in Table 2 are a result of plate measurement in one position only. Tables enclose also the quantities σ_α and σ_δ which are standard deviations. The measuring unit in both coordinates is the arc second.

Data in Table 1 make it apparent that the quantities $|\Delta\alpha|$ and $|\Delta\delta|$ are increasing with the growth of the object's distance from the gravity centre in both of reductions (T(3)) and (T(6)), i.e. the accuracy gets lower as one is farther from the centre (See Debehogne, 1974, and Kiselev, 1981). By increasing the number of reference stars (N(RS)) the impact of the distance D on the accuracy is reduced but remains evident up to N(RS).

This statement is confirmed more convincingly by the standard deviations σ_α and σ_δ.

Being given that objects under consideration are mostly in the vicinity of the plate centre, thanks to their orbits being fairly known, it is always possible to find out such a distribution of reference stars to make it placed in the vicinity of the gravity centre (within the zone a) securing therewith its coordinates to be calculated with the minimum error.

Figures 1 and 2 illustrate deviations $|\Delta\alpha|$ and $|\Delta\delta|$ for the zone a, furnished by reductions T(3) and T(6). They also clearly demonstrate that the reduction according to T(3) has advantage in respect to accuracy over T(6). One should mention as supporting this result the

Table 1. Mean absolute deviations $|\Delta\alpha|$ and $|\Delta\delta|$. N(RS) – number of reference stars, D – distance from the gravity point, f – frequency, σ_α and σ_δ – standard deviations.

		T(3)				T(6)				
N(RS)	D	$\lvert\Delta\alpha\rvert$	σ_α	$\lvert\Delta\delta\rvert$	σ_δ	$\lvert\Delta\alpha\rvert$	σ_α	$\lvert\Delta\delta\rvert$	σ_δ	f
3	a	0.81	±0.51	0.50	±0.37					6
	b	1.30	0.99	1.60	1.61					27
	c	2.60	2.11	1.75	1.37					24
6	a	1.14	0.63	0.30	0.30	1.59	±0.78	1.01	±0.45	9
	b	1.23	0.94	0.66	0.47	4.21	3.17	4.54	4.10	27
	c	2.02	1.70	1.04	1.01	11.76	6.70	6.43	4.49	21
9	a	0.94	0.72	0.33	0.30	1.10	0.48	0.77	0.51	9
	b	0.80	0.54	0.99	1.08	1.63	1.57	2.56	2.16	24
	c	1.26	0.98	0.93	0.83	4.34	3.62	4.52	2.45	24
12	a	0.77	0.81	0.36	0.30	0.96	0.78	0.31	0.30	9
	b	0.84	0.73	0.77	0.62	0.90	0.78	0.99	0.68	27
	c	1.16	0.87	1.27	1.05	1.03	0.82	1.50	1.24	21
16	a	0.71	0.69	0.40	0.30	0.88	0.75	0.52	0.27	9
	b	1.03	0.78	0.57	0.59	1.03	1.03	0.68	0.64	24
	c	1.35	0.98	1.27	0.88	1.72	1.37	1.64	1.13	24

Table 2. Mean absolute deviations $|\Delta\alpha|$ and $|\Delta\delta|$ at measuring the plate in only one position.

		T(3)				T(6)				
N(RS)	D	$\lvert\Delta\alpha\rvert$	σ_α	$\lvert\Delta\delta\rvert$	σ_δ	$\lvert\Delta\alpha\rvert$	σ_α	$\lvert\Delta\delta\rvert$	σ_δ	f
3	a	0.86	±0.63	0.97	±0.47				6	
	b	2.18	2.02	1.77	2.02					27
	c	2.59	2.33	1.95	2.33					24
6	a	1.14	1.03	0.45	0.36	1.27	±1.13	0.86	±0.57	9
	b	1.43	1.27	0.87	0.62	5.81	4.49	4.33	3.71	27
	c	1.66	1.07	1.58	2.04	11.52	9.33	5.20	5.07	21
9	a	1.21	0.97	0.53	0.34	1.46	0.86	0.65	0.37	9
	b	1.35	0.94	1.38	2.13	3.94	4.06	2.94	3.39	24
	c	1.34	0.91	1.10	0.89	8.28	9.31	4.73	3.28	24
12	a	1.13	1.03	0.67	0.39	1.32	1.05	0.64	0.34	9
	b	1.64	1.15	1.03	0.78	2.06	1.92	1.13	0.93	27
	c	1.75	1.57	1.88	2.08	1.94	2.04	2.15	2.59	21
16	a	1.08	1.03	0.56	0.30	1.26	0.92	0.57	0.34	9
	b	1.27	0.90	0.80	0.55	1.39	1.42	0.74	0.50	24
	c	1.47	1.08	1.52	1.86	1.56	1.36	1.69	1.86	24

paper by Kiselev (1981), already quoted above, in which it is claimed that the accuracy, associated with the reduction by T(3), provided the object is situated close to the gravity centre, is higher than the one attained by the reduction T(6). This author puts foreward the suggestion that one should, in any particular case (instrument), check which one of the methods is the most suitable (most accurate) considering that short–focus instruments induce all manners of systematic errors.

It is at once evident that our accuracy in declination is comparable with the one associated with the long–focus astrographs (Debehogne et al., 1983).

Our accuracy in right ascension is markedly lower, but it is still at the level of the one typical of long–focus astrographs (Chernich, 1970). Errors in this coordinate

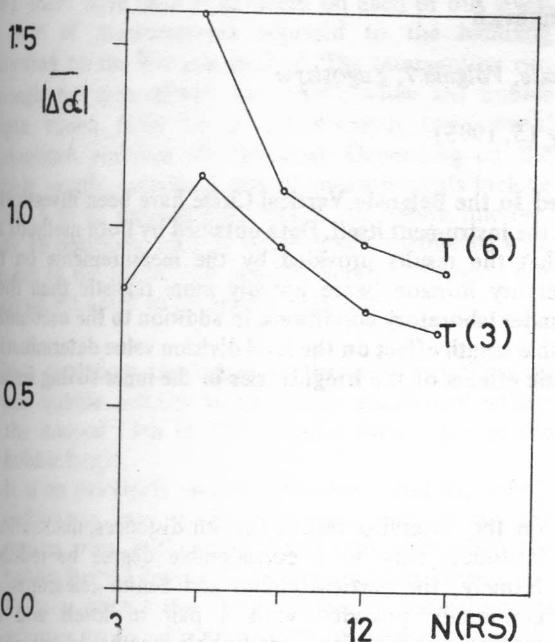

Fig. 1. $\overline{|\Delta\alpha|}$ for the zone a objects, with T(3) and T(6) reductions.

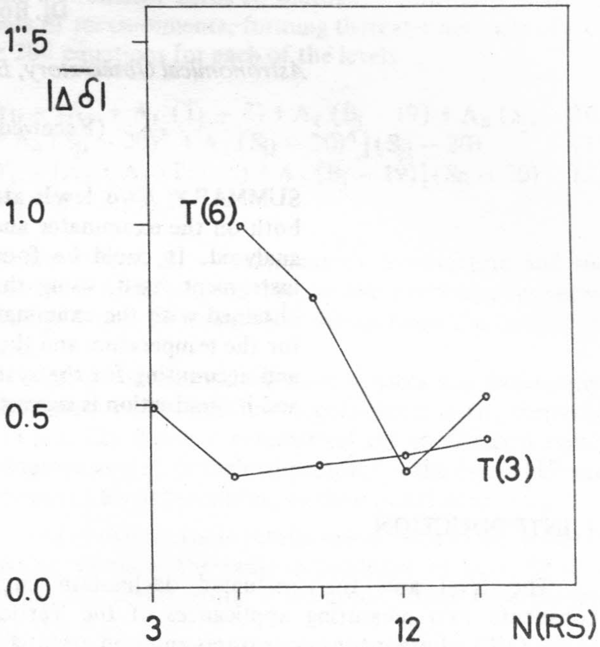

Fig. 2 $\overline{|\Delta\delta|}$ for the zone a objects, with T(3) and T(6) reductions.

have their origin, in these authors' oppinion, in the measuring engine. This conclusion is suggesting itself through instability noted at measuring this coordinate.

Next, results of lower accuracy are obtained by both methods when the measurement is made in one position only. This certainly is a consequence of the personal error not being removed if measurement is performed in only position of the plate (measurements made by the first author only). Since the object images were set upon several times the accidental errors are expected to be reduced to their minimum.

It is self–understood that the results are affected by the accidental errors in the catalogue used (AGK 3). The effect of these errors is minimized through the use of larger number of stars. The object s'coordinates, however, „inherit" systematic errors in the reference stars system.

If is obvious that by increasing the number of reference stars (12 at least), by performing measurement in two plate positions (0° and 180°) and by applying T(3) reduction, results may be achieved which are usable also in high accuracy calculations. Surely, because of the small size of the instrument one would be obliged to make greater number of exposures and to secure more measurements of the object's image in order to supress the accidental errors hith otherwise enter in the coordinates by their full amount.

In concluding we regard it as being of interest to make analogous analysis upon plates measurements performed on some modern measuring engine.

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INVESTIGATION OF LEVELS OF THE BELGRADE VERTICAL CIRCLE

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SUMMARY /Two levels attached to the Belgrade Vertical Circle have been investigated both on the examinator and on the instrument itself. Data obtained by both methods are analysed. It could be found that the results provided by the measurements on the instrument itself, using the mercury horizon, were notably more realistic than those obtained with the examinator under laboratory conditions. In addition to the accounting for the temperature and the bubble length effect on the level division value determination and accounting for the systematic effects of the irregulatiries in the inner sliding surface and its graduation is suggested.

1. INTRODUCTION

The level and the graduated declination circle constitute two measuring applicances of the Vertical Circle (VC) whose intrinsinc features enter on essentially equal terms into the measured zenith distance, i.e. declination. Through these two appliences, therefore, the accuracy of determination of the absolute declinations is importantly conditioned in both random and systematical sense. The effect of the levels is commonly more pronounced with the larger instruments (the VC of the Belgrade Observatory belongs to this category) as these are often distinguished by a stronger inclination instability of their vertical axes.

The level investigation has hitherto been implemented chiefly according to Wanach and Vassilev methods under laboratory conditions, using an examinator. The investigation provided, as a result, the mean angular value of the level division including a qualitative–quantitative assessment of the inner sliding surface of the level tube. (The latter investigations, under roughly equal conditions, are known to often yield contradictory results). The analysis of a series of investigations was principally aimed at determining the dependence of the division value on the air temperature and the bubble length. Other possible reasons of the division value variability have earlier been rarely searched for owing, on one hand, to an apriori awarness of their being essentially petty, and on another, the lack of electronic computers entailed their determination and their subsequent utilization to be highly cumbersome.

Numerous investigations confirm the presence of the simillar and larger irregularities in the sliding surfaces inside the level tubes and in their graduations. Habitually, these errors may, conditionally, be divided into **random** and **systematic** ones. The effects of the former on the observing results (zenith distances, declinations, latitudes) may to a considerable degree be reduced. Namely, the vertical circles and zenith telescopes are commonly provided with a pair of levels and the measured inclinations, the bubble lengths, as well as the utilized level graduations are different from one stars to next during the same night. This is all the more true of different nights when the inclinations may differ even in sign. Even the effect of the systematic irregularities just reffered to on the mean measuring results is reduced, although not comletely removed. These effects keep being present since the mean inclination from a series of mesurements of the same star is not necessarily close to zero nor the same in the north and south stars and, equally, the level bubble positions are not necessarily symetrical with respect to the middle of the graduation.

With this in mind we dedicated the present paper to finding out the ways of determining the systematic irregularities in both sliding surfaces and in graduations of our levels and, more broadly, to the problems connected with the calibration of the angular value of the level division.

2. INVESTIGATION OF LEVELS OF THE BELGRADE VC WITH THE EXAMINATOR

Discussion of all the past laboratory investigations of levels of our VC, implemented according to Wanach's and Vassilev's methods, was performed by Mijatov and Trajkovska (1984). The two authors established the division value variability with time, temperature and the bubble length.

In contrast to them we separated in the present paper the latest, relatively large group of laboratory measurements, those from 1981, having processed them in a somewhat different way.

In the period from 24. January to 25. February 1981 there have been effectuated on each of our levels 18 sets of measurements adjusted to the handling according to the Wanach method. The temperature run through the interval +1° to +15°C, while the bubble length varied from 16 to 22 divisions (our levels' graduations embrace 40 divisions). Depending on the bubble length, individual sets of measurements include from 16 to 22 meaned positions of the bubble middles. Only 16 positions, roughly symetrically distributed with respect to the graduation middle, were processed in our analysis. We acted so for several reasons:

a) This conditions the values of the mean positions of the bubble middles to be evenly distributed within the interval 11th to 29th division irrespective of the bubble length.
b) It is on extremely rare occasions only that the bubble ends come near to the graduation ends during the regular work with our VC and that only when the bubble lengths happen to be uncommonly large.
c) There is always the same number of measurements entering the calculus irrespecitve of the bubble length.

Data handling for each one of the levels was carried out in the following fashion. We first determined by the least square method, for each of the sets j of measures, the coefficients a_j and b_j in the linear set of 16 equations

$(i - 8.5) \cdot E_j = a_j + b_j \cdot (S_{ji} - 20)$ $(i = 1, 2, \ldots, 16; j = 1, 2, \ldots, 18)$ $E_j = 0.99983 + 0.00013 \cdot (T_j - 13.8)$

where:

i – ordinal number of the measurement – zero position on the examinator's disk. This equating is used in order to simplify the calculus without its results being affected, since any following zero position of the examinator screw differed from the preceding one by one division on its disk. To be sure, in order to minimize the effects of errors in the examinator's screw use has been made of different screw's turns and disk's sections.

E_j – Angular value of the examinator disk's division for the temperature during the investigation (Mijatov, Sadžakov, 1968).

a_j – correction to the coordinates' zero, i.e. to the adopted mean position of the disk ($8.5 \times E_j$) in the set j of measurements.

b_j – Mean value of the level division in the particular investigation.

S_{ji} – Mean position of the bubble middle from two measurements at the same disk position i (bubble s' displacement from left to right and vice versa).

20 – the middle of our levels' graduation.

With the coefficients a_j thus determined one made the coordinates' zeros be mutually conforming in all the sets of measurements, forming thereater new sets of $j \times i = 288$ equations for each of the levels

$$Y_{ji} = [A_o + A_1 (T_j - 8) + A_2 (B_j - 19) + A_3 (S_{ji} - 20) + A_4 (S_{ji} - 20)^2 + A_5 (S_{ji} - 20)^4] (S_{ji} - 20) \quad (1)$$

$$Y_{ji} = [A_o + A_1 (T_j - 8) + A_2 (B_j - 19)] (S_{ji} - 20) \quad (2)$$

$$Y_{ji} = (i - 8.5) \cdot E_j - a_j$$

where T_j and B_j – examinator's temperature and the bubble length, respectively, in the particular investigation j, 8 and 19 being their means from the totality of sets.

Using the method of least squares one determined the values of the unknown coefficients in the formulae (1) and (2). Table I summarizes the coefficients values obtained as well as their rms errors for the upper (U) and lower (L) levels (according to their position on VC).

As apparent, these results reveal both of our levels as having virtually the same dependence of their division values on temperature and bubble length (coefficients A_1 and A_2).

At variance with these, the coefficients A_3, A_4 and A_5, typifying the systematic irregularities in the level sliding surfaces and in their graduations, have opposite signs, implying their effects on the final results to be mostly comparatively slight (below $0\overset{''}{.}1$). It is on extremely rare occasions that these features of our levels make themselves felt, when the levels happen to be mutually or otherwise poorly adjusted.

Attention is to be drawn to the notable difference of the coefficient values A_o in the formulae (1) and (2) in both levels, even though they follow from the same observational material. This difference is a consequence, in a way, of different meaning of these coefficients. Specifically, the coefficient A_o in (2) embodies the mean value of the level divisions resulting from the whole of the investigated graduation, while that in (1) is the mean division value as it results from the graduation around its middle. It is precisely this value that is mostly needed in the everyday practice.

For illustration we formed from 18 sets of measurements, for different combinations of instrument's inclinations, the mean differences examinator – level readings, computed by way of (1) and (2) using the coefficients from Table I.

$$O-C = \frac{1}{18} \sum_j [(k-i) \cdot E_j - (Y'_k - Y'_i)_j]$$

$$(i = 1, 2, \ldots, 15; \quad k = i+1, i+2, \ldots, 16)$$

These departures in hundredths of second of arc are listed in Tables II, III, IV and V.

Table I: Coefficients and their rms errors delivered by (1) and (2) for the upper (U) and the lower (L) level.

Level	Set	A_0	A_1	A_2	A_3	A_4	A_5	ϵ
U	1	0".982 ±.005	.0028 ±.0003	.0070 ±.0007	−.0018 ±.0003	−.00082 ±.00027	.0000061 ±.0000031	±0.107
	2	0".959 ±.002	.0029 ±.0003	.0068 ±.0007	–	–	–	±0.116
L	1	0".920 ±.006	.0022 ±.0003	.0080 ±.0009	.0009 ±.0003	.00176 ±.00031	−.0000212 ±.0000037	±0.122
	2	0".948 ±.002	.0025 ±.0003	.0084 ±.0009	–	–	–	±0.127

Table II: The (O–C) values in 0".01 for the upper level computed according to (1)

i \ k	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
1	0	0	0	1	2	0	2	−1	−3	−5	−3	7	2	3	−1
2	1	1	1	3	4	1	4	0	−1	−3	−1	9	4	5	
3	−3	−3	−3	−1	0	−3	0	−4	−7	−8	−6	4	0		
4	−2	−3	−3	−1	0	−2	0	−4	−6	−7	−6	4			
5	−7	−7	−8	−6	−4	−7	−4	−8	−11	−12	−10				
6	3	3	2	4	5	3	6	2	0	−1					
7	4	4	4	6	7	4	7	3	1						
8	3	3	3	5	6	3	6	2							
9	1	1	0	2	3	1	4								
10	−3	−3	−3	−1	0	−2									
11	0	0	0	1	2										
12	−2	−2	−3	−1											
13	−1	−1	−1												
14	0	0													
15	0														

Table III: The (O–C) values in 0".01 for the upper level computed according to (2).

i \ k	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
1	−7	−2	1	8	12	10	13	7	3	0	0	8	3	3	−1
2	−5	−1	3	9	13	12	14	9	4	0	0	9	4	4	
3	−10	−6	−1	4	9	7	9	−4	0	−3	−4	4	0		
4	−10	−6	−1	5	9	7	10	4	0	−3	−4	5			
5	−15	−11	−6	0	4	2	5	0	−5	−8	−9				
6	−6	−1	2	9	13	11	14	8	4	0					
7	−6	−2	2	8	12	11	13	8	3						
8	−10	−6	−1	5	9	7	10	4							
9	−15	−10	−5	0	4	3	5								
10	−20	−16	−11	−5	0	−2									
11	−18	−13	−9	−2	1										
12	−19	−15	−10	−4											
13	−15	−11	−6												
14	−9	−4													
15	−4														

Table IV: The (O–C) values in 0".01 for the lower level computed according to (1).

i \ k	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
1	0	1	1	2	0	−1	−2	−4	−1	2	1	0	−1	1	1
2	−2	0	0	0	−1	−3	−4	−6	−3	0	0	−2	−3	0	
3	−1	0	0	0	0	−3	−4	−6	−3	0	0	−2	−3		
4	1	3	3	3	2	0	−1	−3	0	4	2	0			
5	0	2	2	2	1	0	−2	−3	−1	3	1				
6	−1	0	0	0	0	−2	−4	−5	−3	1					
7	−2	0	0	0	−1	−3	−5	−7	−4						
8	1	3	3	3	2	0	−1	−2							
9	4	6	6	6	5	3	1								
10	2	4	4	4	3	1									
11	1	2	3	3	2										
12	−1	0	0	1											
13	−2	0	0												
14	−1	0													
15	−1														

Table V: The (O–C) values in 0".01 for the lower level computed according to (2).

i \ k	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
1	−4	4	3	0	−5	−10	−11	−12	−6	0	0	−2	−5	−4	−5
2	0	9	8	4	0	−5	−6	−7	−1	5	5	2	0	0	
3	0	9	8	4	0	−5	−7	−7	−1	5	5	2	0		
4	0	9	8	5	0	−4	−6	−6	0	5	5	3			
5	−2	6	5	1	−3	−8	−9	−10	−4	2	2				
6	−5	4	2	0	−6	−10	−12	−12	−6	0					
7	−4	4	3	0	−6	−10	−12	−12	−6						
8	1	10	9	6	0	−3	−5	−5							
9	7	16	15	11	6	1	0								
10	7	16	15	11	6	1									
11	5	14	13	9	4										
12	1	10	9	5											
13	−4	4	3												
14	−8	1													
15	−9														

The O–C values for an inclination roughly equal to k-i ($E_j \approx 1"$) appear at the intersections of the k–th columns and the i–th rows.

The comparison of Table II and III (for the upper level)as well as Tables IV and V (for the lower level) reveal that the terms with the coefficients A_3, A_4 and A_5 in (1) represent fairly well the systematic irregularities in our levels. The values in Tables II and IV come already close to the random errors in determination,

$$\frac{\epsilon\sqrt{2}}{\sqrt{18}} = \pm\ 0''.04.$$

One might conclude that (1) yields markedly better results than the well–nigh classical formula (2).

In concluding this Section let it be noted that we analysed these laboratory measurements by other functional dependences as well, but the coclusion was reached that (1) was the best in representing **both** of our levels.

3. INVESTIGATION OF LEVELS ON THE INSTRUMENT

The applicability problem of the laboratory results is well known and often very acute in the astrometric practice. A settling of this problem is essential when it comes to the absolute star position determination. This is all the more true of the levels in view of their sensitivity and capriciousness on one hand, and the important difference between the conditions prevailing about them during observations with the instrument and those under which they are investigated on the examinator, on the other. Specifically, the heterogeneity of those conditions is reflected by:

a) On the instrument, the illumination devices are beneath the levels, being steadily kept on during observation, the bubble ends being read off in the small mirrors placed above the levels. On the examinator the levels are illuminated by a battery lamp held by the observer, the bubble ends are read off directly (without intermediary of the level mirror).
b) At working with the instrument there takes place, between two successive readings of the bubble ends, the shaking of liquid in the level tubes, their bubbles crossing over from one end of the graduation to another before returning to their proper positions. On the examinator, however, the bubble slowly glides from one position to its next following gentle displacements of the examinator's disk.
c) On the instrument, the levels are exposed to generally harsher external influences.

The solving of this and similar problems is usually sought in investigations, performed wherever possible under conditions made as close as possible to those prevailing during the regular observation with the instrument. In our particular case this would imply: under conditions prevailing in the instrument's pavilion in the course of standard work, without dislodging the levels from their place. That is just the kind of investigation we decided on.

In carrying out measurements necessary for clibrating the angular value of the level division on the instrument itself use was made of two mercury horizons in the nadiral direction. The illumination of threads in the eye–piece micrometer was accomplished by Lj. Paunović's, rather than with the Gaussian, eye–piece. This because the illumination of micrometer threads provided by Paunović's eye–piece proved incomparable superior to the one offered by that of Gauss.

These measurements were performed from time to time, usually following regular astronomical observations. The preparation run roughly according to the following scheme: Paunović's eye–piece was mounted on the eye–piece micrometer and the instrument turned toward nadir. If necessary, the mercury mirror horizons were cleaned up. The cardboard cylinders protecting the mirror horizons against the air disturbances were put on, covering the room between the mercury horizons' cicular priphery and the instrument's dew cap tumed downwards. By suitable gentle pushing the instrument one achieved the coincidence of the micrometer moving thread with its image in the mercury horizon, that position being fixed by the instrument's clamps. Thereupon the threads of the I and IV microscope–micrometers were set in succession upon the junior and the senior division lines in order to periodically verify the instrument's position with respect to the microscope–micrometers. Then followed the reversing of instrument, the same procedure, after two minute time, being once again performed.

Necessary measurements were caried out in the following manner. First, the movable thread was brought to coincide five times with its image, its position being read off each time. Then followed readings of the left and right bubble ends in the upper and the lower level. Then the instrument was reversed and the same measurements were taken up after about two minute time ect.

The measurements were undertaken mostly with the inclination nearly the same as it was during the astronomical observation, provided it has not been less than 2 divisions. Usually after about ten of these measurements, somewhere about the middle of the procedure, one changed the inclination's sign. The change of inclination proceeded relatively simply since one of the legs of the pilar's support, the one lying in the meridian, is leaned against a metalic lever, which is easily lifted or lowered by means of a screw. The inclination's sign is changed in order to enfeeble possible systematic personal error of the observer in the micrometer measurements, being given that his using one auxiliary staircase caused him to be continually to the south or to the north of the instrument. The reversing prism was not used.

In the period from 18 September 1980 to 15 March 1984 one accomplished 47 sets of measurements. The temperature was confined between –8.2 and +23.3°C. while the bubble length run from 15.3 to 25.1 divisions. At the beginning of this experimenting (18 sets) only one mercury horizon was used. The measurements were mostly made in accordance with the usual method as the one applied on the examinator, the inclination being varied all the while. In the later 29 sets of measurements, in order that the measuring procedure be likened as much as possible to that followed in the star observations, we started using both mercury horizons and reversing the instrument between two measurements. As no perceptible difference could be noted between the results of the two procedures, all the measurements were processed in the same manner.

The data processing proceeded in such a way that the same micrometer readings were compared once with the reading of the upper, then with that of the lower level. In helping ourselves with the method of least squares we derived the mean coefficients in the equations of conditions of the form:

$$(M_W-M_E)_i = \{ (S_E-S_W) \cdot [A'_0 + A'_1 (T_j-13) + A'_2 (B_j-19)] + A'_3 [(S_E-20)^2 - (S_W-20)^2] + A'_4 [(S_E-20)^3 - (S_W-20)^3] + A'_5 [(S_E-20)^5 - (S_W-20)^5] \}_i (i = 1, 2, .., 444; j = 1, 2, .., 47) \quad (3)$$

The above formula is obtained as a difference of two formulae (1) applied to each two measurements, the notations therein being:

M_W-M_E – the difference of the mean micrometer readings of nadir at two opposite clamps (E and W). In the measurements carried out on one instrument clamp, the inclination alone having been varied, this in most instances is the difference between two contiguous readings with the eye–piece micrometer.

i – the ordinal number of the pair of any contiguous measurements.

$S_E - S_W$ – the difference of the bubble middles at two instrument clamps of one of the investigated levels.

T_j, B_j – the mean air temperature and the bubble length, respectively, in some of the sets of measurements.

In Table VI are displayed the coefficients values thus obtained as well as their rms errors for both levels. These results, delivered by measurements on the instrument itself, reveal the angular value of the level division to be only weakly dependent on temperature and the bubble length (coefficients A_1' and A_2') but more noticeably (the upper level in particular) in what portions of the graduation one performed the measurements (coefficients A'_3, A'_4 and A'_5).

4. DISCUSSION AND DERIVATION OF THE FINAL VALUES

One realizes from Table I (results from the examinator) and Table VI (results from the instrument itself) that the values obtained are more or less differing. This is in a way understandable on considering the diversity of the purposes, modes and conditions of measurements. The investigation with the aid of examinator is organized in such a way (even distribution of the bubble middle positions, nearly constant temperature but varied bubble length) that the possible division value dependence on temperature, bubble length and irregularities in the sliding surface and the graduation is brought out rather dependably. Owing to reasons cited in Section 3 the applicability of the mean division value A_0 obtained with the examinator to measuremens made with the instrument is highly questionable. The applicability issue as far as the rest of the coefficients is concerned, is not so acute considering their values and effect on the measurements.

The objective of the level investigation on the spot, i.e. on the VC itself, was deducing the division value under conditions as close as possible to those prevailing during the reggular astronomical observations. As one had essentially to deal with what one had caught, the distribution of the bubble positions along the levele graduation within individual sets of measurements, and throughout, was found far from being an perfect one for a trustworthy derivation of the coefficients A_3', A_4' and A_5' appearing in (3). Hence we take these values rather as a proof of the presence of the systematic irregularities in the level tube sliding surfaces and in the level graduations and also of the adequacy of their representation. As apparent, for the case of the upper level, the coherence of the three coefficients is fairly well. With the lower level the coherence is considerably poorer. Concidering the temperature and the bubble length coefficients, the results obtained are in fact contradictory. The investigation on the examinator showed the levels as bieng strongly, and those on the VC as only weekly, dependent on temperature and bubble length. This disparity is apparently a consequence in the first place of the fact that the bubble length, in the regular work with the VC, is adjusted practically seazonally (i.e. four times a year). As the temperature and the bubble length are known to be correlated quantities, this adjustment entails the coefficients A'_1 and A'_2 to be inconclusively determined from the measurement on the instrument. For the same reason one cannot accept the mean division values A'_0 either, albeit deduced from the VC measurements.

Table VI: Values of coefficients in (3) and their rms errors for the upper and lower level

Level	A'_0	A_1'	A'_2	A'_3	A'_4	A'_5	ε'
U	0.949 ±.005	–.0008 ±.0003	–.0027 ±.0011	–.0021 ±.0004	–.00150 ±.00021	.0000067 ±.0000017	±.289
L	0.923 ±.006	.0007 ±.0003	.0028 ±.0013	.0019 ±.0005	.00021 ±.00025	–.0000057 ±.0000021	±.327

The matter was settled in the following way. On considering the reasons quoted above one accepted as more realistic the coefficient values, specifying the angular division variability, obtained on the examinator. The measurements performed on the VC were thereafter corrected by the values of these effects, thereby those only which were obtained when the instrument was reversed during investigation (29 sets of measurements involving 296 measurings of inclination). Then one determined, using the least square method, the mean angular division value. There resulted for the upper level $A_{oU} = 0.''914 \pm 0.''0027$ ($\pm 0.''332$) and for the lower one $A_{oL} = 0.''900 \pm 0.''0030$ ($\pm 0.''360$). In addition, on having introduced corrections for only temperature and the bubble length effects as obtained on the examinator, one determined the mean division value for this particular case. For the upper level there followed $A_{oU} = 0.''899 \pm 0.''0029$ ($\pm 0.''354$) and for the lower one $A_{oL} = 0.''931 \pm 0.''0033$ ($\pm 0.''377$). The rms errors are given in the brackets.

These mean values of the level divisions and the coefficients in Table I yield the following expressions for calculating corrections to the circle readings due to the presence of the VC vertical axis' inclination for any of our levels

$$C_{Ui} = \mp(S_i-20)[0.''914+0.0028(T-15) + 0.007(B-19) - 0.0018\,(S_i-20) - 0.00082\,(S_i-20)^2 + 0.000006(S_i-20)^4]$$

$$C_{Li} = \mp(S_i-20)[0.''900+0.0022(T-15) + 0.008(B-19) + 0.0009(S_i-20) + 0.00176\,(S_i-20)^2 - 0.000021(S_i-20)^4] \qquad (4)$$

$$i = E, W$$

$$C_{Ui} = \mp(S_i-20)[0.''899+0.0028(T-15) + 0.007(B-19)]$$

$$C_{Li} = \mp(S_i-20)[0.''931+0.0022(T-15) + 0.008(B-19)] \qquad (5)$$

As apparent, the angular division values thus obtained are lower than those resulting from the investigations on the examinator (Table I). This is particularly plain with the upper level. In order to verify how these results for the two levels were mutually harmonizing, the following test was carried out.

From the 1983 and 1984 observations we selected 51 nights on which the observing conditions differed among themselves at the most. From each of the nights one picked out 8 star observations. Being given that at any particular observation the VC occupies one inclination, measured by both upper and lower levels, $I_U = (S_E - S_W)_U \cdot A_U$, $I_L = (S_E - S_W)_L \cdot A_L$, the measured inclinations should be equal among themeselves apart from their random errors, provided the level division values A_U and A_L have been correctly determined. We therefore formed the differences of inclinations as supplied by the upper and the lower levels for any individual observation. In order to obviate these differences being dependent on the inclination's magnitude and to make sure they depended solely on error in the adopted division values, we divided them by mean inclination $\Delta A_i = ((I_U - I_L)/I)_i$, $I_i = ((I_U + I_L)/2)_i$. In order, further, to minimize the effect of the random errors we averaged the values obtained $\Delta A_j = \frac{1}{8}\sum_i \Delta A_i$, $i = 1, 2, \ldots, 8$. Thereafter one determined the mean value from all the nights and the rms of individual values

$$\Delta A = \frac{1}{51}\sum_j \Delta A_j\ , \quad \epsilon_j = [(\Delta A_j - \Delta A)^2/50]^{\frac{1}{2}}\ ,$$

$$j = 1, 2, \ldots, 51$$

The actual calculations according to the procedure just laid out was implemented using four different division values. The results obtained are summarized in Table VII.

Table VII: Mutual agreement of the division values obtained by the method applied

Set	ΔA	ϵ_j
1	0.065	±0.068
2	0.065	±0.077
4	0.015	±0.067
5	0.015	±0.077

In the above Table VII 1 and 2 denote the values used from Table I (results supplied by the investigations with the examinator). 4 and 5 indicate that the computations have been performed according to (4) and (5) using coefficients therein of which A_o – mean angular division values are obtained from the investigation made on VC.

Being given that the division values of our levels are roughly about 1" we find $\Delta A \approx \Delta A_{oU} - \Delta A_{oL}$. The agreement of the results obtained on the instrument itself – in Table VII $\Delta A = 0.015$ – points to the possible errors in the division values in both levels being very small, or if larger vitually equal. In our view the former case is true as no larger systematic departure was noted in the more recent star observations whose origin could be attributed to the level division values. The unimportant value 0.015 might be neglected, as it is on the very limit of the measuring accuracy ($\epsilon_j/\sqrt{51}$). Moreover, the method itself, being but an approximate one, involves errors of that order. The reason of so highly concordant division values acquired by the measurements on VC itself lies in the fact that the same micrometer readings have been used in both levels, the latter being simultaneusly under the external conditions nearly identical with those prevailing during the star observation. In contrast to them the mean division values, resulting from the investigation on the examinator, display considerably poorer mutual agreement. The value 0.065 derives chiefly from the upper level. The same value 0.065 of the divergence of the two systems 1 and 2 as well as 0.015 in the systems 4 and 5 is understandable for two reasons:

a) The mean division value used in the present test are a result of different processing of the same observing material alike on the examinator and the VC;
b) The sample formed from inclinations during the star observation an 51 nights did not substantally affect the test results thanks to its having been selected rather well both in respect to the magnitude of inclination and in respect to symetry of measurements with respect to the level graduation middle.

As apparent from Table VII the use of the coefficients A_3, A_4 and A_5, typifying the systematic irregularities in the sliding surfaces of level tubes and in the level graduation, in the systems 1 and 4 results in a diminishing of the errors ϵ_j by about 13% with respect to those in the systems 2 and 5, which is another proof of their reality and the legitimacy of their use.

We would like at this place to pass a few words about the accuracy of measurements on both the examinator and the VC proceding from the rms errors ϵ and ϵ' in them (see Tables I and VI). One may claim both procedures to be of about equal accuracy. Namely, considering that the values S_i in (1) are obtained from two bubble middle positions (involving the bubble motion from left to right and vice versa) and that in (3) one is dealing with the position differences ($S_E - S_W$), we have $\epsilon = \pm\ 0.11$ and $\epsilon'/2 = \pm\ 0.15$. This small difference is due principally to the circumstance that the measurements on VC are affected also by the error in the difference of the eye–piece micrometer readings. This difference is ceratainly twice as great as the error in the mean of two installings of the examinator disk on some particular division. (The reading of some position is always less precise than the installing into that position).

In closing this Section let us note that in the actual employment of the formula (4) which is recommended, or eventually of the formula (4), there might emerge minor difficulties owing to the accounting of the cited dependence of the division values on temperature. This dependence is deduced from the measurements on the examinator under conditions enabling the level to assume the temperature shown on the examinator. At carrying out measurements on he VC one reads off the air temperature in the pavilion which sometimes may differ considerably from the true temperature of the level. One thing is certain: the range of level temperature fluctations during the year is undoubtedly narrower than the one of the air temperature fluctuations in the VC pavilion. Therefore, unless in the future work data on the level temperature are secured, the values specifying the level division dependence on temeprature is perhaps to be somewhat scaled down (by about 0.7 times in our free estimate). In addition to the need of being clear about this temperature matter one is advised to perform, in the future too, measurements designed for keepeing under control the value of the level division. The intricate nature of our levels, brought to light by these investigations, makes it necessary in the future work that our measurements be evenly distributed along the entire working range of the level graduation.

5. CONCLUSIONS

1. From the present work it appears that the level division as determined from the measurements on the examinator may differ considerably from the one furnished by the measurements on the instrument itself, involving therewith appreciable – depending on the amount of instrument's inclination – random and systematic errors in the star zenith distances, i.e. in star declinations and local latitudes. Moreover, the investigation on the examinator is a delicate and laborious undertaking (Teleki et al., 1968) only rarely carried through. Nevertheless, the measurements on the examinator are capable or rendering good sevices in investigating and studying diverse sources conditioning the angular division value to be variable.
2. It is demonstrated by our investigations that the level division may successfully be determined on the instrument itself and that, moreover, level examination in general is thus practicable. One should thereby adjust more rigorously than we did, the organization of measurements to the desired purpose (investigation – one clamp position of the instrument but even distribution of the bubble middles along the working range of the level graduation; calibration of the angular value of the level division – reversing (E – W) the instrument with the use of two mercury horizons).
3. An old rule has once again been reaffirmed by this determination of the angular value of the level division on the instrument itself: by an investigation

under conditions close to those under which regular star observations are carried out, quite fitting results are obtained.

4. Being given that both levels in such investigations on the instrument itself are sumultaneously treated, the furnished division values are mutually harmonizing, which implies that their possible errors are essentially equal. This has its bearing in the case a systematic error has been found in a prolonged observing run, having its origin in the levels, i.e. in the adopted division value. It may then easier be deduced and the results of observation corrected for its amount thanks to its affecting both levels equally.
5. It is our view that the actual measurements are fairly well representable by formulae (1) and (4). The same formulae allow these measurements to be corrected for effects of the systematic irregularities in the ampule sliding surface and the level graduation. The complexity of these formulae does not at the present time involve any trouble in veiw of the modern computing facilities, concerning both the determination of the coefficients and the reduction of the actual astronomical observations.
6. Striving after keeping the inclination as small as possible by properly adjusting the instrument is to be continued. The mean values of the inclinations from several observations of the same star at least should be close to zero.

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NEW DOUBLE STARS DISCOVERED AT BELGRADE OBSERVATORY WITH THE ZEISS REFRACTOR 65/1055 cm

SUPPLEMENT VII

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SUMMARY Reported are positions and measurements of 32 new double or multiple systems discovered in Belgrade with the ZEISS refractor 65/1055 cm.

The present Supplement comprises 32 new double or multiple systems, listed in Table 2. These systems have in part been discovered in the process of systematic checking of BD stars in the zone +34° to +44° declination, and in part in the course of measurements of my earlier discovered systems or systems from the Belgrade standard programme.

Table 1. Distribution of the systems according to ρ

Suppl.	$\rho<1''$	$1''\leqslant\rho<3''$	$\rho\geqslant3''$	Σ
I–VI	18	51	84	153
VII	1	12	19	32
I–VII	19(10,3%)	63(34,0%)	103(55,7%)	185

19 systems from Table 2 with $\rho < 4''$ are published in Circulars of IAU Commission 26.

9 systems in Table 2 have BD number, indicating their composite brightness to be above 9^m5. The rest of the systems are fainter.

It is worthwhile to point out the position of the system GP 192. This system, with components at $\rho = 2''.7$ separation and preliminary brightness estimate at 11.0 – 11.5, is at scarce 2' distance west of the familiar planetary nebula NGC 6720 in Lyra. The proximaty of this pair to the well known nebula is likely to contribute to its being measured more frequently than others.

Table 1 displays distribution of the systems according to ρ separately for the present Supplement and separately for all of them published previously.

The Supplement VI is published in Bull. Obs. Astron., Belgrade, No 131, in 1981.

Table 2. New double stars

Double star	1900 α 1950 δ 2000	t	θ	ρ	m or Δm	mgf.	W	BD $\Delta\alpha$ $\Delta\delta$	C.I. UAI Comm. 26
GP 158	00104N5156 00130N5212 00156N5229	80.709	186°.6	3''.12	11.0–11.1	500	1+1	+51°32(9^m5) $\Delta\delta$ = – 4'	85
GP 182	00305N4255 00332N4312 00358N4331	79.673	289.3	5.47	11.0–13.0	500	1+1	+42°110(9^m1) $\Delta\alpha$ = –7s, $\Delta\delta$ = –3'	
GP 181	00312N4238 00338N4255 00365N4311	79.673	106.4	5.77	11.8–12.6	500	1+1	+42°112(9^m5) $\Delta\alpha$ = +17s, $\Delta\delta$ = +1'	
GP 183	01135N3824 01163N3840 01191N3856	82.735	117.2	8.17	10.0–10.1	590	1+1	+38°236(9^m5)	

Table 2. (continued)

GP 178 AB	01214N4254	83.745	268.4	1.35	9.7–10.0	700	1+1	+42°307 (9$^m_.$5)	91
	01243N4310	85.757	266.2	1.26	10.0–10.0	500	1+1	$\Delta\alpha$ = –18s, $\Delta\delta$ = –2'	
	01260N4326	**84.751**	**267.3**	**1.30**	**9.8–10.0**		**2n**		
AC		83.745	248.4	20.9	9.7–10.0	700	1+1		
GP 180	02014N4237	83.8[illegible]2	141.1	5.18	11.0–12.0	700	1+2	+42°446(8$^m_.$6)	
	02044N4251								
	02075N4305							$\Delta\delta$ = +3'	
GP 162	02205N4104	80.829	95.3	1.54	12.0–12.2	590	1+2	+40°517(8$^m_.$2)	85
	02236N4118								
	02267N4132							$\Delta\alpha$ = –35s,	
GP 163	02217N4102	80.829	53.	2.5	13.0–13.2	590	1+1	+40°522 (8$^m_.$8) = ADS 1895	85
	02248N4116								
	02279N4129							$\Delta\alpha$ = +13s	
GP 161	02267N4224	80.829	265.5	2.	12.5–12.6	590	1+2	+42°547(9$^m_.$0)	85
	02298N4238								
	02330N4251							$\Delta\alpha$ = –10s	
GP 174	03220N4022	82.896	95.	5.	4.0	560	1+1	+40°759(9$^m_.$5)	
	03253N4033	82.902	100.7	7.66	9.5–13.0	560	1+1		
	03286N4044								
GP 173	03223N3953	82.896	76.1	2.74	13.0–13.0	590	1+1	+39°790(7$^m_.$3) =	91
	03256N4004	85.727	70.7	2.85	12.5–12.8	500	1+1	= ADS 2553	
	03288N4014							$\Delta\alpha$ = 2s, $\Delta\delta$ = +2'	
GP 169	05294N4304	82.129	44.4	0.69	10.0–10.3	590	1+1	+43°1312(9$^m_.$4)	88
	05330N4306	82.189	48.8	0.71	10.0–10.2	590	2+1		
	05366N4309	**82.165**	**47.0**	**0.70**	**10.0–10.2**		**2n**		
GP 166	17064N4047	84.675	281.7	5.98	9.5–13.5	500	1+1	+40°3109(5$^m_.$2)	
	17080N4043	85.363	280.7	5.96	9.0–12.0	700	1+1	$\Delta\alpha$ = +6s, $\Delta\delta$ = –7'	
	17097N4039	85.366	279.3	5.80	9.0–12.0	700	1+2		
		85.168	**280.4**	**5.90**	**9.2–12.5**		**3n**		
GP 175	17280N3538	83.482	33.6	5.77	9.0–12.0	590	1+1	+35°2994(9$^m_.$1)	
	17298N3535	83.583	33.3	6.00	9.0–14.0	590	1+1		
	17316N3533	**83.532**	**33.4**	**5.88**	**9.0–13.0**		**2n**	$\Delta\alpha$ = –4s, $\Delta\delta$ = –3'	
GP 152	18277N3443	78.570	317.	2.	13.3–13.0	590	1+1	+34°3225(8$^m_.$7)	79
	18295N3445	80.640	314.0	2.78	13.0–13.2	420	1+2	$\Delta\alpha$ = +2s, $\Delta\delta$ = –2'	
	18313N3447	84.580	314.2	2.82	13.0–13.3	500	1+2		
		82.610	**314.1**	**2.80**	**13.0–13.2**		**2n**		
GP 192	18496N3255	85.705	33.8	2.85	11.0–11.5	500	1+1	NGC6720	98
	18515N3259	85.754	34.7	2.50	12.5–13.0	500	1+1	$\Delta\alpha$ = – 16s, $\Delta\delta$ = +1'	
	18533N3302	**85.730**	**34.2**	**2.68**	**11.8–12.2**		**2n**		
GP 171	19590N3739	82.614	295.9	1.07	10.0–10.7	590	1+2	+37°3735(7$^m_.$0)	88
	20008N3747	82.652	295.9	1.06	10.0–11.0	590	2+1	$\Delta\alpha$ = –7s, $\Delta\delta$ = +7'	
	20026N3755	**82.633**	**295.9**	**1.06**	**10.0–10.9**		**2n**		

Table 2. (continued)

GP 193	20009N3434	85.705	97.8	3.98	9.5–11.5	500	1+1	+34°3862(8$^m_.$6)	98
	20028N3442								
	20047N3451							Δα = +11s, Δδ = –9'	
GP 185	20023N3804	82.614	259	2.	12.0–12.0	590	1+1	+37°3762(9$^m_.$5)	96
	20041N3813	84.675	261	2.	–	500	1+1		
	20060N3821	85.639	272.5	2.12	13.0–13.5	500	1+1	Δα = +10s, Δδ = –0.5	
GP 189	20037N3721	84.675	329.5	7.09	10.0–12.0	500	1+1	+37°3774(8$^m_.$3)	
	20055N3729	85.634	329.2	7.22	10.0–12.0	500	1+1		
	20073N3738	85.639	328.2	7.17	–	500	1+1	Δα = –8s, Δδ = –0.5	
		85.748	327.2	6.68	12.0–13.0	500	1+1		
		85.424	**328.5**	**7.04**	**10.7–12.3**		**4n**		
GP 191	20038N3734	85.639	64.3	3.78	–	500	1+1	+37°3774(8$^m_.$3)	98
	20056N3743								
	20074N3751							Δδ = +13'	
GP 187	20038N3802	84.675	92.7	4.70	10.0–11.0	500	1+2	+38°3910(8$^m_.$9)	
	20056N3810	85.642	90.7	4.78	10.0–11.0	500	1+2		
	20074N3819	**85.158**	**91.7**	**4.74**	**10.0–11.0**		**2n**	Δα = +5s, Δδ = –9'	
GP 188	20039N3732	84.675	60.6	3.68	10.0–12.0	500	1+2	+37°3775(9$^m_.$0)	98
	20057N3740	85.642	68.6	3.68	10.0–12.0	500	1+1		
	20075N3749	**85.062**	**63.8**	**3.68**	**10.0–12.0**		**2n**	Δδ = +12'	
GP 190 AB	20040N3652	84.675	189.9	4.37	11.0–13.0	500	1+1	+36°3884(9$^m_.$5)	98
	20059N3700	85.642	187.1	5.42	10.0–12.0	500	1+1	Δα = +15s, Δδ = –1'	
	20077N3709	**85.158**	**188.5**	**4.90**	**10.5–12.5**		**2n**		
AC		84.675	230.	81.5	11.0–12.0	500	1+1		98
CD		84.675	309.6	3.38	12.0–13.0	500	1+1		98
		85.642	307.2	3.89	11.0–12.5	500	1+1		
		84.158	**308.4**	**3.64**	**11.5–12.8**		**2n**		
GP 157	20505N3603	80.634	224.1	3.24	11.8–13.0	500	1+1	+35°4313(9$^m_.$5)	85
	20524N3614	80.651	228.4	3.27	12.0–13.0	500	1+1	Δα = –4s, Δδ = +10'	
	20544N3625	80.656	228.1	3.98	12.5–14.0	420	1+1		
		80.647	**226.9**	**3.50**	**12.1–13.3**		**3n**		
GP 170	21119N4110	81.770	79.0	1.36	10.0–11.5	590	1+1	+41°4062(8$^m_.$7)	88
	21138N4122	82.652	75.2	1.24	11.0–12.0	590	1+1	Δα = –25s, Δδ = –3'	
	21157N4135	**82.211**	**77.1**	**1.30**	**10.5–11.8**		**2n**		
GP 186 AB	21131N4115	84.599	298.9	10.39	9.0–10.0	500	1+2	+41°4071(9$^m_.$2)	
	21150N4127	84.681	299.0	9.92	9.5–10.0	500	1+2		
	21169N4140	**84.640**	**299.0**	**10.16**	**9.2–10.0**		**2n**		
AC		84.681	131.4	60.4	–	500	1+1		
CD		84.599	91.2	3.92	10.5–11.0	500	1+1		
		84.678	90.2	4.45	11.5–12.0	500	1+2		
		84.681	89.7	4.11	11.5–12.0	500	1+2		
		84.683	91.0	5.00	12.0–12.5	590	1+1		
		84.664	**90.4**	**4.35**	**11.4–11.9**		**4n**		

Table 2. (continued)

GP 184	21501N4238	82.742	245.8	–	–	590	1+1	+42°4244($9^m.2$)
	21521N4253	84.787	242.9	10.99	9.0–10.0	500	1+2	
	21541N4307	**83.969**	**244.1**	**10.99**	**9.0–10.0**		**2/1n**	
GP 165 AB	22147N4155	80.900	265.5	38.1	8.7–10.0	700	1+1	+40°4778($9^m.2$)
	22169N4110							
	22190N4125							
BC		80.900	32.8	2.13	10.0–11.5	700	1+1	
GP 176	22202N4212	84.788	100.7	11.91	9.5–11.0	500	1+1	+41°4483($9^m.5$)
	22224N4227							
	22245N4242							
GP 177	22219N4157	83.706	312.4	7.17	9.5–12.0	500	1+1	+41°4498($9^m.4$)
	22241N4212	84.788	316.7	6.14	9.5–12.0	500	1+1	
	22262N4227	**84.247**	**314.6**	**6.65**	**9.5–12.0**		**2n**	
GP 172	23383N4240	82.653	348.8	1.21	10.0–10.2	590	1+1	+42°4741($8^m.3$)
	23407N4256	83.896	354.4	1.17	0.1	590	1+1	
	23432N4313	**83.274**	**351.6**	**1.19**	**0.2**		**2n**	$\Delta\alpha = +13s$, $\Delta\delta = -1'$

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SOLAR AND STELLAR ACTIVITY PHENOMENA

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SUMMARY. A review is presented of highlights in the solar and stellar activity researches based on laterst information, published in the works of other authors, and on the measurements carried out at the Belgrade Observatory.
New assumptions are advanced concerning discrete magnetic solar field of 1–2 KG strength in tubes of 200–400 km diameter. Dependence is outlined of the stellar rotation rate and magnetic activity on stellar age. It is demonstrated that stars with covective zone display magnetic activity which in some of the stars is cyclically repetitive.

INTRODUCTION

It is no overstatement saying that the astrophysicists's conceptions of stellar activity did thoroughly change after 1980. Two problems were conjointly being solved during seventies:

1) The problem of the solar magnetic field and
2) The problem of the atmospheric mass losses in the stars.

Two seemingly unrelated problems worked on by a score of people for full ten years. The solution of both problems came about simultaneously and as if only Wilson's paper (1978) was awaited to realize that all these were but links of a chain called: stellar activity. The scientists interest in the problems of stellar dynamo and activity was revived; that is, in those fundamental problems to which astrophysicists are returning over and over again – now perhaps on a fair way to get them solved. We will mention only some of the authors whose works are of particular importance for this problem. Apart from currently so often cited Wilson's paper, these are: Skumanich (1972), Deubner (1975), Linski and Ayres (1978), Parker (1979a and 1979b, Robinson 1980 and Hall (1981).

Satellite measurements of the ultraviolet and X radiation with the aid of IUE and Einstein Observatory marked (1978) the beginning of the golden age in the stellar astronomy. All this prompted solar and stellar researchers to get out of their isolation and to join their forces in seeking solution to the problem.

Solar physics abounds in evidence highly valuable for the stellar exploration but as if the scientists were lost in deatils.

Stellar astrophysicists, again, as if they were forgetting the sun to be also – a star. However, what inspires encouragement that the situation is going to change are joint researches and scientific meetings bringing together, after 1979 in particular, both the solar and stellar astrophysicits around the same problems. Joint efforts are already yielding results, although these still are only qualitative.

Thus, the following „scenario" was suggested for the stellar activity:

Stellar rotation and convection through dynamo mechanism generate the surface fields. Convection produces chromosphere and corona, while their structure is maintained by the surface fields. The stellar wind leaves such corona, „starched" by the magnetic field, at distances greatly exceeding the stellar radii. This, in consequence, involves the loss of considerably larger angular momentum whereby the rotation is slowed down, the dynamo and surface field are weakened, therewith the stellar activity as well.

We will try to systemize the information on the stellar activity in the following order:

I Stellar activity theoretical foundations
1) Solar activity, the role of the magnetic field and convective zone
2) Atmospheric mass losses and Scumanich's relation

II Detection methods and observing results
1) Methods of detection of stellar magnetic field and activity
2) By what right do we translate our insisths in the Sun to the stars?
3) Observations of stellar magnetism and activity (examples from literature and measurements of our own at the Belgrade Observatory)

Instead of conclusions – lines of further researches:
A: Solar physics
B: Stellar physics

STELLAR ACTIVITY THEORETICAL FOUNDATION

I – 1) Solar activity, role of the magnetic field and convective zone

Solar activity's basic property is its quasi–periodical cycle, the course of which is attended by all the genres of activity, most important of which being: **spots, faculae, active prominences** and **flares.** These activity phenomena are all located in the active regions, representing vertical structure of the horizontal inhomogeneities. The activity forms just mentioned and many more others (pores, loops, spiculae, arcs, bright spots, knots, coronae, holes and so on, and so forth) are visual manifestations of the magnetic field at different levels. Accessible to measurement through Zeeman effect, from among all of these, appears only the strong local field inside an active, and averaged one inside a quiet, atmosphere. As to the magnetic field as the prime cause of all the forms of solar activity, the scientists set it out during seventies as on imperative to explore it more closely. The problem associated with the measuring of the solar magnetic field consists in the deficient resolving power of contemporaneous magnetometers, failing to resolve details in the photosphere lesser than 700 km.

The magnetic field is generated through the dynamo mechanism deep inside the convective zone, whereupon, in consequence of the vertical motion, it „sloshes out" to the surface. By way of a veritably detective work of a number of theoreticians of whom we quote but some: Frazier and Stenflo (1972), Giovanelli (1977), Spruit (1977), Zwaan (1978) and Parker (1979a and 1979b) wholy unexpected results were reached. Instead of a relatively homogeneous and weak magnetic field of 1–2, maximum 10 gauss strength outside of active areas, a strong magnetic field was uncovered of 1 to 2 x 10^3 G, concentrated inside the so called „magnetic tubes" of 200 to 400 km diameter. These magnetic tubes are mutually insulated by plasma having no magnetic field, on much larger scales (10–100 times) than are diameters of the „magnetic tubes".

In consequence of the strong magnetic filed within the tubes the motion is supressed, hence these are stable, „magneto–static" as if frozen inside the photospheric plazma. They are believed to be distributed along the S.G. cells of the photospheric field. This is about all presently known about the discrete strong field of the quiet photosphere. It is only better resolving power of the magnetometer that may help exploring the fine structure of this discrete magnetic field. It is for the time being unknown what kind of force transcended the density of the photospheric plasma's kinetic energy ($1/2\ \rho\ v^2$), concentrating and supressing the magnetic tubes, calling forth phenomena known as the solar activity. So active regions are currently defined as associations of the magnetic tubes.

Any star with the convective zone probably posseses such a discrete surface magnetic field. And what stars were having convective zone?

For stars on the zero line of the main H–R sequence the convective zone thikness depends on the radius and spectral class. Without any convective zone are the O, B, A to F_2 class stars, this zone getting ever wider as it is proceeded towards the late class stars. In the G class it reacheds 20% to 30% R, extending over the entire envelope in the M class. The convective zone's thickness is changing. What reason makes the convective zone in the stellar envelope that important?

a) It is within it that magnetic fields are formed or strengthened (non–linear dynamo theory);
b) It is by convection taht the chromosphere and corona are created, maintained and heated by way of transfering the matter, energy and magnetic field through the envelope.
c) A smaller fraction of energy and momentum leaves this zone in the form of waves generating surface velocity field, p – mod (Deubner, 1975; 1979).

By these compression waves we are, for the time being, accorded the sole, means of studying the solar interior – solar seizmology. Measurements of the photospheric five–minute oscillation, extended onto global scales and long, continuous 120 hour series (Grec et al., 1980) allowed the thickness of the convective zone (dc) to be calculated from compression vaves. Results of several authors after 1980 are on the whole accordant around the value dc ≈ 30% R; this is consistent with the theoretical evaluations. Much is expected from this method. It enables solar interior to be studied, which the elctro–magnetic waves were unable to offer.

By the interaction of the solar rotation and convection there takes place differential rotation (D.R.), which on the surface can be measured but its change with depth remains unknown. The theoretical dynamo models are all dependent on Rossby's number, itself a function of the angular velocity, i.e. which we fail knowing even for the sun, let alone for the stellar interiors. With the aid of solar seizmology Fossat (1981) established taht 30000 km within the convective zone the velocity increased with depth.

The fact that the rate of rotation of the solar interior is still unknown should not be found astronishing as it is only recently that the mechanism of the sharp deceleration of the solar envelope was uncovered.

I – 2) Atmospheric mass loss and Skumanich relation

This is one of the basic problems which the stellar astrophysics has been trying to solve during seventies, making use of insights into solar corona structure. Magnetic filed carried by convection pervades all the stellar envelopes, maintaining the corona structure by means of the closed and open fields. **The closed magnetic field** through its arcs and loops, maintains the configuration of hot plasma in the corona ($T \geqslant 10^6K$). **The open magnetic field** along whose lines of force the solar wind is flowing out and cooling corona, is manifested as „holes" in the corona (Skylab, 1975). In the course of rotation the solar wind leaves the corona at a distance (R_A) much greater than the solar radius (R_0)

$$R_A \approx 20\, R_0$$

R_A – is called Alfven's radius, being a function of the magnetic field strength.

At Alfven's radius distance the rate of mass loss is a good deal higher owing to the angular momentum being strouger. Therefore, in a star having convective zone and surface fields (magnetic and velocity ones) the rotation of its envelopes is slowed down relatively more rapidly. Slower rotation weakens the dynamo, which in turn generates weaker magnetic field, all resulting in the stellar activity being diminished.

Following this idea, tested on a minor number of the main sequence stars, Skumanich advanced in 1972 the empirical relation: „the rates of stellar rotation and magnetic activity decrease with the stellar age as $t^{-1/2}$". This in recent time so offen quoted relation can graphically be illustrated as in Fig. 1.

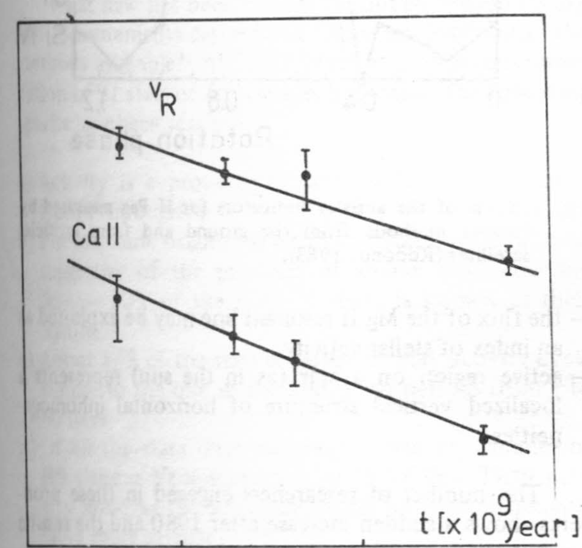

Fig. 1. Relative variations in the rate of rotation V_r and in the calcium emmission flux Ca II with the age $v_r \sim t^{-1/2}$ for some stars (Skumanich, 1972).

Measurements executed in 1972–84 confirmed this relation of Skumanich to which, if confirmed on a greater number of stars, the importance of fundamental relations in astrophysics is predicted.

Apart from inferring the age from the rate of stellar rotation, this relation might be helpful in clearing up the problem: is the Sun having that activity level which is in harmony with its age.

On anslysing Skumanich's relation Whitehouse in 1983 put out an original idea according to which the young sun has been a lot more active than at present, having emitted x–radiation thousand times more intensely. This radiation, in hitting the earth, precluded the life from coming into being all through until in due course the activity level had significally droped. This is an interesting idea indeed, needing confirmation.

DETECTION METHODS AND OBSERVING RESULTS

II – 1) Methods of detection of stellar magnetic field and activity

The most commonly used indexes of solar activity are the relative sunspots number (Wolf number) and the magnetic field intensity in terms of Zeeman effect. These indexes cannot, for the time being, be employed with the stars, being particularly inadequate with the late spectral class stars. This is just why particular importance is assigned to the new method of calibrating magnetic field known as:

1. Robinson method (1980). Although it is workable with only bright and highly active stars, the method is valuable for scaling other, less direct methods of measuring activity, such as:
2. Broad band photometry by which temporal intensity variations of the photospheric continuum attributed to the stellar spots and faculae is measured. The solar flux constancy (solar constant) is accounted for by the extremely minor replenishing factor (0.01–0.02 for the Sun; 0.4–0.8 for stars) entailing the variation effect to be below detectability.
3. Spectroscopic methods proved to be highly valuable for detecting solar activity, especially via strong resonant lines Ca II and Mg II in the optical spectral domain. Since linear correlation has been established in the Sun between these lines's intensity and the magnetic field strength, both of them are accepted as **indexes of stellar activity**.
4. IUE and Einstein Observatory. Satellite measuring of the ultraviolet radiance emanating from the transition regions via C IV and Si IV lines, and detection of X–radiance from the Einstein Observatory disclosed a large number of cool stars as having hot coronae $T \geqslant 10^6K$. Successful measurements of the ultraviolet and X–radiations from these two spacecrafts marked the beginning of the stellar astronomy's „golden age".
5. VLBI microvave radio–measurement. It is only since recently (Gibson, 1980, Gary and Linsky, 1981), as a result of refining new observing technique (VLBI) that began in more earnest the radio astronomers's concern with individual stars. Thus was initiated the

study of active phenomena in the stars by monitoring the increased radiation (radio–impulses) within cm–range. The impulses take from a few minutes to several hours, displaying peculiar pattern. The circularly polarized radio–radiance (80–90%) is suggestive of a coherent non–thermal mechanism. It is from this evidence that the strength of the magnetic field (10^3 G) was inferred.

II – 2) By what right do we translate our solar insights to stellar activity

Until 1970 the answer to the question thus posed had been: no other choice is left while at the same time we happen to possess a wealth of observational material on the solar activity. As the strong resonant line Ca II in the Sun is a good activity indicator (Fig. 2), it started being used as an index also of the stellar activity, without any more serious arguments being forwarded. It is only by satellite measurements that a confirmation was provided of the soundness of using this line as an index of the stellar activity. The result announced by Rodono in 1983 made world round in a short time (Fig. 3).

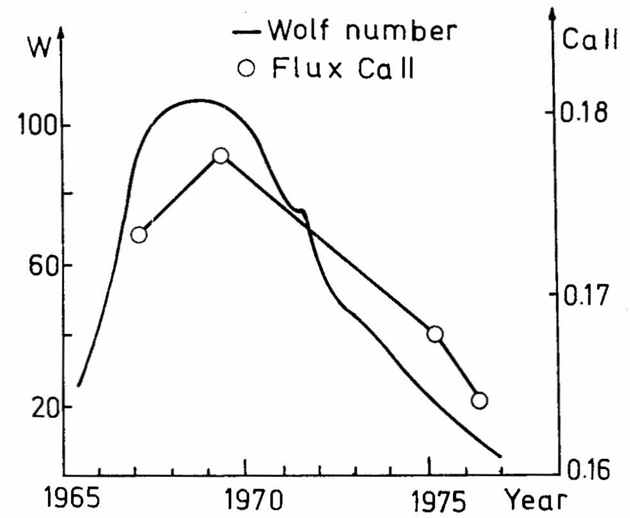

Fig. 2. The number of sunspots and the emission line Ca II as fine indicators of the activity cycle (Wilson, 1978).

It is apparent from Fig. 3 that:

- modulation of the photospheric brightness is present in rhythm with the stellar rotation, presumably due to the „starspots".
- the increased intensity of lines originating in the chromosphere, transition regions and corona, corresponds to the minimum photospheric brightness (accordance of indexes resulting from 2, 3 and 4 methods.

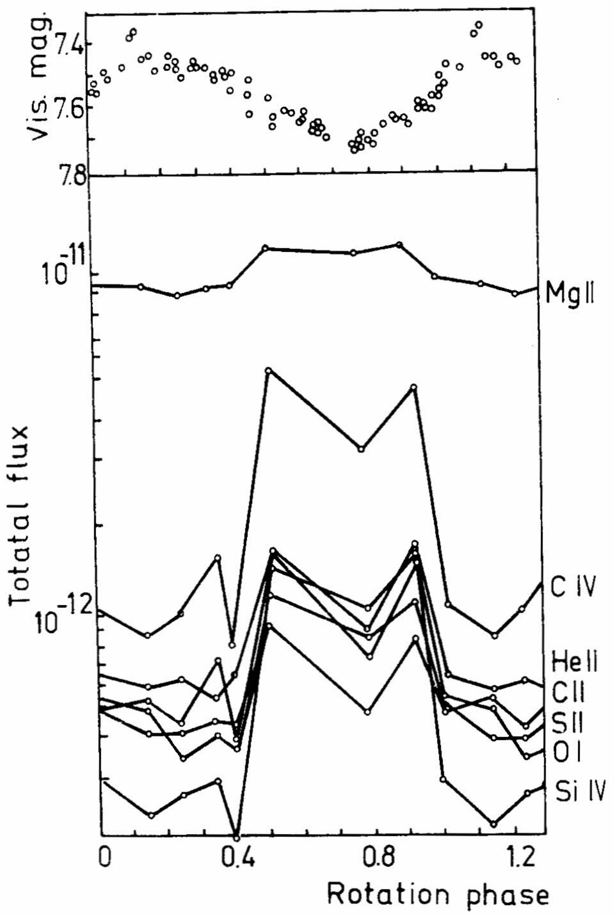

Fig. 3. Some of the activity indicators for II Peg measured by various methods from the ground and from artificial satellites (Rodono, 1983).

- the flux of the Mg II resonant line may be exploited as an index of stellar activity;
- active region on a star (as in the sun) represents a localized vertical structure of horizontal inhomogeneities.

The number of researchers engaged in these problems shows a sudden increase after 1980 and the results are not missing.

II – 3) Stellar magnetism and activity observations

Prior to Wilson s{paper (1978) it was maintained that the activity was a property of some stars only. These, apart from the sun, were

- UV Ceti stars and
- eruptive dwarf–novae

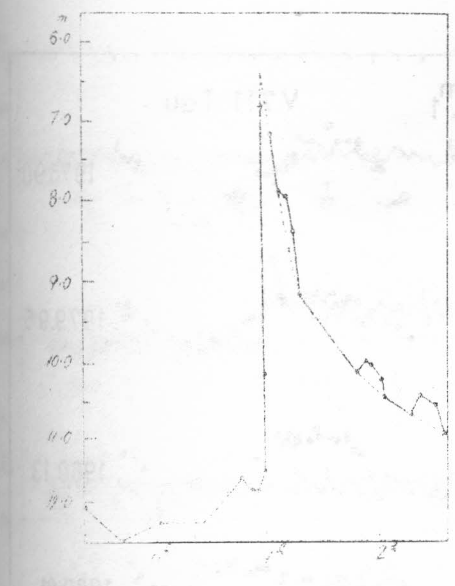

Fig. 4. The outburst of the UV Ceti star (Oskanjan, 1964).

We take as an example the outburst of UV Ceti star registered on 25 Sept. 1952 at the Belgrade Observatory by V. Oskanjan. It was the most violent outburst ever observed on a star (Fig. 4).

What new has been brought about by Wilson's work and measurements carried out following 1980 by all the methods available? After 17 years of continuous observation of 91 stars of diverse spectral classes the following results have been reached:

a) Activity is a property of stars of late spectral class from F through M.
b) Photospheric brightness exhibits rotation modulation suggestive of the presence of stellar spots covering 30% – 50% of the disk. Nothing is known of their nature.
c) About 1/3 of the stars observed display activity cycle similar to the one in the Sun, with periods from 5 to 60 days
d) Of all the stars observed most active are binaries of RS Canum Venaticorum type (RS CVn). Their activity mimicks the solar one, being however incomaparably more intense.

Results of stellar activity observations are shown in Figure 5, 6 and 7.

It transpired from Fig. 5 that the activity is not displayed by the early O–B–A spectral class stars, but by the late F–G–K–M stars, whereby by both main sequence stars (the Sun among them) and those having separated from the main sequence: subgiants, giants and supergiants. This was a surprising result for all those who, in view of the strong magnetic field of changing

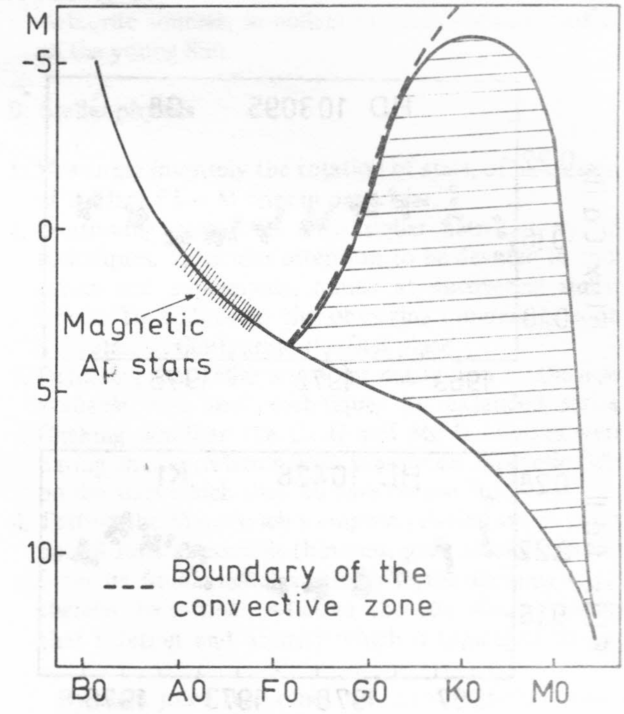

Fig. 5. Activity similar to that of the Sun measured on the stars having convective zone (hatched area in H–R diagram) (Zwaah, 1981).

character, expected the activity to be a property of the so called magnetic A_p class stars. However, the mere presence of the magnetic field is not a sufficient condition for an activity. It has been registered in those very stars of late F–M class in which it is not until 1980 that a magnetic field was measured. This accounts for the result having been unexpected to many. However, provided Fig. 5 is closely inspected and the boundary of the convective zone recognized, the result should not appear as a surprising one. After 1980, using Robinson's method, the magnetic field was measured in the F–M class stars of about 2 x 10^3G strength, of nearly constant intensity, covering about 10% to 30% of the stellar disk. Many of these stars display activity typified by increased Ca II emission or radiation or else by photospheric brightness modulated through rotation. In some of them there is an unmistakable activity cycle (Fig. 6).

Still few are stars whose activity was recorded by all currently available methods. One such is V 711 Tau (HD 1099) (Fig. 7). It has been established from aboard Einstein Observatory that both components (G5 + K1) were having hot coronae T = 10^7K, while VLBI radio measurements at 2.8 cm and 6 cm over five years (1978–82) disclosed this star to be the strongest yet recorded source of the non–thermal microwave radio–

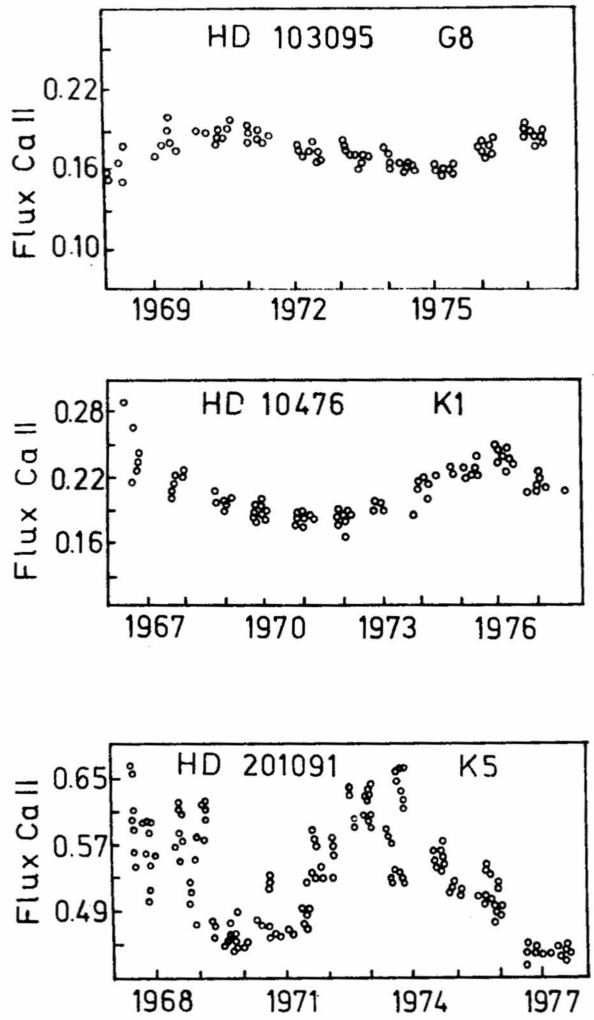

Fig. 6. Samples of stellar activity cycle (Wilson, 1978).

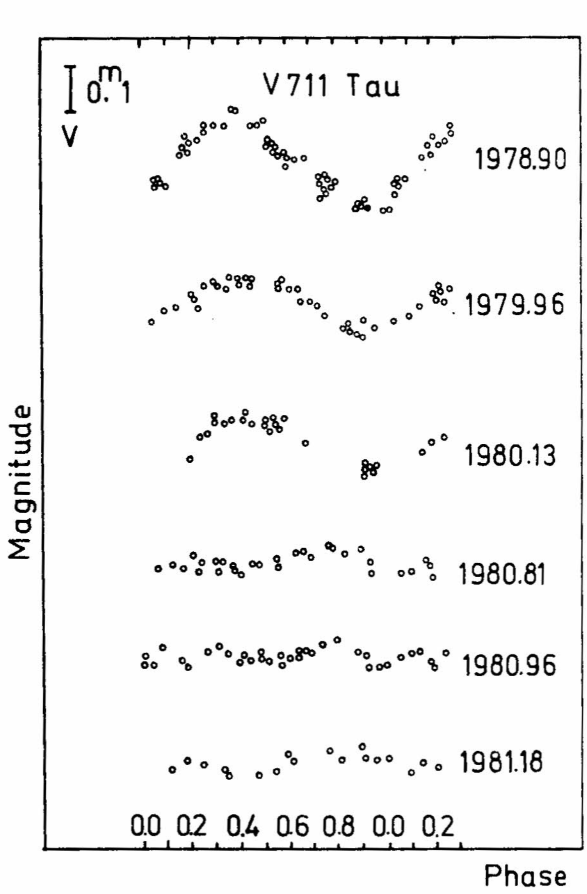

Fig. 7. Variation in the photospheric brightness in the star V 711 Tau (HD 1099) as a consequence of the star's rotation in the course of its activity cycle (Rodono, 1983)

radiation. This radiation exhibited a cyclic pattern with maximum intensity in 1978 (1 Jy), which is in conformity with the photometric measurements.

Such a complex exploration of activity in a star is of major importance for infering true nature of the stellar spots and active regions.

Cool giants and supergiants of G–M class are stars in which, having regard to Fig. 5, one would expect activity, but for which observational data are extremely scarce. For exactly this reason the result acquired at the Belgrade Observatory (Arsenijević, 1985) constitutes a very valuable contribution. Namely, the star μ Cep., a cool, red supergiant, was observed photometrically in the V region (method 2). On August 2, 1981 an outburst was recorded on this star of some 20 minutes duration. As apparent in Fig. 8, the outburst followed a typical course: a violent rise and slow decline of intensity. The monitoring was performed by an automatic photoelectric polarimeter, 100 times more sensitive than the one with which the 1952 outburst was recorded at this same Observatory. The calculated flux strength of μ Cep amounts to 10^{31} J s^{-1}, which is between the strongest solar outbursts (10^{25} J s^{-1}) and the outburts in novae (10^{38} J s^{-1}). According to an estimate of change in the photometric brightness of this same star (Djurašević, 1981; Polyakova, 1982) the outburst took place near minimum phase of its cycle.

INSTEAD OF CONCLUSIONS – LINES OF FURTHER RESEARCHES

The years ahead will see the picture presented here completed by data from observations so that it will become a quantitiative one. Then the theory, too, will

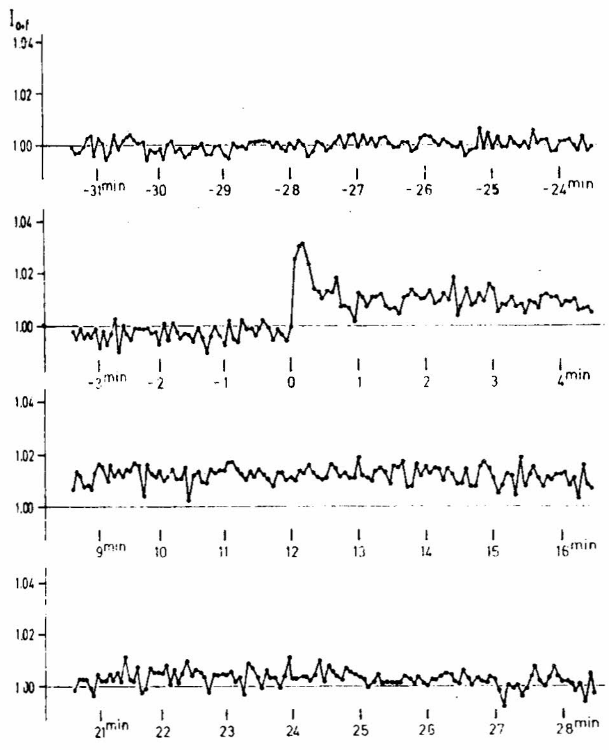

Fig. 8. The flare in the cool suprgiant Mi Cep (Arsenijević).

presumably provide some amendments or, posisbly, minor modifications but the basic picture's structure is likely to remain unaltered. It is already now evident which course will the researches take.

A. Solar physics

1. Solar magnetism forming the pith of the solar activity, the nead appears for the magnetograph resolving power to be increased so as to enable us to „see" the fine structure of the surface magnetic fields and to understand the nature of the magnetic tubes, bright points, knots etc. In other words – the descriptive terminology is to be replaced by a physical one.
2. Exploring the photospheric large scale velocity field (S.G. – cells, giants, meridian circulation, D.R.) their dependence on activity cycle in particular.
3. Thorough study of the coronal structure, plasma motion within open and closed magnetic field. finding out the energy sources of the solar wind accelaration.
4. Greates possible attention to be devoted to the solar rotation, alike the surface and the depth rotation. Making use of solar „seismology" new methods to be developed that would allow solar core below 0.6 R to be tested on whether it was rotating twice as fast as the surface.
5. Making use of the geophysical, planetary, lunar and meteorite sources, to collect as much data as possible on the young Sun.

B: Stellar physics

1. Measuring intensely the rotation of stars, of all classes, of the late F5 – M ones in particular.
2. Continuing researches into stellar activities by all techniques. Particular attention to be devoted to cool giants and supergiants, aimed at uncovering stellar winds. To include in the observing programme southern stars, α Centauri in the first place.
3. Detecting the stellar and solar magnetism by the now available and new techniques by extended series. Cheking whether the Ca II and Mg II indexes were having that correlation with the surface magnetic field on the stars which they do have on the Sun.
4. Testing the Skumanich's empiric relation on as many coeval stars as possible (binaries, open clusters). Apart from its fundamental significance, the dilemma would thereby be settled: whether the Sun was possessing that rotation and activity which is typical of its age.

By such joint researches the astrophysicists expect to solve the problem of stellar activity as a general feature of a large number of stars at a particular evolution stage.

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PRESENT-DAY POTENTIALITIES OF REFRACTION INFLUENCES DETERMINATION AND PERSEPCTIVE DEVELOPMENTS

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ABSTRACT: A critical survey and analysis is presented of those questions that are of acute interest in the astronomical refraction investigation. Special weight is accorded to the development and the present accuracy in the refraction determination as well as to the prospective ways of its further improvement. Regarding futher development put under scrutiny are: implementation of more accurate formulae in the refraction calculus; introduction of atmospheric models better matching the reality; accounting for the refraction influences within an instantaneous meteorological field; instrumental determination and the supression of refraction influences; prevention and more rigorous turning to advantage of the laws governing the radiation propagating. The effects associated with the radio refraction are discussed separately. The conclusion is derived that a marked accuracy improvement in the determination of the refraction influences might be expected in the years ahead.

1. INTRODUCTION

The radiation undergoes changes at its transmission from its source (celestial body) to the observer (registering instrument) at the Earth's surface. At its traveling through the inhomogenous media as: the interstellar and the interplanetary ones, the atmospheres of the parent star and around the Earth, including the observing optics, the radiation gets changed through the interaction with the medium traversed. Physical characteristics are modified and – of particular importance in astrometry – propagation direction.

The laws governing the radiation propagation are not known with full certainty. That is why one cannot speak but of approximation, i.e. of approximations to the actual propagation, since it is considered not integrally but by its portions. Because such a dependable pointer is lacking, formidable difficulties are met at weighing the trustworthiness of some radiation feature, this particularly if some of its general properties is dealt with. The same applies to the direction changes.

All this should, as a matter of cause, be kept in mind at examining the accuracy in refraction effects determination. The uncertainty is present not only at evaluating some – be it termed–absolute accuracy but equally so at confronting different methods by which it is determined.

In connection with the refraction determination one should be aware of the fact that currently only the effects of the Earth's atmosphere and the telescope optics and the registering equipment are accounted for. These, in all likelihood, are the most essential, but when the accuracy improvement is at stake, the quest of other potential effects is required.

The complexity of the refraction phenomenon is equally to be kept in mind. It is relevant in this respect to refer to the papers of Kolchinskij (1984; 1986) in which the author's conclusion is exposed of the refraction fluctuation spectrum having to be consistent with the analogous one of the air temperature. Parting from this he produced a sketch (Fig. 1) from which wide varieties of the refraction effects are apparent. A classification of the atmospheric disturbances is also related to by Goto (1983), with different spatial–temporal scales, affecting, in a compex way, the refraction value too.

In the following discussion we primarily draw on the latest investigations (as many as 126 papers or abstracts were available, more particularly on those acomplished in the period 1982–1985) after our preceding Report (Teleki, 1984) covering the period 1979–1982. In the latter period one more surveying article has appeared: Shamaev (1983). We quote here still another larger surveying article of Sergienko (1981), not mentioned in our earlier report, as well as his paper (1986) on the activities performed in the USSR.

From the greater Meetings one should mention those of the Soviet specialists at Tomsk (1983) and at Irkutsk (1984) (Sergienko, 1986), as well as the international one, organized by the Working Group on Astronomical Refraction of the IAU Commission 8, held in June 1985 in Leningrad (Proceedings of this Meeting will appear as No. 35 of the Publ. Obs. Astron. Belgrade, 1986). At those three Meetings alone as many as 162 (= 72 + 48 + 42) papers have been presented.

Related to in the present review are but some of the published, i.e. of the reported on the above Meetings, investigations, first of all those of consequence in the astrometry.

It is interesting to mention some investigations connected with he geodetic refraction: Proceedings „Geodetic Refraction" (Brunner, 1984), Wunderlich (1985), Džeparoski and Vukmirović (1986), Kushtin (1986), Maksimcev (1986), Ostrovskaya (1986), Pojidaev (1986) and Ware (1986).

Quoted here are two papers: Fillipenko, 1982; Watson, 1984, more dealing with the calculation for the refraction effects in the spectroscopy, resp. spectrophotometry.

2. PRESENT POTENTIALITIES

According to an evaluation (Teleki, 1979) the refraction tables – most of the refraction calculations are made upon them – are capable of yielding 98% of the actual refraction influences for observations within 60° to 70° zenith distances. The 98% accuracy estimate is evidently not equally adequate over the zenith distances just stated: it may be too high in the zenith zone and to low at 70°. It should, therefore, be looked upon as some average value. It may be rated as pessimistic one (for at z = 45°, say, it involves an error of about 1"), but if account is taken of all possible effects, and not only of those in the free atmosphere, of those in the surface layers in particular, (Medestova et al., 1986) it does not apear unrealistic either.

Entirely different are the curcumstances for the zone 70° to 90° zenith distance. Unless there are essential departures from the spheric–symmetric atmospheric model, the 98% accuracy estimate, up to 88° to 89° zenith distance, might appear still adequate. At z = 90° zenith distance, however, if account is taken of all effects (Alekseev et al., 1983), the estimate may run at 84%. If, on he other hand, the observations at the very horizon are omitted, then a typical accuracy estimate for the zenith distances from 70° to near horizon might amount to 96%.

It is pertinent at this juncture to recall an earlier paper of Kirichuk (1973) reporting on a relationship between the terrestrial refraction coefficients and the peri–horizontal refraction values (80° ⩽ z ⩽ 90°). The accounting for the terrestrial data is conductive to refraction effects being notably more accurate than those found without those data. Even though additional measurements (we thereby mean the terrestrial refraction coefficient) are therewith implied, the suggested way is possibly profitable in the practice.

The accuracy of the refraction determination is customarily given for only z = 45°. It is generally assumed that at this zenith distance, under the average meteorological conditions – i.e. excessive disturbances in the surface layer not present – the refraction tables furnish a ± 0.″1 accuracy.

Alekseev et al. (1983) enumarate the errors, potentially evolving from the following factors: aerological data (methods, temperature and pressure changes along the radiation trajectory, variations in time of the data at the site of observation, humidity), statistical atmospheric models (standard and regional atmosphere), analytical atmospheric models, errors in geometric factors (earth's radius, zenith distance, altitude above horizon), spectral characteristics and the approximating formulae. All of these factors are given in terms of zenith distance. It transpires from this analysis too that the magnitudes of different effects for the zenith distances not higher than appr. 70° are rather slight, lending support to the well known Oriani–Laplace's postulation.

The Oriani–Laplace's theory has been dealt with also by Teleki and Sugawa (1986), with the conclusion of its being applicable to the real atmosphere (i.e. not merely to the one underlying the refraction tables), which has its physical explanation. The compensation of tilts of layers of equal density – playing decisive part in this theory – is interpreted as a concequence of the general circulation of atmosphere.

Regarding the accuracy a graph from Kurzynska (1986) as indicative might be here be reproduced. Employing the aerological data acquired at Poznan (Poland) in the period 1970 to 1979, she found – as evident from Fig. 2 – that at the refraction calculation the errors in the meteorological elements at the observing site were dominant all along till z = 80°, the errors in the aerological data coming to the fore only near horizon. The magnitudes of the aerological effects are in harmony with those stated by Alekseev et al. (1983). It is to be emphasised that these effects reveal a relatively severe variability with seasons (e.g. at z = 89° the effect reaching 9.″5 in summer and 14.″1 in winter). Relevant to Fig. 2 is to note that the curve 3, according to Kurzynska (1986), represents the physical limit of the refraction determination.

Concerning the accuracy associated with the refraction influences calculation let us have another look at Fig. 1. One is reminded of the fact that the effects of the gavitational waves (within 5 to 50 cycles per hour domain), and of those of the temperature micropulsation (100 to 10000 cycles per hour domain) are not taken into account. The temperature variations give rise to the so called „accidental refraction" effects (with periods of a few tens of seconds of time) and to „image motion" (the periods ranging from a few seconds to a few tenths of second).

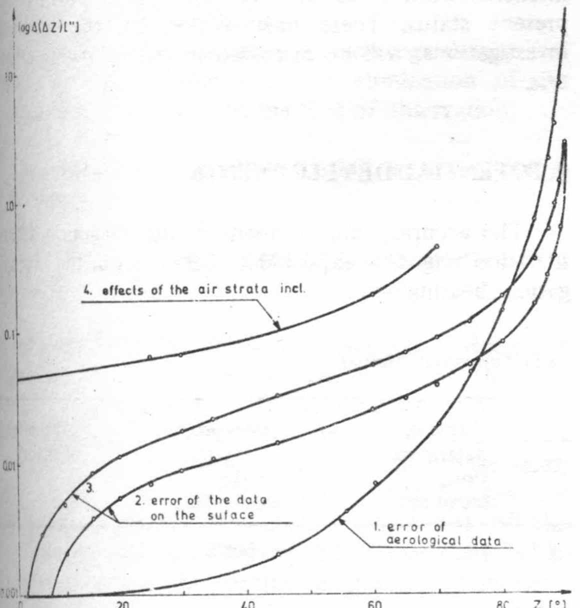

Fig. 1. The air temperature fluctuation spectrum (a) and the probable refraction fluctuation spectrum – according to Kolchinskij (1984). 1 – synoptic maximum, 2 – micropulsation, 3 – fluctuation from the refraction tables, 4 - gravitation waves effects, 5 – accidental refraction, 6 image motion. Notations: f – frequency, E(f) – spectral density; vertical axis in graph b) – squared fluctuation's semi-amplite (half the annual refraction variation).

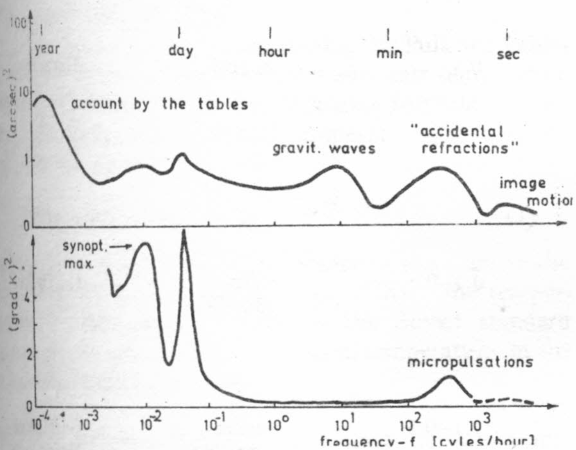

Fig. 2. Errors in refraction at different zenith distances, determined from the aerological data (Kurzynska, 1986).

3. DEVELOPMENT

The present–day accuracy of the refraction determination, by comparison to the one in the past, marks great progress. Consult in this connection Table 1 (Teleki, Atanacković, 1983) exhibiting the estimated determination errors in these effects in the course of time at z = 45°, assuming average meteorological conditions, i.e. under not exceptional conditions (this specification applies first of all to the present–day error).

Table 1. Estimated error in the refraction effects determination at 45° zenith distance (Teleki, Atanacković, 1983).

Author	Year	Estimated error
Tycho	1587	60"
Kepler	1604	15
Cassini	1661	2
Bradley	1798	1
Gylden	1868	0.2
Today	1982	0.1

Another estimate was provided by Sergienko (1986) – see Table 2.

The two estimate are somewhat diverging – quite understandably – but both of them make it evident how significantly increased is our knowledge of the refraction phenomenon. The question, however, is to what extent are met the current astrometric needs. The unambigous answer surely is: not satisfactory. The limitations set to the atmospheric – implying those refractional – effects are brought forward by a comparative analysis of the growth of accuracy possessed by refraction tables and the stellar position catalogues (Teleki, Atanacković, 1983). It turned out that the refraction accuracy growth does not, in the course of time, follow that of the catalogue growth. Thus, the quality level of the present –day catalogues is not a result of the improvement of the refraction accuracy, but rather a result of the achievements in other fields (instrumentation, automation, prevention etc.). All this comes forth again by considering separately the errors in the stellar positions obtained with the classical and in those obtained with the up–to–date instruments. The errors have dropped from about 0."4 to about 0."2, the refraction effects having all along been calculated with nearly the same accuracy. The instrumental errors associated with the modern astrolabes and PZTs are of the order of 0."01. A rather large error, 0."1, in the group means of the observations defies interpretation – one suspects the refraction anomaly as having its say in it (Hu et al., 1984). Naito and Sugawa (1984) have shown that refraction influences in visual zenith–telescope and the astrolabe observations are of the other of 0."01.

It is curious that while the astrometry cannot be satisfied with the accuracy attainable in the refraction calculation, there are fields in which sufficiently accurate results are deduced from the measured refraction angles. In this, so called, indirect task (Alekseev et al.,

1983) one is able to determine the refractive index, the density and the temperature, as well as the humidity. It could be demonstrated (Gaikovich, Summin, 1986) that the vertical profile of the meteorological parameters is thus deductible with the same accuracy as the one associated with the radiometric measurements (from the Earth's surface).

The Table 2 gives the prospective accuracy of the refraction determination. How correct is the estimate runing to 0.″1 to 0.″001? No definitive answer can presently be given but one is bound to state that an intensive work is under way aimed at improving the present status. These new works, i.e. the required investigations, will be discussed in the following chapters.

4. POTENTIAL DEVELOPMENTS

The accuracy improvement in the refraction determination might be expected to follow from the investigations bearing on:

Table 2. Improvement of the accuracy of refraction angles determinations (Sergienko, 1986a)

Period	Atmosphere model	Atmospheric structure, calculations of n	Error of determination, sec of arc	Meteorological data on the atmosphere	Author(s) of theory
Before the 17th cent.	one–dimensional	empirical instrument	10	hypoth.	Kepler
First half of the 17th cent.	one-dimensional	n=const.	1	hypoth.	Cassini
Before the mid–19th century	one-dimensional	n = 1 + 2 C	1	hypoth.	Newton
Till the begining of the 20th cent.	one–dimensional	n = 1 + 2 C	1	hypoth.	Gylden Radau
Till the '30s of the 20th cent.	initiation of studies of refr. anomalies using metor. and astr. data	n = 1 + 2 C	0.5	hypoth.	Harzer
1940–1960	one–dimens. model, obtained from radio sounding data	n = 1 + C	0.1–0.5	radio sounding	Garfinkel
1960–1970	attempts to apply the one-dimens. model atmosph.	Owens' formulae 1.10^{-8}	0.1–0.5	rocket sounding	Garfinkel Nefed'eva
Toward the end of the 20th cent. (prediction)	many–dimens. model atmosphere of equal arbitrary order	Owens'–type formulae or special method	0.1–0.001	laser sounding, use of the art. satellite borne data	Sugawa, Teleki a.o.

- more fitting formulae for the calculation and closer reality atmospheric models;
- employing the instantaneous meteorological data;
- instrumental determination or elimination of the refractional influences at the time of observation;
- prevention;
- accounting for the full variation in the radiative propagation.

Here is a summarized presentation of papers dealing with these problems.

4.1. Tables, formulae, atmospheric models. – Regarding Pulkovo Tables, Fourth Edition, criticism has been voiced concerning incorect refraction constant as well as inhomogeneity in accounting for the air temperature effects (the chortcomings of these Tables have lately been pointed out by Motrunich, 1984; Fukaya and Yoshizawa, 1985 and Yoshizava et al., 1986). All this has been rectified in the Fifth Edition of these Tables (Abalakin, 1985), fine results being achieved (Guseva, 1986b; Kharin, 1986). It is these Tables' great merit that the chromatic refraction is motably more properly accounted for. What important consequences in the astrometric observations follow from the accounting for the chromatic refraction is clearly demonstrated by Bagildinsky et al. (1986). It has been shown by these authors that the results obtained with the Pulkovo vertical circle over the zenith distances up to 60° were chromatically homogenous, a fact of great importance. In this connection an interest must be attached also to the paper of Stone (1984).

The central point at constructing the Pulkovo Tables has been the ensuring of the most adequate temperature profile (Guseva, 1986a). The following formula, expressing the daily and/or annual temperature (T) variation with height(h) has been used

$$T(h) = T^r(h) + (T_o - T_o^r)e^{-\alpha\,(h-h_o)} \qquad (1)$$

where h_o – the altitude of the observing site above the sea level, T_o – local temperature, $T^r(h)$ – the temperature in the adopted model – the Soviet standard atmospheric model 1976, T_o^r – local temperature in the adopted atmospheric model.

It is well known that in calculating the refractional influences only local meteorological data are taken into account for the given instant. However, Equ. (1) allows it to include into tabular data some correction for the atmospheric model, making thereby the tables more effective than would have been the case if the model were rigid.

Similar ideas are expounded in the paper of Huang and Shen (1986). The refractivity ($N = n - 1$) according the these authors is represented by

$$N = N_o\, e^{-ah} \qquad (2)$$

The authors developed a formula giving the refraction in terms of Δa, i.e. dependent on changes in the refractive index profile. Employing the U.S. Standard Atmosphere they obtained for a the values –0.1170/km and –0.1050/km on the basis of the aerological data for Shanghai. From this difference they deduced the local refraction variations.

It is worthwhile noting that earlier Teleki (1967) arrived at results resembling those of Huang and Shen. With the Belgrade aerological data there would follow for a the value –0.1337/km.

The question arises whether one is correct using (1) or (2) uniformly over the entire atmosphere or should it not be more appropriate to have the atmosphere divided into parts, calculating separate parameters (Teleki, Sugawa, 1986). It is at once to note that such a division is imaterial for zenith distances up to about 70°, but acquires its justification beyond this limit. Sugawa and Kikuchi (1973) were the first to suggest a two layer model – applying the formulae of the form (2) separately to the troposphere and the stratosphere. Recently, the two layer model was suggested by Rukina et al. (1986). These authors computed N for the optical and radio radiations for 16 regions of the central part of the European teritory of the USSR, drawing the conclusion that the radio–domain profile was more realistic if given for two layers: the first from 0 to 9 km and the second from 9 to 30 km. Analysing the seasonal and annual variations in both profiles they found them notably larger for the profiles in the optical than in the radio range. According to Blinov (1983) the usage – for astrometric needs – of the expression (2) as a mean for the troposphere and the stratosphere is common place.

The tables or, for that matter, the computation of refraction from the aerological data, imply one–dimensionality, for they pertain to one only vertical atmospheric cross–section. To be sure, one tends to pass over to the three–dimensional models or, more preferably, to the real atmospheric models. Universally recognized as the progenitor of the refraction three–dimensionality is Harzer, who compiled, as early as 1922 and 1924, corresponding tables. A critical analysis of Harzer's work by Yatsenko and Teleki (1985) enabled them to point out its merits and to come to realization that Harzer's basic conceptions – if simplifications used by him are ignored – might be turned to good account even at present. Yatsenko (1986) gave an algorithm of modern use of Harzer's theory for computer.

It is to be noted, however – as pointed out by Sibilev (1983) – that a formula for the light beam propagation in a three–dimensional continuum was given by Numerov as early as 1919, but it failed to be implemented.

A transition from the one to the full three–dimensional refraction calculation was suggested by Yunoshev (1986) which would imply two parts: the first would be referred to some average (standard) atmosphere while the second would involve the vertical and the lateral departures in the free atmosphere relative to the adopted atmospheric model, computed on the basis of the aerological measurements. Using data at three aerological stations in the Central Russia he derived for stars at $z = 40^{o}$ the following values of the second part (related to above): 0."017 for azimuth and 0."03 for the zenith distance.

Various atmospheric models were thoroughly studied by Sergienko (1986a) which led him to the realization that currently, in the refraction calculations, one is able to employ three atmospheric models implying arbitrary layers of equal density: the one is two–dimensional (denoted MAS–2) wherein the variations of **n** in height and in the horizontal plane are known; the second is a simplified three–dimensional (MAS–3–S) implying the variations of **n** along the x– and the y– axes are known, the variations of **n** with height being constant; the third is a three–dimensional one (MAS–3), the variations of **n** in the vertical direction being expressible by AB^{h} and those along the x– and y– axes by $\epsilon = \frac{1}{n}\frac{\Delta n}{\Delta x}$ and $\omega = \frac{1}{n}\frac{\Delta n}{\Delta y}$, respectively. A transition from the statical three–dimensional model to a dynamical one would necessitate the constant values of ϵ and ω being replaced by expressions furnishing the spatial–temporal variations of **n**, considerably more complex. According to Sergienko, for the observations at medium zenith distances, the meteorological data allow the astronomical refraction to be determined with an error less than 0."1 to 0."5 upon a dynamical atmospheric model.

Kushtin (1986) analysed in detail different methods of determination and calculation of optical refraction in the Earth atmosphere. The methods of refraction determination were classified by him as measuring, computing, measuring–computing and instrumental ones.

Employing local statistical atmospheric models in the refraction calculus is suggested by Nelyubin (1983), such that would embody the averaged annaul profiles of the meteorological quantities at the given place, their variations in time, the cloudiness and the synoptic situation being accounted for. It is demonstrated by the author that the implementation of these models lead to the hitherto most accurate refraction results. Provided the humidity is taken into account, these models could be used in the radio band.

Taking the earth s'global atmosphere as a reference in the refraction calculation is argued by Teleki (1986). The interconnection is thus promoted of the astrometric data as well as the determination of the local refraction effects.

Nefed'eva (1986) analysed the longitudinal and latitudinal distribution of the air density and concluded that tilts of layers of equal density as obtained by her are in accordance with the corresponding values given by Saastamoinen (1980).

Shabel'nikov (1983) established formulae for a three–dimensional inhomogeneous atmospheric model. Account is taken of the layer inhomogeneity and of the horizontal gradients of the refactive index **n** (note that such a model is termed two–dimensional MAS–2 by Sergienko) and corresponding formulae given for the refraction calculation. It is stated by the author that the horizontal gradients and the inversions can affect the refraction value by as much as 0."05 to 0."5 over zenith distances up to 70^{o}, and considerably more at larger zenith distances. Applying his formulae to the observations near horizon separately he obtained good agreement with the experimental data.

In another paper Shabel'nikov (1986) analysed the calculation methods of the refraction influences in the three–dimensional inhomogeneous atmosphere, offering simpler formulae.

Vasilenko (1985) investigated possible refraction corrections proceeding from an ellipsoid atmospheric model. He found them to be larger than 0."01 only for observations at zenith distances over 75^{o}.

Kushtin (1984) set forth formulae suited to determination of the refraction angle in the observations close to horizon.

Five novel refraction tables, i.e. five modes of calculating pure local refraction all resting upon aerological measurements, have appeared in the most recent time: in Shangai (Shen, 1984), Uzhgorod (Motrunich, 1984), Tokyo (Fukaya, Yoshizawa, 1985; Yoshizawa et al. 1986), Kazan (Nefed'eva et al., 1986) and the ones meant for the polar regions (Zablotsky, Kulish, 1986).

Saastomoinen (1983) extended his mathematical theory of the atmospheric refraction, published in 1972 and 1973 in Bull. Geod., achieving better data convergence for z above 80^{o}.

Anything so far related to pertains to the calculation in some free atmosphere model. A step farther has been made by Sibilev (1983) who provided formulae for the light ray propagation in the surface layer. He derived the following approximate formula furnishing – with an accuracy not inferior to 5% – the anomalous refraction between the points **a** and **b**

$$\rho'' = C \int_a^b \frac{\bar{P}_1}{T^2} \left(\frac{\partial T}{\partial x} \sin z - \frac{\partial T}{\partial y} \cos z \right) ds + D\, s \sin z$$

where: $C = 21."7$ k/mm Hg, $D = 0."0068$ m, $\bar{P}_1$ – mean surface pressure (in mm Hg) and T – temperature in K. The trouble with this formula, however, derives from the fact that, in consequence of the highly intricate nature of the meteorological element field in the surface layer, it cannot actually be employed (Sibilev, 1986). He therefore utilized a simpler formula

$$\rho'' = B \sum_{k=1}^{n} \left(\frac{D_{k+1}}{T_{k+1}} - \frac{D_k}{T_k} \right) \mathrm{tg}\, i_k$$

where: i – incidence angle, $D = 1 - 1.184\ 10^{-4}$ h and h – the height.

For the sake od comparison be it mentioned that in Tokyo (Yoshizawa et al., 1986) the pavilion refraction was computed by the formula

$$R = \int_{\substack{\text{path}\\ \text{length}}} Q(P, T)\ \mathrm{grad}\ T\ dl$$

where $Q(P,T) \approx 0''.22/K$.

Hu et al. (1984; 1986) made use of a similar formula (originally due to Courvoisier)

$$r = 0''.22 \frac{\Delta T}{a} h$$

where: $\Delta T/a$ temperature gradient, h – height.

Concerning the temperature and humidity structure in the boundary layer of the Earth atmosphere refer to Webb's review (1984).

4.2. Employing the instantaneous meteorological data is certainly preferable over the use of tables and various atmospheric models which, for all their accuracy provide but some average values. The acquisition of the instantaneous meteorological data involves a good deal of effort.

This becomes clear from the measurements already acomplished or those planed in Irkutsk, at the Observatory of Siberian branch of VNIIFTRI (Modestova et al., 1986). Detectors are already installed for measuring the meteorological field up to 16 m height (distributed at 3 to 6 m spacing in height and at 5 to 10 m horizontally). The lifting is planned of four balloons to heights between 300 to 350 m, carrying detectors to cover a 200 x 200 m^2 area. The whole assemblage will incorporate 144 detectors: 127 of them are temperature, 2 humidity, 5 wind parameters and 8 air refractive index. The measurements are to be performed at intervals not exceeding 3 seconds. As a matter of fact, the data acquisition and their treatment are performed automatically. Besides these on spot measurements, those from four nearby aerological stations are also used. The refraction angle is computed by the formula

$$R_z = \alpha_0 \alpha_\rho + \beta_0 \beta_\rho + \gamma_0 \gamma_\rho$$

where α, β and γ are the ray direction cosines, the subscript 0 indicating those corresponding to airless state and the subscript ρ stands for the actual air at the observing point.

The comparison is made wih the results following from the use of the Pulkovo Tables for astrolabe observations: mean differences amounts to about 0".9, fluctuating within 1" to 2" during the evening hours! These preliminary data demonstrate that once the whole of this system of acquisition and treatment of the meterological data – labelled ACTSMI – completed and operational, it will constitute a major contribution to the study of the refractional effects.

It is at this juncture to be recalled that the accuracy improvement in the refraction determination is first of all conditioned by better understanding of the surface air layer properties, of the one immediately surrounding the instrument in particular. It is therefore understandable for the researchers to have addressed exactly this task. Clearly, the data should be provided as close to the time of observations as possible.

Here will be presented but brief information on some recently published papers on this subject, complementing thereby Shamaev's (1983) review pertaining to the pavilion refraction.

In Tokyo (Miyamoto et al., 1985) the efforts are centered on measuring the temperature field within the very pavilion of the photoelectric meridian circle. 40 termistors measuring the temperature differences are installed, their readings being recorded every 25 seconds. It proved that the calculated anomalies were considerably wind–dependent. It was found that a ±0".1 accuracy could not be secured if the wind velocity were less than 2 m/sec. The relative star coordinates, corrected for the anomalous refraction, attest to the correcting procedure being justified.

Analogous results have been achieved in Nikolaev where Sibilev (1980) executed day–time measurements of the temperature fields within and immediately outside the pavilion (with 15 termistors up to 16 m height, at 5 minutes intervals) demonstrating that the determination accuracy of the star, Sun and Venus declinations were considerably improved by applying the corrections for the anomalous refraction. By applying the anomalous corrections, the random error in the star position was reduced by 20% in the course of day (amounting to 0".54 at z = 45°). The like improvement has been achieved in the observations of the Sun and Venus.

Fedorov (1984) carried out measurements of the temperature differences (at 11 points) along the line of sight in the transit instrument pavilion at Nikolaev, followed by those in Kislovodsk, deriving the lateral refraction. It turned out that these anomalies were dependent on the Sun's hour angle, reaching their maximum about noon. While bieng insignificant during night, they become considerable during daytime, thus calling for their being accounted for.

At Kazan, Yatsenko (1985) measured using classical thermomers the temperature inside meridian circle pavilion at 21 points (every 20 minutes), calculating inclinations of the layers of equal density and anomalous refraction. The anomalies were found comparatively slight – in most cases (98%) – less than 0."15. It could be established that on accounting for these anomalies in the star and planet observations the (O–C) values got reduced.

Exact temperature differences measuring appears imperative in all of these investigations. Hu and associates (Hu et al., 1984; Hu, Jiang, 1986) suggested the technique and method of determining the minute temperature differences, ensuring a 0."003 sensitivity. Anomalous refraction has been studied inside a telescope tube in its horizontal and vertical positions as well as at a 30° inclination. Anomalies taking place inside the dew cap were stated (0."03 to 0."07). Temperature differences outside pavilion up to 4 m height were measured also. This technics will be implemented at the Tienjin latitude station (China).

The air pressure measuring at three points close to pavilion, in addition to that of the temperature differences, is suggested by Hu (1986). Provided the microbarographs yielding a 0.01 mb precision, installed at 0.5 km separation, were used an accuracy of the anomalous refraction determination of about 0."01 would be attained. In the macro- and meso–scale atmospheres, under the average meteorological conditions, an anomaly of about 0."00467, and with drastic conditions one of about 0."0467 would follow. Greater effects may occur in a micro–scale atmosphere. In this author's oppinion, the pressure and the temperature differences should conjointly be determined, their combined effects being applied. It is planned to put this into effect at a number of observatories throughout China.

In the papers just referred to contact methods are envisaged for calibrating the meteorological elements. The use of non–contact methods, e.g. of LIDAR, in the atmospheric structure investigations, in particular when surface layer is concerned, are to be expected.

4.4. The refraction influences determination from astrometric data is handicapped by a series of at present unsolved problems (Teleki, 1984; Zablotsky, Kirichuk, 1986; Redichkin. 1986), but the matter is continuously being worked on and the solutions searched for.

Ostrovsky et al. (1986) studied the refraction from the star and Sun observations near horizon, concluding their results as having confirmed the already known anomalous effects.

A method affording prompt refraction determination near horizon by exploiting the photographic recordings of the shape deformations due to refraction of the extended celestial objects (Moon, Sun, stellar pairs) is advanced by Archangelskij and Velshanin (1986). The method has been tested on the Sun. The near–horizon refraction is obtainable with a 4" to 8" accuracy.

These and similar measurements reveal the atmosphere as not being spherical in shape. It is on the strength of these measurements that Fedyanin and Vasilenko (1984) approximated the atmosphere by a three–axial ellipsoid. Proceeding from this ellipsoidal atmosphere, Fedyanin and Tyuterev (1986) computed the lateral anomalous refraction.

Mao et al. (1986) outlined a method of the refraction determination from star observation in the prime vertical, using a new meridian instrument designed for the medium and low latitudes.

Measuring the angular distances between selected stars forms the foundation of a method of refraction determination suggested by Efimov et al. (1986). The arc values could be extracted from the space (Hipparcos) measurements, by VLBI techniques or from the prolonged ground based measurements. A specially designed instrument, permitting an arc measuring accuracy of about ± 0."1 (in three minute time) is envisioned for the method. The determination of the chromatic effects is made feasible by suitable filters.

4.5. Instrumental refraction influences determination. By this methods are understood serving for the determination, and authomatic exclusion from the astrometric observations, of the refraction effects.

According to Martensson (1985; 1986) the elimination of the refraction effects from geodetic measurements is approachable in two ways: theoretically and practically. The theoretical approach implies the search for the more or less complex atmospheric models, while the designing and implementation of suited equipment constituded the practical component. In neither of areas has complete success been achieved, yet the instrumental developing is slightly ahead. Underlying the instrument construcition is the principle of dispersion of various wave lengths, the instruments on that account being termed dispersiometer. These are designed for measuring the angular difference between two wave lengths after the latter have completed their passage through the atmosphere. In the paper from 1985 are set forth the characteristics of the NPL and of Tengström's dispersiometers. New technics is developed by the author as the extent one proved incapable of yielding the desired results owing, first of all, to the atmospheric turbulence. The new technique is aimed at minimizing the difference in turbulence between two light beams, at employing the temporally integrated measurements and at promptly furnishing the instantaneous refraction angle. Preliminary results proved satisfactory.

A two color refractometer has been developped at the Maryland University (Currie, Wellnitz, 1986), directly yielding full atmospheric dispersion by measuring stellar cetroids within two spectral bands. The internal error in dispersion amounts to 0".02 with 30 minutes measurings. Currie (1986) is working out a new astrolabe, which would incorporate this two color refractometer enabling the refraction influences to be authomatically removed.

Description is supplied by Sorokin and Tokovinin (1986) of a chromatic micrometer. yielding image photocenter positions in two colors simultaneously.

Sibilev and Shulga (1986) analysed the determination of the refraction influences by dispersion method, taking into account the humidity of air. They gave exact formulae.

Putting the instrumental optical system inside a vacuum chamber. with a horizontal entrance window, as suggested by Hu (1985). constitutes potentially, an important step towards suppressing pure refraction. dispersion and refraction influences taking place in a telescope tube. In such a case, under the standard air conditions. the refraction correction is: – 0".076 (tg z + tg^3 z). It is the difference between the refraction influences in the plane parallel layer model and in the spherically symmetric shell model. It means that the astrometric results would continue to be loaded by the anomalous refraction (which is the correction of the spherical model influences). The vacuum chamber is able to reduce the atmospheric dispersion to a completly negligible amount. The engineering problems relating to the vacuum chamber are: deformation of entrance window, temperature difference between the inner and outer surfaces of the entrance window. fabricated wedge' angle of the entrance window and residual air in the chamber. Independently of these sources of possible negative effects, the observational results obtained by vacuum photoelectric astrolabes and a vacuum photographic zenith tube – both constructed in China – are very positive. Namely, the observational errors are significantly reduced in comparison with the instruments without vacuum chamber.

All these papers taken together are potentially of great value for the ground based astrometry, since ways are indicated in them for considerable improvement of accuracy of the observational results.

4.6. Prevention keeps being an important factor regarding elimination of some refractional influences.

The importance of the site selection for the astrometric instruments has in recent time been considered by Shamaev (1983) and Teleki (1985).

The elaboration of a method of predicting the most probable optical refraction values, i.e. of predicting „the refraction weather" is attacked by Alekseev (1984). This concerns both the site selection and the working efficiency at a particular place. The long–term prediction involved the calculation of the most probable values of **n** in the surface layer and of the vertical gradient dn/dh for the whole USSR territory. The short–term predictions require, additionally, the accounting for the solar radiation flow, which brings about a redistribution of the temperature field in the surface layer. It should be remarked that such an analysis concerns primarily the geodetic measurements.

The pavilion issue. i.e. of its most suitable shape has been treated by Shamaev (1983) and Miyamoto et al. (1985). According to Shamaev, currently there is no unambigous and clear stand concerning the most appropriate shape of the astrometric pavilions. Thus it is as yet impossible to be clear as to the recommendable prevention.

Removing external effects implies first their being thoroughly understood. Such an empiric and statistical analysis is due to Goto (1983) and it deals with meteorological environment effects in Mizusawa (pertaining essentially to PZT). It could be shown that nearly 50% of the systematic erorrs in the time and latitude group values were generated by the mountain wind and the „lee waves". The contribution of the microturbances in the surface layer in the PZT observations comes to ± 0".1. All this is to say how essential a part is played by the meteorological environment at the observing site.

4.7. Fundamental refraction researches are of prime importance at the present development stage. It has been pointed out in Introduction that the radiative transfer laws are not fully known. This accounts for the refraction researches being still at the geometric optics stage, thus in a static status. Dynamical parameters usually are only enumerated, but one obstains from making their actual use. This is a consequence of our being denied a complex theory of the radiative transfer through the inhomogeneous Earth's atmosphere – an, be it termed, astrometric – theory that would account not only for the annual and daily periods refractions (Fig. 1) but for all shorter periods and other possible effects as well (e.g. chromatic ones). A broader theoretical foundation appears necessary also when instrumental determination (elemination) of the refractional influences are concerned.

Clearly, relevant physical researches are necessary, i.e. the necessity is felt of exploiting the results of these studies in the refraction calculus. It is to be stated, moreover, that our undestanding of the atmosphere is lagging behind. The practice makes it clear that real time atmospheric parameters are to be employed. A prerequisite for this is the knowledge of these parameters on one hand, and adequate technique on the other. For instance, the gravitational waves effects in the atmosphere (Fig. 1) are practically ignored, although their amounts are not negligible. In this connection one is referred to the papers of Goto (1983) and Sergienko and Tatarinov (1984).

The following definition of the astronomical refraction is set forth by Sergienko (1986a): „Astronomical refraction is the phenomenon of varying geometrical–energetic parameters of electromagnetic waves as their propagation from the emitter to the receiver, under the action of the electromagnetic and gravitational fields in a spatio–temporal four–dimensional continuum". Evidently, this theory's implication is the knowledge of rather more physical and meteorological data than hitherto available or used. Sergienko stipulates all the effects which, in his opinion, are to be taken account of.

Woyk (1986), in contributing to these fundamental physical researches, points at the bad practice of overlooking some basic principles.

The fundamental and applied aspects of astronomical seeing are discussed in detail by Coulman (1985).

Ostrovsky (1986) pointed out the basic refraction determination problems and on their basis he searched for basically new methods of determination and registration of refraction influences.

Grafarend (1984) investigated the electromagnetic wave propagation in a refractive medium corotating with the Earth and gave adequate equations.

With this connected in some way is the question of establishing correct terminology (Kolchinskiy, 1986; Teleki, 1986; Ostrovsky, 1986) and fixing the refraction standards (Teleki, 1986). The following standards are suggested: the spheric–symetrical atmospheric model (the one uderlying the Pulkovo Tables, Fifth Edition), the global simple three–dimensional model (outlined by Saastamoinen, see: Teleki, Saastamoinen, 1982), pure refraction (Pulkovo Tables, Fifth Edition, serving as standard) and the Oriani–Laplace refraction influences (values derived from all the current tables, algoriths and theories of the astronomical refraction up to 70° zenith distance).

5. RADIO–REFRACTION

In the preceding presentations it was, in the first place, the light ray refraction that was dealt with. Clearly, a few words should be passed on the radio–refraction in view of the ever greater importance of the radio observations (CERI, VLBI) in the astrometry.

A detailed survey of refractional effects in the radio astrometry was provided by Spoelstra (1986). Two aspects of the refraction problem are pointed out by this author: the first concerns the physics and the structure of the refraction medium, and the second – developing the methods of treating the refraction corrections. Dwelling principally on the latter subject the author examines the effects of the regular or the large–scale atmospheric components (including the Earth's sphericity) and different atmospheric disturbances with diverse spatial and temporal characteristics. The refraction affects the image in the field of view in two ways: by displacing it in celestial coordinates and by distorting it. In single dish observations the former effect is decisive. Regarding the radio–interferometry (CERI, VLBI) the refraction problem is connected with the phase instability in the course of observation which is apt to produce a degradation of the image qulaity. Being given that, in radio–astrometry, use is made not of a single, but of pairs of dishes, the basic problems are associated with the interference. It has been found out that the main source of accidental errors in these measurements was the refraction–generated phase instability. Accordingly, a not small contribution to the refraction absolute error – typically 0.″1 for CERI and 0.″001 for VLBI – is due to refraction.

An overview of the radio–refraction problems in VLBI observations may be found in Blinov's (1983) article. He points out that the radio–refraction, in this field, was the No. 1 problem.

A contribution to the astronomic radio–refraction prediction is due to Gaikovich et al. (1986), based on the radio–metric remote sensing observations performed from the Eath's surface. Rather good results have been obtained.

Atmospheric effects on radio–location, Doppler and the VLBI observations were discussed by Yakovlev (1984; 1986). He considered also the effects due to the propagation velocity being different for the troposphere, stratosphere and ionosphere – as yet not sufficiently understood.

6. CONCLUSION

From what has been stated in Sections 4 and 5 it follows that a realistic possibility presented itself for the current accuracy in the refraction effects determination to be improved. How great that improvement will be, is dependent on many complex researches, particularly on those most promising stated in 4.2, 4.5, 4.6 and 4.7. To be sure, a progress may be brought about only gradually, in the course of years. The astrometric practice will show what advance in this area is achieved.

* * *

The present progress report, compiled by the Chairman of the Working Group on Astronomical Refraction of the IAU Commission 8, has partially been presented at this Commission's Session at New Delhi, November 1985.

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SOLAR ACTIVITY EFFECTS ON THE DANUBE RIVER LEVEL

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SUMMARY An attempt is made to establish the existence of a correlation between the Sun activity (using the total area of sunspots on the visible solar disc as a parameter) and the Danube river level (using its fluctuations in Smederevo, Yugoslavia). The best fitting corresponds to one to two years lag.

1. INTRODUCTION

The fluctuations of different geophysical quantities such as: water flow in rivers, lake, sea or ocean level, atmospheric precipitations, air temperature etc. play an important role in agriculture, various branches of industry and economics.

An enormous benefit would follow could one rule over them, but the opportunities in this sense are for the time being very limited. Therefore one tries, as far as it is possible, to study all these phenomena and after having observed them in the course of many years, to predict their changes in near and, possibly, in more distant future.

This imposes the necessity to explain the mechanism of these phenomena usnig the present–day scientific knowledge, as well as involves a highly complex and tedious work, yet there are from day to day more and more useful results.

2. ORIGINS

From the papers and books dealing with the subject it follows that sudden, daily, seasonal and yearly as well as secular solar phenomena exercise influence on some geophysical quantities referred to above.

This was also the subject of many scientific meetings, i.e. the interconnection of the solar phenomena and their impact on Earth. Such meetings in more recent time took place e.g. in 1972 in Moscow, in 1976 in Leningrad, in 1978 in Columbus, Ohio, in 1979 in L'vov and in 1981 in Kirov etc.

The present paper will be devoted to only one of the effects: to the water level fluctuations, more specifically, to those of the Danube river (in Smederevo, Yugoslavia).

3. PREVIOUS RESULTS

Most of the works relating to this subject (they are not many) might, having regard to the methods of handling the problem, be divided into two groups. In the one, such as Afanas'ev (1967), Druzhinin et al. (1966), Eigenson et al. (1948), Miroshnichenko (1981), Rubinstein, Polozova (1966), Mac–Cormac, T. Selig (red.) (1982), comparisson is used of data and diagrams delivered separately for hydrologic phenomena and separately for the solar activity. In the second, such as Rodriguez–Iturbe, Yevjevich (1968), use is made of the statistic analysis methods – cross–correlation and cross –spectral analysis.

Most of the authors from the first group were affirmative as to the reality of the influence. The conclusion of the second group is a negative one, but they are dealing with the Earth as a whole (in such a treatment the mutually oppsoing effects or data may cancel each other).

The common feature of both groups is their using the Wolf's number as the solar activity's indicator. However, one must ask: is it really the best possible criterion? The conclusion depends on it, too, and one has to be cautious: does it provide a realistic picture of the solar phenomena scope sufficient to produce consequences on Earth, or not?

Vitinski (1973) wrote: „More objective index, with respect to sunspot number, is the total sunspot area on the visible solar disc."

Therefore, I decided to use this index. Systematic observation of this particular parameter started at the Greenwich Observatory as early as 1874. It is customary to express it in millionths of the visible hemisphere of the solar disc.

4. DEFINING THE PROBLEM

To start with I selected the Danube river because therewith are available data series covering a rather long time.

At choosing the site whose level fluctuation data I was to use I paid my attention to the following considerations:

(1) its river basin to be as large as possible,
(2) data series to be extended over long enough time,
(3) data series not to be interferred with, to the extent possible, by the man–made construction.

Thus I selected SMEDEREVO, Yugoslavia. Its basin occupies an area 525 820 km^2 large. The data on the river level are being recorded since 1920 continuously to the present day. It is sufficiently far–off (in the hydrology experts' opinion) from the Djerdap hydro-electric power station dam for the interference of the latter to be of any appreciable effect.

5. RESULTS

As a rough measure of correlation I used the correlation coefficinet r_{XY}, X being the total area of the sunspots on the visible solar disk, and Y – the Danube river level at Smederevo.

Use has been made of data pertaining to the period 1947–1984. Data on the solar activity are borrowed from Slonim, Kuleshova (1982), and on Danube river level from Hidrološki godišnjak Jugoslavije 1947–1978, and Hidrološki godišnjak 1979–1984.

Table 1. Correlation coefficinets (sunspot areas – Danube river level at Smedervo)

R_{XY}	Phenomena Lag Sun – Earth		
	0 years	1 year	2 years
LL	–0.2149	–0.2864	–0.2908
ML	–0.2459	0.3536	–0.2463
HL	–0.1784	–0.4068	–0.4069

Data in Table 1 represent the correlation coefficients for the yearly lowest river level (LL), yearly mean level (ML) and yearly highest level (HL).

The highest correlation is found for the highest river levels with one and two years lag. Longer time intervals are obviously necessary for the results to be more conclusive.

NOTE. This paper is an excerpt of a short communication to the VIII National Conference of Yugoslav Astronomers, Priština, Yugoslavia, 23–26 IX 1985.

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THE STABILITY ANALYSIS OF THE VACUUM MERIDIAN MARKS OF THE LARGE TRANSIT INSTRUMENT AT BELGRADE OBSERVATORY

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SUMMARY: The stability analysis of the vacuum meridian marks of the Large Transit Instrument at Belgrade Observatory is shown using the variation of the angle between the southern and northern meridian mark. The review of similar examinations at some other observatories and the comparison of the results are given. For Belgrade meridian marks a significant annual variation is determined.

1. INTRODUCTION

The most important characteristic of the meridian marks of every meridian instrument is their stability in relation to the meridian plane i.e. in relation to the variation component which is perpendicular to the meridian plane. From the literature, it is known that these variation can be examined by tracking the variations of the value of the angle between the meridian marks. This enables us to get an impression of the stability of each pair of meridian marks. Practically, this can be achieved by reading both meridian marks with the main instrument for a longer period (several years). The angle between the meridian marks is given by the following relation

$$S = \pm(2M_o - M_n - M_s) \tag{1}$$

where S represents the angle between the meridian marks, M_o noncollimation reading and M_n and M_s readings of northern and southern mark, respectivily. By this relation, at the same time, the influence of the main instrument is eliminated.

2. HISTORY

Up to the present time, various different authors have treated the problem of the stability of meridian marks mostly using observing material for the determination of star catalogues in various epochs. We will show the results obtained by examination of meridian marks of the Pulkovo Observatory Large Transit Instrument in the period of 60 years, during the compilation of five catalogues in 1845, 1865, 1885, 1900 and 1905 (Struve 1845; Nemiro 1958). The variations of the angle S are presented as follows

$$\begin{aligned} S_{1845} &= 0''.70 \sin(L + 283^o) + 0''.19 \sin(2L + 173^o) \\ S_{1865} &= 0''.80 \sin(L + 297^o) + 0''.15 \sin(2L + 123^o) \\ S_{1885} &= 0''.77 \sin(L + 317^o) + 0''.19 \sin(2L + 105^o) \\ S_{1900} &= 0''.22 \sin(L + 173^o) + 0''.47 \sin(2L + 273^o) \\ S_{1905} &= 0''.30 \sin(L + 297^o) + 0''.19 \sin(2L + 72^o) \end{aligned} \tag{2}$$

where L is the Sun's longitude. A certain variation in the values of amplitudes, Nemiro (1958) explained by the fact that variations of the angle between meridian marks have a complexed character and that they depend on many meteorological factors.

In the similar way the examinations of the stability of underground meridian marks of Cape Observatory in the period of 1918–1925 are given (Nemiro 1958):

$$\begin{aligned} S_E &= a_o + 0''.16 \sin(L + 108^o) - 0''.24T \\ S_W &= a_o + 0''.17 \sin(L + 106^o) - 0''.17T \end{aligned} \tag{3}$$

for two clamp positions (E and W); a_o is a constant and T is a time in years from a certain initial moment. Inspite of the fact that here the underground meridian marks are considered, and a priori has to be supposed that they are in firm connection with the Earth, the variation of the mutual angle between marks exists, so that the underground factor, alone by itself, does not solve the problem of stability.

The meridian marks of the Meridian Circle in Tashkent (Varina, Kim Gun–der 1964) have been examined twice in a period of ten years and the variations could be approximated in the following way

$$\begin{aligned} S_{1946-48} &= -1''.07 \sin(L + 15^o) \\ S_{1955-56} &= -0''.93 \sin(L + 35^o) \end{aligned} \tag{4}$$

where the notings previously have been adopted. Here we can also discuss about a good accordance between the values of the amplitudes on the beginning and the end of the period and an undoubted presence of the annual variation of the angle between marks.

The author had an opportunity to be introduced to similar examinations carried out by Varina (1984) from Pulkovo Observatory, using the observation material collected in the period 1969–1973 at the Pulkovo Large Transit Instrument at the Cerro–Calan Observatory (Chile) (Varin et al. 1981). The results fully confirm the previous discussions.

At Belgrade Observatory some examinations of the stability of the astronomical pillars have been carried out in the past but in a different way (Brkić 1961, Đokić 1970). However, in this case the foundations of the pillars were much shallower so that the amplitudes are larger.

The main characteristic of all these examinations is that various authors have set down slightly different conditional equations which can be explained with different characteristics of the locality in the view of the ground and the climate.

3. THE EXAMINATION OF BELGRADE MERIDIAN MARKS

Collected six–year observation material (1978–1983) has been obtained in connection with the observation programme for determining absolute right ascensions of stars from the List of 308 bright polar stars, the first catalogue carried out at LTI in Belgrade. That material has been used to carry out a similar analysis of the variation of the angle between the marks. The special characteristic of these examinations is undoubtedly the fact that these are vacuum meridian marks and that they are relatively near to the main instrument (30 and 51 meters) (Mitić 1975; Pakvor 1975, 1981; Mitić, Pakvor 1976, 1977, 1978, 1979, 1984). This is the shortest distance of all above mentioned meridian marks. An idea to carry out such complex examination and to compare its results with ones similar at other observatories sprang to the authors mind by the obtained results of previous examinations of Belgrade meridian marks (Pakvor 1984). As is shown in Fig. 1 an undoubted annual variation exists. Using this theoretical method we wanted to confirm the existence of the annual variation and to discover possible causes.

Starting from these results we set down the following conditional equation

$$S = x_0 + x_1 \sin T_1 + x_2 \cos T_1 + x_3 t \qquad (5)$$

which according to our opinion most accurately and realisticly represents the variations of the angle S of our meridian marks; x_0 is a constant term, x_1 and x_2 are the amplitudes of the periodical terms, x_3 is the temperature coefficient; T_1 (multiplied by 2π) is the time from beginning of the year in the units of the year which naturally can be connected with the Sun's longitude; t the temperature given in units of ^oC. This term in equation (5) plays the role as the correction to the periodical terms in the function T_1. It is obvious that S, T_1 and t are measured values and that 4 unknown x_0, x_1, x_2 and x_3 have been determined by the method of least square from the 456 equations of the type (5), because we obtained 456 measurements in the above mentioned six–year period. The following relation has been obtained

$$S = 27''.090 + 0''.555 \sin T_1 + 0''.300 \cos T_1 + 0.030t$$
$$\pm 100 \quad \pm 45 \qquad \pm 90 \qquad \pm 9 \qquad (6)$$

where the coefficient in front of t has the dimension $''/^oC$. The figures in the second row represent the mean square erorrs of the corresponding coefficients given in units of milisecond of arc. To be able to compare these results with the results of other authors we had to carry out necessary mathematical transformations after which we obtained

$$S = 27''.090 + 0''.631 \sin (T_1 + 28^o) + 0.030\,t \qquad (7)$$

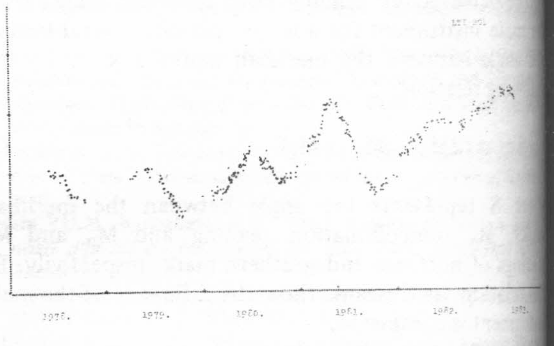

Fig. 1. Graphical examinations of the variation of the angle S between southern and northern meridian mark of Belgrade LTI (Pakvor 1984).

Comparing these results with the results obtained by other authors immediately has to be point out already previously mentioned fact that the meridian marks of Belgrade Observatory are approximately 4 times nearer to the main instrument than the marks of other observatories, so our angle variations have to be reduced in that ratio to make the comparison adequate. This is the result of the fact that for the same angle shift the nearer meridian marks have relatively smaller physical displacement of the pillars than the farther ones.

Relation (7) shows an undoubted existence of the annual variation with the amplitude objectively smaller than the amplitude of the Pulkovo marks, that is at the same level with one of the underground marks at Cape Observatory and that is far smaller than the amplitude of the Tashkent meridian marks. By all means previous graphical examinations (Fig. 1) have been confirmed in view of the periodicity of the variation of the angle between marks. Concerning the semi–annual term, it has not been even forseen in the conditional equation (as at some other authors) because the previous examinations (Pakvor 1984) did not show so. The corrective temperature coefficient is relatively small and practically negligible. The mean square errors in relation (6) show a fairly good accuracy of the calculated values, specially in the first two terms.

A similar analysis has been tried with a different shape of the conditional equation, this time enlarged by linear and square term of time as follows

$$S = x_0 + x_1 \sin T_1 + x_2 \cos T_1 + x_3 t + x_4 T_1 + x_5 T_1^2 \tag{8}$$

The notings are the same as in the previous case considering that it is clear that x_4 and x_5 are the coefficients of the progressive term T_1. The physical explanation for such enlargement of the conditional equation lies in the fact that in Fig. 1 a certain parabolical variation of angle S with the time T_1 can be noticed.

Using the method of the least square in this case again, we obtained

$$\begin{aligned} S = {} & 26''.520 + 0''.330 \sin T_1 - 0''.345 \cos T_1 - \\ & \pm 105 \quad \pm 30 \qquad \pm 60 \\ & - 0.0015\, t - 0''.0045\, T_1 + 0''.0015\, T_1^2 \\ & \pm 4 \qquad \pm 9 \qquad \pm 3 \end{aligned} \tag{9}$$

After necessary transformations we get

$$\begin{aligned} S = {} & 26''.520 + 0''.477 \sin (T_1 - 46^{\circ}) - 0.0015\, t - \\ & - 0''.0045\, T_1 + 0''.0015\, T_1^2 \end{aligned} \tag{10}$$

The above expression in the two first terms mostly confirms previous considerations but the big difference show the coefficients which have to define linear corrective influence of temperature. The coefficient in the relation (7) is 20 times bigger than the one in relation (10), although both are absolutely very small. This fact results in the conclusion that linear influence in the whole variation of the angle between the marks is practically negligible. Last two terms in the relation (10), as the calculated dispersion of the value S corresponding relations (6) and (9) too, do not justify the enlargement of the conditional equation in the way as in (8).

Lastly it is necessary to mention that in all our considerations the time T_1 is calculated from the beginning of the year when L from the relations (2), (3) and (4) has the value of about 280°.

4. CONCLUSION

Adopting relation (7) as the best representative of our measurements, we can repeat the conclusion that the variation of the angle between the vacuum meridian marks of Belgrade Observatory Large Transit Instrument has a significant annual period with the amplitude which is less than the amplitude for the meridian marks at other observatories. This is the result of locality, climate but also of solid foundation of pillars of our marks.

The relative newness of Belgrade meridian marks does not allow, at the present stage, to carry out examinations over a long period of time as it was done e.g. at Pulkovo. This study points out such possibility so the further examinations are forseen.

The author wants to express his gratitude for the useful advise and help which was given during the work on this study, primarly to Prof. A.A. Nemiro, from Pulkovo Observatory, Dr. Lj. Mitić and Dr. G. Teleki, from Belgrade Observatory and to A. Valskij from the Computer Center at Pulkovo Observatory.

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ORBITS OF FOUR VISUAL DOUBLE STARS (ADS 8718, ADS 8926, IDS 14012S4924, IDS 14571S4012)

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(Received Oct. 3, 1985)

SUMMARY. **Presented are preliminary orbital elements, dynamical parallaxes, absolute magnitudes, masses, ephemeris and residuals of four visual double stars.**

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ORBIT OF ADS 8718 = IDS 12534N5021 = HU 641

App. mag.: 10.3–10.3, Sp.–

Table I

P = 323.48 years			
n = 1°.1129	A = +0".1833	$\pi_{dyn.orb.}$	= 0".006
T = 1963.41	B = +0".3173	M_A	= 4.1
e = 0.51	F = +0".2490	M_B	= 4.1
a = 0".366	G = −0".1373	$\mathfrak{M}_A$	= 1.22 ⊙
i = 140°.8	C = ±0".0089	$\mathfrak{M}_B$	= 1.22 ⊙
Ω = 58°.3	H = ±0".2309	a	= 63.4A U
ω = 357°.8			
$T_{\Omega, \varpi}$ = 1963.97,1806 96.			

Table II

t	θ	ρ
1985.0	354°.4	0".19
1986.0	351.6	0.19
1987.0	348.9	0.19
1988.0	346.2	0.19
1989.0	343.6	0.20
1990.0	341.0	0.20
1991.0	338.5	0.20
1992.0	336.1	0.20
1993.0	333.7	0.21
1994.0	331.4	0.21

Table III

N.	t	θ	ρ	Obs.	n	Reference	(O–C)θ	(O–C)ρ
1.	1903.86	189°.7	0".39	HU	3	Lick Obs. Bul. **2**, 180, 1904.	− 3°.1	+ 0".06
2.	1923.467	150.9	0.22	VBS	3	Pub. Yerkes Obs. **5**, Pt. 1, 1927.	−16.1	−0.03
3.	1943.30	138.2	0.19	VBS	1	Pub. Yerks Obs. **8**, 159, 1954	+ 15.1	+ 0.01
4.	1945.34	118.7	0.16	VBS	2	Pub. Yerkes Obs. **8**, 159, 1954.	+ 1.7	−0.02
5.	1946.53	93.2	0.17	VBS	1	Pub. Yerkes Obs. **8**, 159, 1954.	−20.1	−0.01
6.	1950.33	–	–	VBS	1	Pub. Yerkes Obs. **8**, 159, 1954.	–	–
7.	1953.03	–	0 1	VBS	1	Pub. Yerkes Obs. **9**, Pt. 2, 1960.	–	0.0
8.	1956.37	–	0.1	VBS	1	Pub. Yerkes Obs. **9**, Pt. 2, 1960.	–	0.0
9.	1957.27	–	0.1	VBS	1	Pub. Yerkes Obs. **9**, Pt. 2, 1960.	–	0.0
10.	1962.33	–	–	VBS	1	Pub. Yerkes Obs. **9**, Pt. 2, 1960.	–	–
11.	1974.34	188.*	0.15	HEI	3	Astrophys. J. Suppl. **29**, 315, 1975	−18.	−0.03
12.	1980.30	202.*	0.1	HEI	2	Astrophys. J. Suppl. **51**, 249, 1983	+ 14.	0.0

*Quadrant changed

ORBIT OF ADS 8926 = IDS 13255N0800 = A 1789

App. mag.: 9.3–9.3, Sp. A5

Table IV

P = 127.89 years		
n = 2.8150		
T = 1841.97	A = +0".1150	$\pi_{dyn.orb.}$ = 0".006
e = 0.39	B = −0".1690	M_A = 3.2
a = 0".213	F = −0".1775	M_B = 3.2
i = 155°.3	G = −0".0975	$\mathfrak{M}_A$ = 1.43 ⊙
Ω = 163°.7	C = ∓0".0597	$\mathfrak{M}_B$ = 1.43 ⊙
ω = 222°.2	H = ∓0".0659	a = 36.0A.U.
$T_{\Omega,\mho}$ = 1877.55; 1835.60		

Table V

t	θ	ρ
1985.0	213°.9	0".16
1986.0	210.1	0.17
1987.0	206.5	0.18
1988.0	203.1	0.18
1989.0	199.9	0.18
1990.0	196.0	0.19
1991.0	194.1	0.20
1992.0	191.3	0.20
1993.0	188.7	0.20
1994.0	186.3	0.21

Table VI

N	t	θ	ρ	Obs.	n	Reference	(O−C)$_\theta$	(O−C)$_\rho$
1.	1908.28	123°.2	0".26	A	2	Lick Obs. Bul. **5**, 28, 1908.	+ 2°.1	−0".02
2.	1914.47	119.0	0.20	A	2	Lick Obs. Bul. **14**, 62, 1929.	+ 6.4	−0.08
3.	1916.32	106.4	0.26	A	2	Lick Obs. Bul. **14**, 62, 1929.	− 3.6	−0.01
4.	1921.41	92.6	0.24	A	2	Lick Obs. Bul. **14**, 62, 1929.	− 9.8	−0.02
5.	1926.42	88.2	0.19	A	2	Lick Obs. Bul. **14**, 62, 1929.	− 6.1	−0.06
6.	1932.81	85.4	0.25	FIN	3	Union Obs. Circ. **6**, 104, 1951.	+ 2.6	+ 0.01
7.	1933.42	88.2	0.29	FUR	2	Greenwich Observations B1, 1937.	+ 6.6	+ 0.06
8.	1934.71	69.8	0.17	A	4	Lick Obs. Bul. **18**, 109, 1937.	− 9.2	−0.06
9.	1939.18	68.4	0.19	VOU	3	Ann. Bosscha Obs. Lembang, **6**, PT 4, D1, 1947.	− 1.0	−0.03
10.	1940.90	61.4	0.22	VBS	3	Pub. Yerkes Obs. **8**, 159, 1954.	− 4.0	+ 0.01
11.	1944.25	51.3	0.16	VBS	3	Pub. Yerkes Obs. **8**, 159, 1954.	− 5.7	−0.04
12.	1945.35	34.0	0.14	VBS	2	Pub. Yerkes Obs. **8**, 159, 1954.	−20.0	−0.06
13.	1946.52	63.8	0.15	VBS	3	Pub. Yerkes Obs. **8**, 159, 1954.	+ 13.0	−0.04
14.	1949.47	34.0	0.17	B	1	Union Obs. Circ. **6**, 266, 1956.	− 7.0	−0.01
15.	1951.06	–	0.1	VBS	2	Pub. Yerkes Obs. **8**, 159, 1954.	–	0.0
16.	1954.59	204.2*	0.11	VBS	3	Pub. Yerkes Obs. **9**, Pt. 2, 1960.	0.0	−0.06
17.	1961.32	180.3*	0.11	WOR	1	Astron. J. **67**, 403, 1962.	+ 5.4	−0.04
18.	1967.263	261.7	0.19	WAK	1	Pub. U.S. Naval Obs. **22**, Pt. 1, 1969	−59.7	+ 0.06
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22.	1980.30	238.6	0.12	HEI	2	Astrophys. J. Suppl. **51**, 249, 1983.	+ 3.0	−0.02

*Quadrant changed

ORBIT OF IDS 14012S4924 = SLR 19

App. mag.: 7.2–7.4 Sp. GO

Table VII

P = 233.28 years		
n = 1°.5432		
T = 1841.74	A = −0".4333	$\pi_{dyn.orb.}$ = 0".021
e = 0.32	B = + 0".9500	M_A = 3.8
a = 1".068	F = −0".7800	M_B = 4.0
i = 44°.0	G = −0".1867	$\mathfrak{M}_A$ = 1.29 ⊙
Ω = 127°.6	C = ∓0".2274	$\mathfrak{M}_B$ = 1.25 ⊙
ω = 342°.1	H = ∓0".7058	a = 51.7A.U.
$T_{\Omega,\mho}$ = 1847.43; 1979.34		

Table VIII

t	θ	ρ
1986.0	311°.8	1".35
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1988.0	313.2	1.34
1989.0	313.8	1.34
1990.0	314.5	1.33
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18.	1967.263	261.7	0.19	WAK	1	Pub. U.S. Naval Obs. **22**, Pt. 1, 1969	−59.7	+ 0.06
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20.	1976.375	79.0*	0.13	WAK	2	Unpublished	0.0	0.00
21.	1977.528	55.0*	0.12	WAK	3	Unpublished	−16.6	−0.01
22.	1980.30	238.6	0.12	HEI	2	Astrophys. J. Suppl. **51**, 249, 1983.	+ 3.0	−0.02

*Quadrant changed

ORBIT OF IDS 14012S4924 = SLR 19

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Table VII

P = 233.28 years		
n = 1°.5432		
T = 1841.74	A = −0".4333	$\pi_{dyn.orb.}$ = 0".021
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1993.0	316.6	1.31
1994.0	317.3	1.30
1995.0	318.0	1.30

Table IX

N.	t	θ	ρ	Obs.	n	Reference	(O–C)θ	(O–C)ρ
1.	1895.48	229.6	1".07	SLR	3	Astron. Nachr. **141**, 137, 1896.	–2°.9	+0".24
2.	1901.58	244.0	0.89	I	1	Ann. Cape Obs. **2**, Pt. 4, 1905.	+1.6	0.00
3.	1913.42	259.9	1.27	DAW	4	Pub. La Plata Obs. **4**, Pt. 1, 1918.	+1.8	+0.25
4.	1913.46	261.4	1.02	VDS	2	Union. Obs. Circ. **1**, 97, 1914.	+3.3	0.00
5.	1914.53	254.7	0.95	VOU	4	Ann. Bosscha Obs. Lembang, **1**, Pt 3, C1, 1925.	–4.7	–0.09
6.	1915.34	261.6	1.02	VOU	4	Union Obs. Circ. **1**, 205, 1915.	+1.3	–0.02
7.	1917.48	263.2	1.06	VOU	4	Ann. Bosscha Obs. Lembang, **1**, Pt. 3, C1, 1925.	+0.6	–0.01
8.	1920.65	267.4	1.18	DAW	2	Pub. La Plata Obs. **4**, Pt. 2, 1922.	+1.6	+0.08
9.	1922.49	268.5	1.21	I	1	Union Obs. Circ. **5**, 193, 1948.	+0.9	+0.09
10.	1924.35	269.1	1.05	VOU	4	Ann. Bosscha Obs. Lembang, **1**, Pt. 2, B1, 1926.	– 0.2	–0.09
11.	1927.21	272.4	1.19	VOU	4	Ann. Bosscha Obs. Lembang, **6**, Pt. 1, A1, 1932.	+0.5	+0.02
12.	1927.30	272.3	1.09	BRU	4	Ann. Bosscha Obs. **1**, Pt 4, 1928.	+0.3	–0.08
13.	1927.40	273.9	1.26	FIN	2	Union Obs. Circ. **3**, 35, 1928.	+1.8	+0.09
14.	1928.62	273.9	1.30	RST	2	Pub. Univ. Michigan Obs. **11**, 1, 1955.	+0.7	+0.12
15.	1929.95	274.6	1.24	B	4	Union. Obs. Circ. **3**, 183, 1931.	+0.3	+0.04
16.	1930.17	274.6	1.39	WAL	4	Ann. Bosscha Obs. Lembang, **6**, Pt, 2, 1934.	+0.1	+0.19
17.	1932.42	276.3	1.16	VOU	4	Ann. Bosscha Obs. Lembang, **6**, Pt. 1, A1, 1932.	0.0	–0.06
18.	1934.10	278.7	1.33	B	4	Union Obs. Circ. **4**, 362, 1937.	+1.1	+0.10
19.	1935.48	279.9	1.25	FIN	4	Union Obs. Circ. **4**, 263, 1936.	+1.2	+0.01
20.	1936.42	280.3	1.16	SMW	3	Ann. Bosscha Obs. **9**, Pt 1, 1951.	+0.8	–0.09
21.	1937.65	280.7	1.18	TAN	3	Union Obs. Circ. **5**, 193, 1948.	+0.3	–0.08
22.	1942.10	283.5	1.33	VOU	3	J Obs. **38**, 109, 1955.	–0 2	+0.03
23.	1944.49	283.6	1.39	WOH	3	Sydney Obs. Papers N. 6, D.	–1.8	+0.08
24.	1946.11	286.4	1.42	WOY	3	Mem. Commonwealth Obs. Mt. Stromlo, **2**, N. 9, 1948.	–0.1	+0.10
25.	1946.15	287.5	1.43	HIR	1	M.N R/ Astron. Soc. **110**, 455, D.	+1.0	+0.11
26.	1946.47	283.3	1.62	WOH	2	Sydney Obs. Papers, N 6, D	–3.4	+0.30
27.	1947.36	287.4	1.33	SMW	3	Mem. Obs. Mt. Stromlo, **2**, N 9, 1948.	+0.1	0.00
28.	1949.45	289.1	1.27	B	2	Union Obs. Circ. **5**, 371, 1950.	+0.4	–0.07
29.	1955.51	293.4	1.40	HEI	4	M N/R/ Astron. Soc. **116**, 248, 1956.	+0.7	+0.03
30.	1956.47	293.1	1.38	CHU	4	Union Obs. Circ. **6**, 298, 1958.	–0.2	+0.01
31.	1959.42	294.9	1.44	KNP	2	Union Obs. Circ. **6**, 331, 1960.	–0.3	+0.06
32.	1960.49	298.6	1.27	MRO	3	Obs. Nacional Brasil, N. 12, D	+2.8	–0.11
33.	1961.42	297.0	1.40	MRO	5	Obs. Nacional Brasil, N. 19, D.	+0.6	+0.01
34.	1963.25	298.3	1.39	MRO	4	Obs. Nacional Brasil, N. 21, 1966.	+0.7	0.00
35.	1966.43	297.9	1.40	KNP	2	Republic Obs. Circ. **7**, 130, 1967.	–1.6	+0.01
36.	1966.47	300.0	1.33	NBG	4	Republic Obs. Cric. **7**, 135, 1967.	+0.4	–0.06
37.	1968.48	300.5	1.32	NBG	1	Republic Obs. Circ. **7**, 184, 1969.	–0.3	–0.07
38.	1975.266	301.1	1.57	HLN	2	Pub. Astron. Soc. Pacific, **87**, 945, 1975.	–3.9	+0.18
39.	1978.63	304.8	1.87	WRH	2	Astron. Astrophys. Suppl. **39**, 197, 1980.	–2.3	+0.49
40.	1980.228	305.5	1.39	WOR	2	Unpublished	–2.6	+0.01

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App. mag.: 9.4–9.6; Sp. F5

Table X

P = 108.08 years		
n = 3°.3310		
T = 1890.48	A = –0".0050	$\pi_{dyn.orb.}$ = 0".006
e = 0.28	B = + 0".1638	M_A = 3.3
a = 0".190	F = –0".2025	M_B = 3.5
i = 23°.5	G = –0".0125	$\mathfrak{M}_A$ = 1.40 ⊙
Ω = 6°.8	C = ±0".0755	$\mathfrak{M}_B$ = 1.35 ⊙
ω = 85°.9	H = ±0".0054	a = 31.8A.U.
$T_{\Omega, \mho}$ = 1874.04;1909.11		

Table XI

t	θ	ρ
1986.0	20°.2	0".17
1987.0	24.1	0.16
1988.0	28.2	0.16
1989.0	32.5	0.15
1990.0	37.2	0.15
1991.0	42.2	0.14
1992.0	47.5	0.14
1993.0	53.2	0.13
1994.0	59.3	0.13
1995.0	65.9	0.13

Table XII

N.	t	θ	ρ	Obs.	n	Reference	$(O-C)_\theta$	$(O-C)_\rho$
1.	1927.04	223°.4	0".20	B	2	Ann. Leiden Obs. **14**, P, D.	−7°.4	−0".02
2.	1930.18	232.2	0.22	VOU	4	Ann. Bosscha Obs. Lembang, **6**, Pt, 1, A1, 1932.	−5.8	0.00
3.	1934.57	242.5	0.25	B	2	Union Obs. Circ. **4**, 362, 1937.	−5.6	+0.04
4.	1934.78	244.9	0.27	FIN	4	Union Obs. Circ. **5**, 74, 1941.	−3.7	+0.06
5.	1936.58	251.0	0.19	B	4	Union Obs. Circ. **4**, 362, 1937.	−1.8	−0.02
6.	1937.17	255.1	0.20	VOU	4	Ann. Bosscha Obs. Lembang, **6**, Pt. 4, D1, 1947.	+0.9	−0.01
7.	1939.17	216.0	0.19	VOU	3	Ann. Bosscha Obs. Lembang, **6**, Pt. 4, D1, 1947.	+2.0	−0.02
8.	1945.13	267.4	0.18	VOU	2	J Obs. **38**, 109, 1955.	−5.8	−0.03
9.	1959.51	332.1	0.19	B	2	Union Obs. Circ. **6**, 321, 1960.	+23.9	−0.02
10.	1976.312	158.0*	0.22	HLN	2	Pub. Astron. Soc. Pacific, **89**, 582, 1977.	−12.1	+0.02

*Quadrant changed

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OCCULTATION OF SIGMA SAGITTARII BY VENUS ON 17 NOVEMBER 1981 OBSERVED FROM HVAR OBSERVATORY

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(Received July 10, 1986)

SUMMARY: Essentials are reported of the occultation of Sigma Sagittarii (Nunki) on November 17, 1981, observed at Hvar Observatory (Yugoslavia). The parameters of the occultation are given and analysed.

According to the prediction of G. Taylor (Taylor, G., 1981), the occultation of Sigma Sagittarii ($2^m.14$,B3) by Venus on 17 November 1981 was to be visible from Yugoslavia. He kindly supplied all the data for the Belgrade and Hyar observatories, requisite for the observations of the event to be properly carried out: the times and position angles of disappearance and reappearance of the star behind the Venus disk, respective elevations of Venus and the star above the horizon. The predicted data implied a ten minute duration.

Since Venus was placed east of the Sun and its disk illuminated by 0.461 per cent, the disappearance of the star was to take place at the dark limb and its reappearance at the bright limb.

It is well known that the occultations of bright stars by the planets, by the inner ones in particular, are extremely rare occurences. This is why we were anxious not to miss the unique opportunity of observing, weather permitting, this exeptional phenomenon. The prospect of accomplishing comparative observations (the respective times at Belgrade and Hvar differed by about 12 seconds) was thereby specially important.

Unfortunately, dense clouds at Belgrade ruled out any possibility of observation. At Hvar, on the contrary, the weather conditions were quite favourable, so the times of both disappearance and reappearance, observed visually by H. Božić, could be duly registered. The trouble, however, was presented by the precise timekeepers on the spot being lacking. The difficulty could, to some extent, be alleviated by ascertaining, through telephone connection with the Belgrade Observatory, the clock correction immediately before and after the event. In addition, use has been made of the time signals of the Geophysical Institute, transmited hourly by the Zagreb Radio Station.

The observation has been implemented with a 65 cm Cassegrain telescope. The following times have been registered:

Disappearance:	15^h	30^m	30.52	UTC.
Reappearance:	15	41	07.52	UTC.

All the computations, aimed at comparing the predicted with the observed values, have been performed at the Belgrade Observatory under the direction of V. Protić–Benišek.

Considering the geographical coordinates of the Hvar Observatory as:

$$L = -16^{\circ}27' = 1^h5^m48^s$$
$$\varphi = +43^{\circ}10,$$

i.e.:

$$\rho \cos \varphi' = 0.730507$$
$$\rho \sin \varphi' = 0.679923$$
$$\mathrm{tg}\, \varphi' = 0.679923$$

and the correction to the sideral time:

$$\Delta\theta_1 = 10^s.81.$$

The apparent position data on Venus and ohter related parameters are taken from Astronomical Ephemeris for 1981, and data on the star are taken from the Apparent Places of stars for 1981. Upon reducing the geocentric to the topocentric positions of Venus disk, allowing for the correction ΔT = ET – UT = 52.40, the theoretical topocentric distances of the star from the midpoint of the Venus disk ΔS' for both instances have been derived using the formula:

$$\Delta S'^2 = (\alpha'_* - \alpha'_V)^2_{app} \cos \delta'_* \cos \delta'_V + (\delta'_* - \delta'_V)^2_{app}.$$

Thus was found:

$\Delta S'$

Disappearance: 13."913
Reappearance: 13."510.

However, as these distances must be equal to the apparent semi–diameter r_V of he Venus disk in the registered instants of disappearance and reappearance which, at the geocentric position of the planet, amounted to r_V = 13."625, one readily finds the deviation:

$$\Delta(\Delta S') = (O - C)_{top}.$$

Disappearance: −0."288
Reappearance: + 0."125.

Making use of the classical Innes'method (Innes, R.T.A., 1924.) of treating the lunar occultations, we find the goecentric deviations Δ (ΔS):

$$\Delta(\Delta S)$$

Disappearance: −0."139
Reappearance: + 0.237

On the assumption of both deviations being accurate and the star position well determined, there follows:

1º The observed position angles of disapearance and reappearance diverge from the predicted ones by +11°.9 and −10°.8, respectively.

2º The planet did pass over the star by 2."2 more to the north (see Figure 1) than predicted.

3º The planet's transit over the star took about 1^m longer than predicted.

The above conclusions are, in any case, to be considered as preliminary ones, keeping in mind that they have been obtained from observation at one single station, i.e. they are certainly affected by appreciable errors, introduced bv the observer in the recorded times

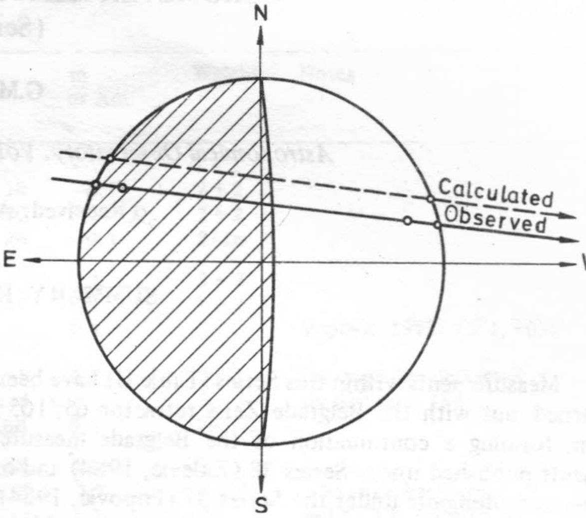

Fig. 1. The apparent path of Sigma Sagittarii behind Venus (calculated and observed) as seen from Hvar.

(„personal error"). It is, therefore, necessary to wait until more observations from other places are available. It seems, however, that owing to the adverse November weather, few observers (nothing, to our knowledge, has been published to date) have succeded. Hence, our failing to observe at Belgrade, in spite of all the preparations, is all the more to be regreted.

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MICROMETER MEASURES OF DOUBLE STARS (Series 39)

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(Received: August 27, 1985)

SUMMARY: Reported are 230 measurements of 64 double or multiple stars

Measurements within this Series (Table II) have been carried out with the Belgrade Zeiss refractor 65/1055 cm, forming a continuation of the Belgrade measurements published under Series 38 (Zulević, 1984) and of my measurements under the Series 37 (Popović, 1984). The Series comprises 230 measurements of 64 double or multiple systems. The distributions of the measured pairs according to the distance is presented in Table I.

Table I Distribution of the measured pairs according to distance

$\rho < 0''.50$	$0''.50 \leq \rho < 1.00$	$1''.00 \leq \rho < 2''.00$	$\rho \geq 2''.00$	Σ
2m 0.9%	37m 16.1%	104m 45.2%	87m 37.8%	230 100%

19 pairs in the Series possess known orbital elements while 20 pairs displey distinct variation in time of the position angle. Accordingly, many of these stars can rightly be expected to obtain before long their orbital elements.

The question of exact identification of the pair ADS 7186 = Brt 102 did not yet receive definite solution since S.G. Barton's measurements from the year 1893 can poorly be reconciled with my own from 1974 to the present.

The mean weights for the epoch of observations, P, ρ, m or Δm have been deduced as in the previous series.

The comparison with the orbits has been performed according the P. Muller and P. Couteau's (1979) ephemeris.

Table II Micrometer measurements of double stars

ADS	IDS DISC. m (IDS)	Mult.	Epoch 1900+	P	ρ	m or. Δm	Weight	Notes
1081	01147S0061	AxBC	83.816	15°.0	1".94	1.0	1 + 1	
	STF 113		83.881	12.8	1.48	–	1 + 2	
	6.4 – 7.4		84.837	15.3	1.71	0.5	1 + 2	
			84.848	**14.3**	**1.68**	**0.8**	**3n**	
1161	01225N4216		83.745	92.6	0.93	8.0–8.5	1 + 1	
	AC 14		83.804	90.3	0.83	0.5	1 + 2	
	8.1–9.1		84.949	90.8	0.74	8.0–9.0	1 + 2	
			84.219	**91.1**	**0.82**	**0.7**	**3n**	
1223	01288S1244		83.739	345.5	0.97	0.2	2 + 2	
	HWE 4		84.949	348.5	0.84	0.1	1 + 1	
	9.6–9.7		**84.142**	**346.5**	**0.93**	**0.2**	**2n**	Van den Bos, 1951: +9°.9, +0".15
1538	01507N0121		83.783	54.9	1.21	–0.3	1 + 2	
	STF 186		84.837	57.0	1.24	7.0–7.0	2 + 2	
	7.0–7.0		84.949	56.3	1.22	–0.1	1 + 3	Freitas–Mourao, 1976:
			84.590	**56.3**	**1.22**	**–0.1**	**3n**	+ 0°.7, – 0".11
1615	01569N0217		83.794	281.5	1.80	1.0	1 + 2	
	STF 202		83.810	281.9	1.73	1.0	1 + 2	
	4.3–5.2		83.816	280.4	1.69	1.2	1 + 2	
			83.991	281.6	1.64	–	1 + 1	
			83.840	**281.3**	**1.72**	**1.1**	**4n**	Rabe, 1943: +3°.1, +0".05

Table 2. (continued)

ADS	IDS DISC. m (IDS)	Mult.	Epoch 1900 +	P	ρ	m or Δm	Weight	Notes
1758	02120N2147		83.816	288.8	–	–	1 + 1	
	STF 244		83.881	288.0	4.18	–0.1	2 + 2	
	9.3–9.5		84.837	290.1	4.30	9.1–9.0	3 + 2	
			84.304	**289.1**	**4.25**	**–0.1**	**3/2n**	
2377	03027N7110	AB	83.794	167.5	1.13	0.1	3 + 3	
	STT 50		83.879	169.1	1.11	0.1	1 + 2	
	8.5–8.5		**83.822**	**168.0**	**1.12**	**0.1**	**2n**	Popović, 1972: +3°1, +0.″07
3329	04307N1933		83.740	16.9	0.51	0.2	3 + 3	The angle has decreased
	STT 86		83.794	17.1	0.48	0.0	3 + 3	by 62° since 1845.
	8.2–8.2		**83.767**	**17.0**	**0.50**	**0.1**	**2n**	
4950	06132N5925	AB	83.740	134.5	0.68	1.0	2 + 2	
	STF 881		85.176	132.0	0.75	1.5	1 + 2	The angle has increa-
	6.2–7.7		**84.355**	**133.4**	**0.71**	**1.2**	**2n**	sed by 43° since 1830.
5269	06316N4140	AB	85.176	82.6	1.79	7.0–8.0	1 + 2	
	STF 941		85.258	84.4	1.71	1.0	2 + 1	
	7.2–8.2		**85.217**	**83.5**	**1.75**	**1.0**	**2n**	
5831	07034N3817	AB	85.176	317.1	1.11	9.0–10.0	1 + 2	
	STF 1024		85.256	316.6	1.36	1.0	2 + 2	
	9.0–9.5		**85.222**	**316.8**	**1.25**	**1.0**	**2n**	
5871	07066N2724	AB	85.242	319.2	1.21	0.1	2 + 1	
	STF 1037		85.245	316.9	1.20	0.1	2 + 2	
	7.2–7.2		**85.244**	**317.9**	**1.20**	**0.1**	**2n**	Karmel, 1938: –0.°9, –0.″10
	STT 166 rej.	AB–C	85.242	80.1	–	m_c = 12.0	2 + 1	The angle has decreased
	–12.3							by 31° since 1899.
6671	08086N0177		85.247	16.3	0.92	0.7	2 + 1	
	BU 1244		85.256	16.2	0.80	0.7	1 + 2	The angle has decreased
	8.3–8.5		85.258	16.9	0.89	0.5	1 + 1	by 34° since 1891.
			85.252	**16.4**	**0.87**	**0.6**	**3n**	
6727	08114N5646		85.242	169.6	1.57	0.3	2 + 1	The angle has decreased
	STF 1205		85.245	170.2	1.58	8.5–9.0	2 + 2	by 17° since 1831.
	9.6–9.9		85.248	166.6	1.58	0.5	2 + 2	The increase in
			85.245	**168.7**	**1.58**	**0.4**	**3n**	distance still continues.
6811	08207N2452	AB	84.234	49.3	5.59	–	1 + 1	
	STF 1224		84.286	49.4	5.76	–	1 + 2	
	7.1–7.6		84.292	50.3	5.63	0.7	1 + 1	Slow direct orbital
			84.303	50.7	5.65	7.0–8.0	2 + 2	motion.
			84.284	**50.0**	**5.67**	**0.9**	**4n**	
7186	09013N4362		85.245	56.9	3.82	11.0–11.1	1 + 2	The position of the pair related to BD +44°1827, (9^m5): Δα = +14s, Δδ = +2'. My measurements from 1974 up to date do not yield confirmation of the position angle variations, thought this could have been expected in respect to Barton's measurements in 1893. I am possibly measuring a different pair after all !
	BRT 102		85.256	56.2	4.02	0.1	1 + 1	
	10.5–10.7		**85.249**	**56.6**	**3.90**	**0.1**	**2n**	
7307	09147N3837	AB	85.242	263.9	1.08	–0.1	1 + 1	
	STF 1338		85.245	259.6	0.97	0.0	2 + 1	
	6.6–6.8		85.248	260.6	0.97	0.3	2 + 1	
			85.256	260.7	0.97	0.1	1 + 1	
			85.259	262.8	1.10	0.2	1 + 1	
			85.249	**261.3**	**1.01**	**0.1**	**5n**	

Starikova, 1966: –7.°7, +0.″22

Table 2. (continued)

ADS	IDS DISC. m (IDS)	Mult.	Epoch 1900 +	P	ρ	m or Δm	Weight	Notes
7588	09509N4583		84.232	251.4	3.68	–	1 + 1	
	STF 1394		84.235	249.3	3.76	–	1 + 1	
	9.0–10.0		84.286	248.0	3.84	2.0	1 + 2	
			84.292	249.2	3.67	–	1 + 1	
			84.303	250.1	4.17	8.0–9.0	1 + 2	Decrease in distance.
			84.274	**249.5**	**3.85**	**1.5**	**5n**	
7704	10108N1774		85.242	183.5	1.31	0.1	1 + 1	Wierzbinski, 1953: +1°.9, −0".09
	STT 215		85.245	184.6	1.28	0.0	2 + 1	Zaera, 1957: +4.4, −0.07
	7.3–7.5		85.248	184.1	1.37	0.2	1 + 2	
			85.245	**184.1**	**1.32**	**0.1**	**3n**	
7721	10137N2064		85.245	4.3	0.74	1.0	1 + 1	
	STF 1423		85.256	7.0	0.75	0.5	1 + 1	
	9.0–10.0		**85.250**	**5.6**	**0.74**	**0.8**	**2n**	Heintz, 1959: −0°.2, −0".29
7874	10347N1946	AB–C	84.205	357.8	4.73	–	1 + 1	
	STT 225		84.286	357.4	5.77	3.0	1 + 1	
	8.3–10.5–10.6		84.303	357.9	6.59	m_c = 10.0	1 + 1	
			84.308	357.7	6.26	7.5–10.0	1 + 2	
			84.368	357.5	6.26	8.0–10.0	2 + 2	
			84.306	**357.6**	**6.00**	**m_c = 10.0**	**5n**	
8119	11128N3166		85.245	89.3	2.34	0.7	1 + 1	
	STF 1523		85.256	88.8	2.20	0.5	1 + 1	
	4.4–4.9		**85.250**	**89.0**	**2.27**	**0.6**	**2n**	Heintz, 1966: −0°.9, −0".01
8355	11511N3560	AB	84.303	143.1	1.39	7.0–9.0	1 + 2	
	STT 241		84.369	138.9	1.56	7.5–9.5	2 + 2	
	6.8–8.7		84.396	137.0	1.33	8.0–9.5	1 + 1	
			84.353	**139.9**	**1.45**	**7.5–9.4**	**3n**	P component is not seen.
8539	12194N2568	AB	84.396	325.4	1.45	8.0–9.0	2 + 2	
	STF 1639		84.432	329.1	1.57	1.5	1 + 2	
	6.6–7.8		84.437	327.1	1.53	7.0–8.5	2 + 2	
			84.448	328.1	1.32	1.2	1 + 2	
			84.427	**327.2**	**1.47**	**1.3**	**4n**	Aller, 1947: +2°.4, −0".05
8553	12222N2735		84.289	13.7	2.46	0.5	3 + 2	
	STF 1643		84.437	14.5	2.44	0.3	3 + 3	
	9.2–9.5		84.443	14.3	2.44	0.5	1 + 2	Since 1830 the
			84.448	14.3	2.32	0.3	1 + 2	angle has decrea-
			84.396	**14.2**	**2.42**	**0.4**	**4n**	sed by 57°.
8974	13330N3648	AB	84.453	99.9	1.57	1.5	1 + 3	
	STF 1768		84.470	101.6	1.50	–	2 + 2	
	5.1–7.0		**84.462**	**100.8**	**1.54**	**1.5**	**2n**	Wierzbinski, 1955: −2°.0, −0".29
		AC	84.454	321.4	–	−11.0	1 + 2	
9020	13418N4132		84.383	49.0	2.08	8.0–10.0	1 + 2	A component is
	STF 1783		84.437	48.8	1.97	9.0–11.0	2 + 2	red.
	8.1–10.3		84.443	50.2	2.01	2.0	2 + 2	
			84.424	**49.4**	**2.01**	**2.0**	**3n**	
9174	14095N2934		84.289	87.2	0.78	–	2 + 2	
	STF 1816		84.396	86.3	0.67	0.3	2 + 2	Distance is closing in.
	7.5–7.6		84.437	85.6	0.79	0.2	2 + 2	
			84.470	87.7	0.69	0.1	3 + 2	
			84.402	**86.8**	**0.73**	**0.2**	**4n**	

Table 2. (continued)

ADS	IDS DISC. m (IDS)	Mult.	Epoch 1900 +	P	ρ	m or Δm	Weight	Notes
9338	14360N1651	AB	84.446	108.5	5.54	1.0	1 + 2	
	STF 1864		84.448	108.3	5.60	1.0	1 + 1	
	4.9–5.8		84.453	109.0	5.48	1.0	1 + 2	
			84.449	**108.6**	**5.53**	**1.0**	**3n**	
9539	15095N4857	AB	84.437	340.7	26.21	–	2 + 1	
	ES		84.448	342.3	26.58	8.0–11.0	1 + 1	
	7.4–10.6		**84.441**	**341.3**	**26.36**	**8.0–11.0**	**2n**	
	–	AC	84.437	61.				
9571	15134N4139		84.383	122.3	8.48	–	1 + 1	
	ES 74		84.388	124.7	8.17	8.0–12.0	1 + 1	
	8.4–12.4		84.443	122.7	8.87	8.0–12.0	1 + 2	
			84.410	**123.2**	**8.56**	**8.0–12.0**	**3n**	
9639	15230N4421	AB	84.289	281.4	1.83	2.5	2 + 2	The angle has
	STT 296		84.437	281.6	1.89	7.0–9.0	1 + 2	decreased by 47°
	7.6–9.2		84.448	281.4	1.93	1.5	1 + 1	since 1845.
			84.454	280.6	1.68	8.5–10.0	3 + 3	
			84.459	282.1	1.88	–	1 + 1	
			84.416	**281.2**	**1.80**	**1.9**	**5n**	
	STT 296	AC	84.290	313.9	77.65	–	1 + 1	Physical connection
	7.4–12.5		84.437	313.5	77.47	7.0–12.0	1 + 2	between A, B, C
			84.448	312.8	77.08	–	1 + 1	is still uncertain.
			84.454	314.2	76.23	–11.0	2 + 2	
			84.459	313.5	–	–	1 + 1	
			84.425	**313.7**	**76.98**	**m_C = 11.3**	**5n**	
	–	AD	84.290	~346	–	–	1 + 1	
9716	15325N3968	AB	83.482	230.4	0.56	0.1	1 + 2	
	STT 298		84.290	233.0	0.61	0.2	2 + 2	
	7.4–7.7		84.454	234.3	0.63	8.0–8.0	3 + 3	
			84.462	236.5	0.46	–0.3	3 + 2	
			83.482	**230.4**	**0.56**	**0.1**	**1n**	Couteau, 1965: +4°.0, +0″.04
			84.413	**234.7**	**0.57**	**–0.1**	**3n**	Couteau, 1965: +2°.8, +0″.10
9979	16109N3367	AB	84.290	233.8	6.69	1.5	1 + 1	σC Bor
	STF 2032		84.473	233.9	6.75	7.5–8.5	2 + 2	
	5.8–6.7		84.607	233.7	6.67	1.0	1 + 2	
			84.477	**233.8**	**6.71**	**1.1**	**3n**	Rabe, 1954: +0°.1, –0″.07
	STF 2032	AC	84.473	103.8	–	m_C ~ 14	2 + 1	
	5.8–13.3		84.612	101.6	18.04	–	1 + 2	
			84.542	**102.7**	**18.04**	**m_C ~ 14**	**2/1n**	C is optical.
	STF 2032 5.8–10.8	AD	84.473	83.5	84.8	m_D ~ 12.5	2 + 2	
10345	17033N5436	AB	83.624	41.6	2.01	–0.1	1 + 2	
	STF 2130		83.629	40.4	2.06	0.0	2 + 2	
	5.8–5.8		83.638	40.1	1.96	0.0	2 + 2	
			83.643	40.4	2.10	0.0	2 + 2	
			84.607	38.5	2.10	0.3	1 + 3	
			83.839	**40.1**	**2.05**	**0.0**	**5n**	Heintz, 1965: +4°.5, +0″.15
10394	17078N2121	AB	84.623	190.8	8.06	1.0	2 + 1	The angle has incre-
	STF 2135		84.678	190.9	8.01	–	2 + 2	ased by 25° since
	7.5–8.8		**84.654**	**190.9**	**8.03**	**1.0**	**2n**	1829.

Table 2. (continued)

ADS	IDS DISC. m (IDS)	Mult.	Epoch 1900 +	P	ρ	m or Δm	Weight	Notes
10429	17114S0020		84.462	359.4	0.81	–	3 + 1	The angle has in-
	A 2984		84.599	2.0	1.11	3.0	2 + 1	creased by 62°
	4.9–7.9		**84.521**	**0.5**	**0.94**	**3.0**	**2n**	since 1915.
11158	18088N4013		83.709	142.9	1.19	9.0–9.7	1 + 1	
	LEO 1		84.675	144.3	1.44	10.5–11.5	2 + 2	
	10.5–11.2		84.678	148.8	1.70	10.0–11.0	1 + 1	
			84.434	**145.1**	**1.44**	**10.0–10.9**	**3n**	
11483	18314N1654	AB	83.629	163.2	1.60	–	2 + 2	
	STT 358		83.632	165.1	1.95	–	1 + 1	
	6.8–7.2		83.635	162.6	1.76	0.0	2 + 2	
			83.638	163.4	1.64	0.1	2 + 2	
			83.643	164.9	1.63	0.0	1 + 1	
			83.703	161.1	1.62	0.1	2 + 2	Starikova, 1966: +4°.3, +0".17
			83.648	**163.1**	**1.68**	**0.1**	**6n**	Hopmann, 1970: +3°.1, +0".16
11811	18505N3715		83.586	157.4	1.43	0.3	1 + 1	The angle has incre-
	BU 137		83.629	157.2	1.47	0.2	1 + 1	ased by 34° since
	8.2–8.7		83.635	157.2	1.40	0.2	3 + 2	1875.
			83.638	157.9	1.46	0.3	3 + 2	
			84.599	158.5	1.56	0.5	2 + 2	
			83.844	**157.7**	**1.46**	**0.3**	**5n**	
11869	18531N2558		83.586	74.9	0.83	–0.1	1 + 1	The angle has de-
	STF 2422		83.643	75.6	0.81	0.3	1 + 1	creased by 31° since
	8.0–8.1		84.599	75.5	0.86	0.2	2 + 2	1832.
			84.107	**75.4**	**0.84**	**0.2**	**3n**	
–	18546N4315		80.681	33.6	1.76	10.5–10.7	1 + 2	
	COU 1794		80.711	33.8	1.86	0.0	1 + 1	
			80.693	**33.7**	**1.80**	**0.1**	**2n**	
12040	19023N3017	AB	84.599	281.6	1.17	8.5–9.5	1 + 1	
	STF 2454		84.675	280.6	1.14	8.5–9.5	3 + 2	Baize, 1975: +0°.7, –0".11
	8.5–9.7		84.678	280.1	1.08	2.0	1 + 1	Olević, 1977: +0°.3, –0".01
			84.659	**280.7**	**1.13**	**1.5**	**3n**	(rect. trajectory)
12075	19044N3646	AB	83.742	122.6	1.31	8.0–9.0	2 + 2	
	STF 2469		84.462	125.1	1.20	1.0	1 + 1	
	7.8–8.9		84.566	122.0	1.20	–	1 + 2	
			84.599	123.8	1.32	–	2 + 2	
			84.307	**123.2**	**1.27**	**1.0**	**4n**	
	–	AC	84.462	162.4	37.4	m_C = 12.0	1 + 1	
			84.599	162.0	38.0	m_C = 12.0	1 + 1	
			84.530	**162.2**	**37.7**	**m_C = 12.0**	**2n**	
12550	19273N3454	AB	73.612	298	27.71	9.0–11.0	1 + 1	
	ES 2241 = BD + 34°3589							
		BC	73.606	24.5	2.20	10.0–11.0	1 + 1	
			73.612	20.0	2.45	11.0–12.0	1 + 2	
			73.623	23.3	2.48	10.0–10.5	1 + 1	
			73.613	**22.2**	**2.39**	**10.3–11.2**	**3n**	
12581	19286N3404		83.731	219.6	7.23	8.0–10.0	1 + 2	The angle has decre-
			84.566	219.4	6.94	8.5–10.0	1 + 1	ased by 21° since
			84.599	221.3	7.42	7.0–9.0	1 + 2	1904.
			84.839	221.0	7.11	9.0–10.2	2 + 2	Probably an optical
			84.456	**220.5**	**7.19**	**8.3–9.9**	**4n**	pair.

Table 2. (continued)

ADS	IDS Disc. m (IDS)	Mult.	Epoch 1900+	P	ρ	m or Δm	Weight	Notes
13277	19578N2439		84.777	118.6	0.95	0.3	2 + 2	The angle has increased by 40° since 1844.
	STT 395		84.787	119.7	0.87	0.5	1 + 2	
	5.9–6.3		**84.781**	**119.1**	**0.92**	**0.4**	**2n**	
14558	20580N3852		84.777	314.3	1.05	0.7	3 + 2	The angle has increased by 38° since 1830.
	STF 2746		84.787	314.9	1.01	8.5–9.0	1 + 2	
	8.0–8.6		**84.781**	**314.5**	**1.04**	**0.6**	**2n**	
14778	21105N4044		83.641	119.7	1.20	0.3	1 + 2	The angle has decreased by 14° since 1847.
	STT 432		83.703	117.5	1.25	8.0–8.3	1 + 1	
	7.8–8.2		83.728	113.5	1.30	0.5	1 + 1	
			83.736	116.1	1.21	0.3	1 + 2	
			84.866	113.1	1.26	0.1	1 + 1	
			84.870	115.3	1.11	0.2	1 + 1	
			84.033	**116.2**	**1.22**	**0.3**	**6n**	
+41°4049	21109N4118		84.580	270.2	55.42	–	1 + 2	The pair has been observed also in 1982 with the purpose of checking whether the B component were not identical with the star BD +41°4053. The measurements in 1982 and 1984 do not verify this identity. In the Series 37 Notes a mistake has been commited concerning this pair. Instead of BD +41°4053 reference is made to the star BD +41°4054.
			84.678	269.0	55.62	9.5–10.0	1 + 1	
			84.839	270.1	55.08	9.0–10.0	1 + 1	
			84.842	269.3	55.14	–	1 + 1	
			84.718	**269.7**	**55.33**	**9.2–10.0**	**4n**	
14894	21163N0228		83.638	230.9	0.62	0.3	2 + 2	The angle has increased by 28° since 1848.
	STT 435		84.462	230.6	0.65	0.1	2 + 2	
	8.1–8.6		84.777	232.6	0.57	–	1 + 2	
			84.248	**231.2**	**0.62**	**0.2**	**3n**	
14889	21166N3202	AB	83.586	25.5	2.01	0.3	1 + 2	The angle has decreased by 43° since 1845
	STT 437		83.635	23.7	2.23	0.3	2 + 2	
	6.9–7.6		83.638	25.4	2.25	0.5	3 + 2	
			83.641	25.5	2.15	0.5	1 + 2	
			84.760	24.3	2.17	0.3	1 + 2	
			84.866	26.6	2.04	0.6	1 + 2	
			84.870	25.6	1.99	0.5	1 + 1	
			84.872	25.7	2.13	0.2	1 + 1	
			84.111	**25.2**	**2.14**	**0.4**	**8n**	
14928	21188N3136		83.641	27.3	3.37	9.0–9.2	1 + 1	Direct motion. The measurements of ρ in ADS discordant.
	HO 157		83.703	26.6	3.40	9.0–9.5	1 + 2	
	9.2–9.2		83.728	27.7	3.44	0.2	1 + 1	
			83.736	26.4	3.49	0.1	1 + 1	
			83.702	**27.0**	**3.42**	**0.2**	**4n**	
15007	21240N1039	AB	83.586	267.9	1.59	0.0	1 + 1	The angle has decreased by 66° since 1831.
	STF 2799		83.624	267.2	1.72	0.0	1 + 2	
	7.5–7.5		83.635	267.4	1.70	0.0	3 + 3	
			83.638	267.3	1.72	0.0	3 + 3	
			83.641	267.0	1.71	0.0	1 + 2	
			83.709	266.0	1.64	–	1 + 1	
			83.637	**267.2**	**1.69**	**0.0**	**6n**	

Table 2. (continued)

ADS	IDS DISC. m (IDS)	mult.	Epoch 1900+	P	ρ	m or Δm	Weight	Notes
15407	21491N6517	AB	83.638	146.4	1.48	0.1	3 + 3	The distance has
	STF 2843		84.676	147.0	1.43	0.2	1 + 2	decreased by 1"
	7.1–7.3		84.760	146.1	1.54	0.2	1 + 2	since 1831.
			84.856	147.9	1.32	0.2	1 + 1	
			84.859	145.7	1.35	0.5	1 + 1	
			84.348	**146.6**	**1.45**	**0.2**	**5n**	
15769	22100N2905		83.739	77.5	1.22	8.5–9.0	3 + 3	The angular decrease
	STF 2881		83.881	76.4	1.20	7.7–8.2	1 + 2	by 34° since 1830
	7.6–8.1		84.676	77.9	1.19	0.5	1 + 2	with decrease in
			84.760	74.0	1.24	0.5	1 + 2	distance.
			84.870	79.8	1.05	0.3	1 + 1	
			84.243	**77.0**	**1.19**	**0.5**	**5n**	
15971	22237S0032		83.728	215.8	1.76	0.7	1 + 1	
	STF 2909		84.676	213.3	1.62	0.2	1 + 1	
	4.4–4.6		**84.202**	**214.6**	**1.69**	**0.4**	**2n**	Harrington, 1967: – 3°.3, –0".11
15988	22249N0355		83.745	115.1	0.70	7.0–8.0	1 + 1	
	STF 2912		84.681	112.8	0.61	1.5	1 + 1	
	5.8–7.2		**84.213**	**114.0**	**0.66**	**1.2**	**2n**	Knipe, 1960: –3°.5, –0".33
16317	22474N6109	AB	83.813	285.3	1.42	1.5	1 + 2	The angle has decreased
	STF 2950		83.881	286.8	1.45	8.0–9.0	1 + 2	by 33° since 1832.
	6.1–7.4		84.681	288.0	1.47	6.0–7.5	1 + 1	The distance closes in.
			84.760	285.1	1.42	1.0	1 + 2	
			84.839	287.6	1.41	7.0–8.0	1 + 1	
			84.856	285.1	1.42	1.3	1 + 1	
			84.408	**286.2**	**1.43**	**1.2**	**6n**	
	STF 2950	AC	83.813	354.8	39.14	m_c = 10.0	1 + 1	Unchanged.
	5.8–10.7		84.839	355.0	39.33	m_c = 9.0	1 + 1	
			84.326	**354.9**	**39.23**	**m_c = 9.5**	**2n**	
16561	23055N3156	AB	83.622	88.5	0.70	7.8–8.5	2 + 1	The angular decrease
	BU 385		84.675	88.3	0.61	0.5	3 + 2	by 48° since 1876.
	7.3–8.1		**84.280**	**88.4**	**0.64**	**0.6**	**2n**	
16896	23339N4351	AB	83.895	73.8	1.59	9.0–11.0	3 + 2	ADS 16896 = BD + 43°4516
	D 26		84.681	76.6	1.73	9.0–11.5	1 + 1	The distance closes in.
	10.5–11.8		**84.120**	**74.6**	**1.63**	**9.0–11.1**	**2n**	
16902	23343N4322		83.895	134.4	3.55	9.0–11.0	2 + 1	
	COM		83.898	134.0	3.04	9.0–11.0	1 + 1	
	9.4–11.4		**83.896**	**134.2**	**3.35**	**9.0–11.0**	**2n**	
17037	23455N4252		80.793	103.7	5.09	8.5–10.0	1 + 2	
	STT 509		80.810	104.8	5.24	8.0–10.0	2 + 2	
			80.889	104.6	5.20	8.5–10.0	2 + 2	
			80.834	**104.4**	**5.18**	**8.5–10.0**	**3n**	
17149	23544N3310	AB	83.881	312.8	1.49	0.2	1 + 2	
	STF 3050		84.788	314.9	1.68	0.2	1 + 1	
	6.6–6.6		84.870	315.9	1.60	0.2	1 + 2	Franz, 1954: –1°.8, –0".23
			84.479	**314.5**	**1.58**	**0.2**	**3n**	Heintz, 1973: –0°.9, 0".00

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MICROMETER MEASURES OF DOUBLE STARS
(Series 40)

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SUMMARY: Presented here are 289 measures of 103 double stars made with 65/1055 cm refractor of Belgrade Observatory

The present series of measures is the continuation of my own measurements published under Series 38(D.Zulević, 1984). The measures were made with the 65/1055 cm refractor of the Belgrade Observatory between 1983 July 28 and 1985 May 5. In Table I 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 Notes comparisons have been made with the latest available orbits (Muller, P., Couteau, P. 1979). In the present work the distribution of 289 measures of distances is as follows:

Distances	Measures
0".00 to 0".50	4
0.50 to 1.00	96
1.00 to 1.50	117
1.50 to 2.00	21
2.01 or greater	51
	289

Table I Micrometer measures of double stars

ADS	Disc. IDS	Mult.	Epoch 1900+	P	ρ	Est. Mag.	n	Notes	
48	STT 547	AB	83.704	175°5	5".87	8.9– 9.0	1		
	00002N4516		84.760	174.6	5.87		1	Guntzel–Lingner, 1954:	+0°.1, –0".06
			84.232	**175.1**	**5.87**		**2**	Hopmann, 1961:	–0.7, –0.02
61	STF 3062		83.704	296.2	1.44	6.4– 7.2	1		
	00010N5753		83.742	297.5	1.45		1		
			84.760	298.1	1.43		1		
			84.834	297.3	1.44		1		
			84.864	301.3	1.39		1		
			84.381	**298.1**	**1.43**		**5**	Baize, 1957:	+ 1.4, –0.01
207	STF 13		83.704	58.6	0.87	6.8– 7.1	1		
	00106N7624		83.742	59.4	0.88		1		
			84.864	58.0	0.89		1		
			84.103	**58.6**	**0.88**		**3**	Heintz, 1959:	+ 2.7, + 0.01
283	HJ 1018		84.834	86.2	1.42	8.6– 9.2	1		
	00154N6707		84.864	85.0	1.43		1		
			84.849	**85.6**	**1.43**		**2**	Muller, 1956:	- 0.7, –0.06
1223	HWE 4		83.704	340.3	0.90	9.4– 9.5	1		
	01288S1244		83.742	339.4	0.76		1		
			83.723	**339.8**	**0.83**		**2**	Van den Bos, 1951:	+ 3.1, + 0.06
1522	STF 183	AB	83.842	172.4	0.37	7.8– 8.5	1	Couteau, 1973:	+ 0.1, + 0.08
	01494N2818								
1538	STF 186		83.742	55.7	1.20	6.8– 6.8	1	Palacios, 1947:	+ 0.3, + 0.05
	01507N0121							Freitas–Mourao, 1976:	+ 0.4, –0.15
1709	STF 228		83.742	268.7	1.03	6.6– 7.1	1		
	02076N4701		84.864	271.3	1.04		1		
			84.303	**270.0**	**1.04**		**2**	Heintz, 1952:	+ 0.6, –0.02

Table 1. (continued)

ADS	Disc. IDS	Mult.	Epoch 1900+	P	ρ	Est. Mag.	n	Notes	
2446	STT 53 03113N3816		83.742	260°.5	0".82	7.8– 8.3	1	Rabe, 1948: Zulević, 1983:	–3°.2, –0".03 –0.1, –0.04
2612	STF 400 03268N5942		83.742	258.0	1.25	6.8– 7.6	1	Baize, 1951: VBs, 1954:	–1.8, –0.07 –6.7, –0.08
2959	STF 483 03574N3914		83.742	74.0	0.96	7.5 8.6	1	Couteau, 1958:	+ 1.8, +0.00
5269	STF 941 06316N4140	AB	85.258	84.2	1.74	7.0– 8.0	1	Unchanged since 1830.	
5831	STF 1024 07034N3817	AB	85.176 85.256 **85.216**	317.6 317.6 **317.6**	1.18 1.30 **1.24**	8.0– 9.0	1 1 **2**	Unchanged since 1831.	
5871	STF 1037 07066N2724	AB	85.176 85.242 **85.209**	318.9 320.8 **319.9**	1.22 1.22 **1.22**	7.2– 7.2	1 1 **2**	Karmel, 1938:	+ 1.1, –0.08
6175	STF 1110 07282N3166	AB	85.176 85.261 **85.219**	85.6 87.1 **86.3**	2.77 2.54 **2.66**	2.0– 2.9	1 1 **2**	Muller, 1955: Rabe, 1957:	–0.5, –0.03 + 3.7, + 0.05
6671	BU 1244 08086N1177		85.247 85.256 85.258 **85.254**	15.4 16.0 15.6 **15.6**	0.99 0.96 0.94 **0.96**	8.0– 9.0	1 1 1 **3**	Changed 34° since 1891.	
6727	STF 1205 08114N5646		85.242 85.247 85.261 **85.250**	168.3 168.8 168.2 **168.4**	1.53 1.46 1.50 **1.50**	8.5– 8.8	1 1 1 **3**	Changed 18° since 1831.	
7067	STF 1280 08460N7071	AB	85.258 85.262 **85.260**	139.9 138.0 **138.9**	1.01 1.01 **1.01**	7.5– 7.6	1 1 **2**	Heintz, 1973:	+ 0.1, –0.11
7186	BRT 102 09013N4362		85.256	236.5	3.76	10.0–10.1	1	Changed 110° since 1893.	
7284	STF 3121 09120N2860		84.289 85.261 **85.275**	27.3 35.0 **31.1**	0.44 0.51 **0.48**	8.1– 8.1	1 1 **2**	Van den Bos, 1937:	–2.5, +0.00
7307	STF 1338 09147N3837		84.289 85.242 85.247 85.259 **85.059**	261.6 260.8 263.7 263.9 **262.7**	0.97 1.14 1.00 0.97 **1.02**	6.6– 6.8	1 1 1 1 **5**	Starikova, 1966:	–4.9, + 0.22
7704	STT 215 10108N1774		84.289 84.388 85.242 85.247 85.261 **84.885**	182.7 181.3 183.1 183.1 183.8 **182.8**	1.28 1.43 1.40 1.36 1.28 **1.35**	7.3– 7.5	1 1 1 1 1 **5**	Zaera, 1957:	+ 3.0, –0.04
7721	STF 1423 10137N2064		84.289 85.245 85.256 85.261 **85.013**	6.4 6.9 5.5 7.1 **6.5**	0.96 0.94 0.91 0.98 **0.95**	9.3–10.0	1 1 1 1 **4**	Heintz, 1959:	+ 0.6, –0.08

Table 1. (continued)

ADS	Disc. IDS	Mult.	Epoch 1900+	P	ρ	Est. Mag.	n	Notes
8119	STF 1523	AB	84.371	91°.4	2".24	4.4– 4.9	1	
	11128N3166		85.245	96.7	2.21		1	
			85.256	92.0	2.22		1	
			84.854	**93.4**	**2.23**		**3**	Heintz, 1966: + 3°.4, –0".09
8128	STF 1527		85.259	40.4	1.14	7.0– 8.1	1	
	11138N1449		85.261	40.4	1.16		1	
			85.260	**40.4**	**1.15**		**2**	Hopmann, 1958: + 7.6, –0.21
8148	STF 1536		85.259	135.8	1.13	4.1– 7.3	1	Baize, 1951: –6.4, –0.17
	11187N1065							
8539	STF 1668		85.245	325.6	1.40	6.6–, 7.8	1	
	12194N2568		85.261	326.4	1.40		1	
			85.253	**326.0**	**1.40**		**2**	Aller, 1947: + 1.3, –0.14
8553	STF 1643		84.289	11.3	2.38	9.2– 9.5	1	
	12222N2735		84.388	11.0	2.28		1	
			85.245	11.7	2.40		1	
			85.261	12.4	2.34		1	
			84.786	**11.6**	**2.35**		**4**	Hopmann, 1959: +54.9, +0.46
8887	HO 260		85.369	71.1	0.93	9.6– 9.8	1	
	13189N2945		84.462	72.9	1.08		1	
			84.467	73.1	1.00		1	
			84.245	76.4	0.99		1	
			84.636	**73.4**	**1.00**		**4**	Ambruster, 1955: –1.4, –0.11
8949	STF 1757		84.478	115.8	2.18	7.4– 8.8	1	
	13292N0012		85.245	117.2	2.02		1	
			84.861	**116.5**	**2.10**		**2**	Heintz, 1955: –1.0, +0.03
9020	STF 1783		84.470	48.7	2.24	7.8–10.0	1	Unchanged since 1832.
	13418N4132							
9031	STF 1785		84.478	161.3	3.27	7.9–, 8.2	1	
	13445N2689		82.522	162.5	3.21		1	
			85.245	164.2	3.42		1	
			84.748	**162.7**	**3.30**		**3**	Strand, 1953: –0.1, –0.11
9174	STF 1816		84.396	89.2	0.72	7.0–, 7.1	1	
	14095N2934		84.522	86.7	0.71		1	
			84.459	**87.9**	**0.71**		**2**	Very changed in ρ
9182	STF 1819		84.462	50.9	0.93	7.7–, 7.8	1	Baize, 1971: + 3.6, –0.11
	14103N0336							
9211	BU 1272	AB	85.245	137.2	1.01	Δm = 0.8	1	Unchanged since 1892.
	14141N4873							
9229	STF 1834		84.369	101.9	1.17	7.9– 8.0	1	
	14166N4858		84.478	100.4	1.13		1	
			84.423	**101.1**	**1.15**		**2**	Van den Bos, 1936: –3.9, –0.12
9380	STF 1837		84.369	91.6	1.42	7.6–, 8.6	1	
	14414N0965		84.478	91.3	–		1	
			84.423	**91.4**	**1.42**		**2**	Wierzbinski, 1956: + 2.6, –0.10
9418	STT 287		84.462	346.9	0.94	8.5– 8.6	1	
	14478N4480		84.467	345.8	1.00		1	
			84.533	347.1	0.98		1	
			84.487	**346.6**	**0.98**		**3**	Heintz, 1959: –0.4, –0.10

Table 1. (continued)

ADS	Disc. IDS	Mult.	Epoch 1900+	P	ρ	Est. Mag.	n	Notes
9425	STT 288 14487N1567		84.369	175°.1	1".38	6.9– 7.6	1	
			84.380	171.2	1.41		1	
			84.396	169.6	1.36		1	
			84.467	170.8	1.35		1	
			84.395	**171.7**	**1.38**		**4**	Heintz, 1950: +2°.5, +0".22
9578	STF 1932 15140N2672	AB	84.380	252.1	1.46	7.1– 7.6	1	
			84.396	251.9	1.47		1	
			84.522	253.6	1.40		1	
			84.433	**252.5**	**1.44**		**3**	Heintz, 1964: –0.1, –0.01
9617	STF 1937 15191N3039		84.530	7.6	0.76	5.6– 5.9	1	Danjon, 1938: +0.9, +0.00
9626	STF 1938 15207N3442	BC	84.527	14.9	2.06	7.2– 7.8	1	
			84.530	14.3	2.13		1	
			84.533	14.2	2.12		1	
			84.549	14.3	2.18		1	
			84.535	**14.4**	**2.12**		**4**	Baize, 1951: +0.2, –0.08
9639	STT 296 15230N4421	AB	84.448	282.0	1.89	7.0– 8.6	1	
			84.522	283.3	1.94		1	
			84.524	283.0	1.88		1	
			84.498	**282.8**	**1.90**		**3**	Changed 45° since 1845.
9716	STT 298 15325N3968	AB	84.454	232.1	0.50	7.4– 7.7	1	
			84.462	239.2	0.63		1	
			84.470	235.2	0.49		1	
			84.462	**235.5**	**0.54**		**3**	Couteau, 1965: +3.1, +0.07
9756	STF 1969 15394N6018		84.530	21.0	0.49	8.9– 9.6	1	Heintz, 1974: +0.5, –0.01
9925	BU 812 16026N1670		84.538	110.3	0.70	8.2– 8.2	1	
			84.555	106.5	0.66		1	
			84.546	**108.4**	**0.68**		**2**	Changed 19° since 1881.
9982	STF 2026 16111N0737		84.484	24.2	2.77	9.1– 9.6	1	
			84.522	22.5	2.88		1	
			84.524	22.8	2.92		1	
			84.510	**23.2**	**2.86**		**3**	Heintz, 1962: +0.5, –0.04
10036	BU 951 16198N3335	ABxC	84.536	34.5	0.92	8.2– 9.6	1	
			84.538	35.5	0.87		1	
			84.549	34.2	0.92		1	
			84.552	34.1	0.92		1	
			84.544	**34.6**	**0.91**		**4**	Changed 22° since 1879.
10070	STF 2049 16238N2612		84.536	196.9	1.09	6.5– 7.5	1	
			84.538	197.5	1.16		1	
			84.549	199.6	1.16		1	
			84.552	198.8	1.16		1	
			84.544	**198.2**	**1.14**		**4**	Changed 17° since 1829.
10071	BU 813 16239N2646		84.539	174.9	1.01	8.4– 8.4	1	
			84.550	172.9	1.09		1	
			84.555	175.3	1.11		1	
			84.548	**174.4**	**1.07**		**3**	Changed 9° since 1881.

Table 1. (continued)

ADS	Disc. IDS	Mult.	Epoch 1900+	P	ρ	Est. Mag.	n	Notes	
10075	STF 2052		84.380	131°.4	1″.38	7.8– 7.8	1		
	16245N1837		84.396	132.8	1.46		1		
			84.448	132.8	1.35		1		
			84.454	132.7	1.39		1		
			84.419	**132.4**	**1.40**		**4**	Siegrist, 1950:	+ 0°.7, – 0″.15
10093	STF 2059		84.539	194.7	0.96	8.2– 8.3	1		
	16274N3817		84.550	193.1	0.70		1		
			84.555	199.1	0.72		1		
			84.548	**195.7**	**0.79**		**3**	Changed 13° since 1829.	
10188	D 15		84.484	140.0	1.04	9.1– 9.1	1		
	16408N4340		84.522	141.1	1.06		1		
			84.524	140.3	1.06		1		
			84.528	141.0	1.06		1		
			84.514	**140.6**	**1.06**		**4**	Wierzbinski, 1955:	+ 2.5 –0.03
10235	STF 2107		84.380	92.1	1.15	6.7– 8.2	1		
	16479N2850		84.397	91.2	1.10		1		
			84.448	91.1	1.19		1		
			84.454	90.3	1.23		1		
			84.419	**91.2**	**1.17**		**4**	Rabe, 1926:	+ 1.0,–0.22
10279	STF 2118		84.484	69.4	1.10	6.9– 7.4	1		
	16559N6511		84.522	67.5	1.08		1		
			84.524	67.5	1.07		1		
			84.510	**68.1**	**1.08**		**3**	Giannuzzi, 1955:	–0.2, –0.24
10341	BU 823	AB	84.530	131.0	0.94	8.7– 9.7	1		
	17015N0047		84.533	130.2	0.92		1		
			84.531	**130.6**	**0.93**		**2**	Arend, 1955:	+ 7.7, –0.11
10345	STF 2130		84.528	219.1	2.18	5.8– 5.8	1		
	17033N5436		84.531	219.7	2.14		1		
			84.533	219.8	2.09		1		
			84.534	**39.5**	**2.14**		**3**	Heintz, 1965:	+ 5.1, + 0.25
45°2505	KUI 79	AB	84.530	240.2	1.10	10.1–10.4	1		
	17092N4551		84.533	240.2	0.97		1		
			84.703	240.2	1.06		1		
			84.588	**240.2**	**1.04**		**3**	Baize, 1951:	–0.9, –0.08
10786	AC 7	BC	83.706	50.2	1.45	10.3–10.8	1		
	17425N2747		83.738	49.5	1.46		1		
			84.397	51.0	1.44		1		
			84.470	52.4	1.53		1		
			84.078	**50.8**	**1.47**		**4**	Couteau, 1957:	+ 0.4, –0.01
11005	STF 2262	AB	83.706	277.9	1.79	5.2– 5.9	1		
	17576S0811		83.738	278.6	1.84		1		
			84.524	276.5	1.77		1		
			83.987	**277.7**	**1.80**		**3**	Wierzbinski, 1957:	–0,2, –0.02
11123	STF 2289		83.706	221.1	1.21	6.5– 7.2	1		
	18057N1627		83.722	220.9	1.20		1		
			84.397	221.1	1.17		1		
			84.454	221.1	1.14		1		
			84.072	**221.1**	**1.18**		**4**	Hopmann, 1956:	+ 1.2, –0.05

Table 1. (continued)

ADS	Disc. IDS	Mult.	Epoch 1900+	P	ρ	Est. Mag.	n	Notes
11186	STF 2294		84.484	97°.4	0".97	8.5– 8.8	1	
	18094N0009		84.522	94.3	1.09		1	
			84.524	94.8	1.11		1	
			84.697	97.4	0.96		1	
			84.557	**96.0**	**1.03**		**4**	Wilson, 1935: + 2°.5, +0".02
11235	J 759		84.552	81.2	2.11	9.2– 9.3	1	
	18130N2023		84.555	85.6	2.05		1	
			84.705	81.4	2.21		1	
			84.604	**82.7**	**2.12**		**3**	Unchanged since 1912.
11334	STF 2315		83.744	129.3	0.68	6.5– 7.5	1	
	18210N2720		83.788	132.3	0.68		1	
			84.454	134.8	0.70		1	
			83.995	**132.1**	**0.69**		**3**	Heintz, 1958: + 4.01, –0.02
11483	STT 358		83.665	163.3	1.65	6.8– 7.2	1	
	18314N1654		83.668	162.2	1.66		1	
			84.524	162.5	1.75		1	
			84.697	161.3	1.68		1	
			84.138	**162.3**	**1.68**		**4**	Hopmann, 1970: + 2.6, + 0.16
11568	STF 2384	AB	84.484	299.9	0.59	8.6– 9.1	1	
	18385N6702		84.522	304.2	0.50		1	
			84.524	307.5	0.51		1	
			84.510	**303.9**	**0.53**		**3**	Heintz, 1975: –8.3, + 0.02
11623	A 253		83.744	120.4	0.81	9.4–10.0	1	
	18400N3135		83.788	124.7	0.75		1	
			84.454	121.9	0.73		1	
			84.470	123.0	0.82		1	
			84.114	**122.5**	**0.78**		**4**	Muller, 1954: –0.4, + 0.01
11635	STF 2382	AB	84.531	354.8	2.52	5.0– 6.1	1	
	18410N3934		84.533	354.4	2.60		1	
			84.675	355.5	2.67		1	
			84.700	354.7	2.52		1	
			84.716	355.5	2.45		1	
			84.631	**354.9**	**2.55**		**5**	Guntzel–Lingner, 1955: –1.0, –0 10
11635	STF 2383	CD	84.531	90.6	2.31	5.1– 5.5	1	
	18410N3934		84.533	91.1	2.28		1	
			84.675	91.9	2.23		1	
			84.700	91.6	2.29		1	
			84.716	91.9	2.35		1	
			84.631	**91.2**	**2.29**		**5**	Guntzel–Lingner, 1955: + 9.6, –0.05
11871	BU 648	AB	83.744	40.9	1.13	5.4– 7.5	1	
	18533N3246		83.782	42.0	1.13		1	
			84.454	37.3	1.05		1	
			84.471	36.9	1.07		1	
			84.113	**39.3**	**1.09**		**4**	Vlaicu, 1956: –0.1, –0.08
11879	STF 2438		84.484	3.5	0.89	6.8– 7.4	1	
	18558N5805		84.523	5.0	0.83		1	
			84.524	2.8	0.86		1	
			84.510	**3.8**	**0.86**		**3**	Jastrzeobski, 1956: + 2°3, –0".04
12033	HU 940		84.533	201.8	0.58	9.6– 9.6	1	
	19018N3343		84.550	202.7	0.47		1	
			84.552	202.0	0.50		1	
			84.703	202.2	0.61		1	
			84.585	**202.2**	**0.54**		**4**	Muller, 1953: –0°2, –0".04

Table 1. (continued)

ADS	Disc. IDS	Mult.	Epoch 1900+	P	ρ	Est. Mag.	n	Notes	
33°3323	DZ 1		84.550	163°.7	1".16	10.5–10.5	1		
	19029N3346		84.552	164.7	1.15		1		
			84.551	**164.2**	**1.15**		**2**		
12040	STF 2454	AB	83.706	284.0	1.21	8.5– 9.7	1		
	19023N3017		83.722	281.6	1.21		1		
			84.454	282.3	1.15		1		
			84.471	283.0	1.17		1		
			84.088	**282.7**	**1.18**		**4**	Baize, 1975:	+ 2°.9, −0".05
12201	STF 2484		84.550	239.3	2.17	7.9– 9.4	1		
	19099N1854		84.675	236.5	2.01		1		
			84.703	236.4	2.12		1		
			84.643	**237.4**	**2.10**		**3**	Hopmann, 1973:	+ 1°.4, −0".08
12447	STF 2525		83.744	294.3	1.94	8.1– 8.4	1		
	19225N2707		83.783	293.7	1.77		1		
			84.471	295.4	1.83		1		
			84.484	294.8	1.79		1		
			84.120	**294.5**	**1.83**		**4**	Job Tamburini, 1967:	+ 2°.0, − 0".05
12889	STF 2576	AB	83.722	358.1	2.13	8.3– 8.4	1		
	19418N3322		83.738	354.1	2.15		1		
			84.471	355.5	2.27		1		
			84.484	355.7	2.08		1		
			84.104	**355.8**	**2.16**		**4**	Rabe, 1943:	+ 2°.9, + 0".00
12972	STT 387	AB	83.722	161.5	0.72	7.2– 7.7	1		
	19450N3504		83.739	162.5	0.61		1		
			84.471	161.2	0.63		1		
			83.977	**161.7**	**0.65**		**3**	Baize, 1960:	+ 0.7, + 0.04
13649	BU 984		84.550	244.1	0.62	7.9– 8.2	1		
	20134N2604		84.553	246.5	0.55		1		
			84.705	252.3	0.65		1		
			84.716	253.5	0.70		1		
			84.631	**249.2**	**0.63**		**4**	Changed 45° since 1880.	
13665	A 1205		83.744	106.4	0.60	9.2–10.0	1		
	20141N2864		83.783	106.7	0.61		1		
			84.523	104.2	0.60		1		
			84.015	**105.8**	**0.60**		**3**	Heintz, 1978:	+ 5.6, −0.04
13723	STT 406		83.723	117.4	0.67	7.4– 8.3	1		
	20166N4503		83.739	113.6	0.59		1		
			84.523	113.3	0.63		1		
			83.995	**114.8**	**0.63**		**3**	Heintz, 1975:	−0.9, + 0.05
14088	A 744		84.550	271.4	0.65	8.6– 8.6	1		
	20340N2932		84.553	271.1	0.63		1		
			84.705	271.3	0.61		1		
			84.603	**271.3**	**0.63**		**3**	Unchanged	
14196	BU 152		84.553	84.2	1.02	7.2– 8.0	1	Changed 27° since 1876.	
	20398N5702								
14238	BU 64	AB	83.744	162.4	0.56	8.7– 9.0	1		
	20403N1222		83.783	165.8	0.56		1		
			83.764	**164.1**	**0.56**		**2**	Baize, 1956:	−1.2, + 0.01
14286	BU 364		84.553	240.9	0.98	8.7– 8.9	1		
	20427N2503		84.705	245.1	1.05		1		
			84.629	**243.0**	**1.01**		**2**	Changed 24° since 1876.	

Table 1. (continued)

ADS	Disc. IDS	Mult.	Epoch 1900+	P	ρ	Est. Mag.	n	Notes	
14296	STT 413	AB	83.706	13°.6	0".90	4.8– 6.1	1		
	20435N3607		83.723	13.9	0.87		1		
			83.715	**13.8**	**0.88**		**2**	Rabe, 1946:	+ 0°.5, + 0".03
14360	STF 2729	AB	83.706	11.7	0.95	6.4– 7.2	1		
	20461S0600		83.738	12.0	0.88		1		
			83.722	**11.8**	**0.91**		**2**	Vlaicu, 1955:	+ 0.2, + 0.00
14424	BU 367	AB	83.723	121.0	0.49	8.4– 9.8	1		
	20508N2743		83.739	122.1	0.53		1		
			84.523	123.4	0.53		1		
			83.995	**122.2**	**0.52**		**3**	Heintz, 1961:	+ 0.4, + 0.01
14499	STF 2737		83.788	287.0	1.01	6.0– 6.3	1		
	20541N0355		84.524	288.9	0.97		1		
			84.156	**287.9**	**0.99**		**2**	Zeller, 1957:	+ 2.6, –0.04
14573	STF 2744	AB	83.788	125.8	1.21	6.7– 7.2	1		
	20580N0108		84.524	126.0	1.19		1		
			84.156	**125.9**	**1.20**		**2**	Popović, 1962:	+ 2.9, –0.06
14778	STT 432		84.550	120.2	1.28	6.8– 7.2	1		
	21105N4044		84.553	118.7	1.25		1		
			84.796	119.2	1.34		1		
			84.867	115.5	1.24		1		
			84.869	117.5	1.25		1		
			84.727	**118.2**	**1.27**		**5**	Changed 12° since 1847.	
14783	HI 48		83.788	260.0	0.59	7.0– 7.2	1		
	21117N6400		84.484	251.4	0.67		1		
			84.136	**255.7**	**0.63**		**2**	Baize, 1949:	+ 3 5,/+ 0.04
14889	STT 437	AB	84.553	24.0	2.18	6.5– 7.2	1		
	21166N3202		84.705	23.5	2.37		1		
			84.835	25.8	2.16		1		
			84.867	23.1	2.08		1		
			84.869	24.2	2.11		1		
			84.872	25.4	2.05		1		
			84.783	**24.3**	**2.16**		**6**	Changed 44° since 1845.	
14931	HU 591		84.553	137.0	0.67	9.0– 9.5	1	Changed 13° since 1902.	
	21194N5148								
15407	STF 2843	AB	84.856	147.9	1.48	m=0.2	1		
	21491N6517		84.859	147.4	1.46		1		
			84.864	148.6	1.46		1		
			84.860	**147.9**	**1.47**		**3**	Changed 14° since 1831.	
15769	STF 2881		83.739	83.7	1.26	7.6– 8.1	1		
	22100N2905		83.745	81.9	1.31		1		
			83.786	82.4	1.35		1		
			84.834	80.2	1.39		1		
			84.869	81.7	1.23		1		
			84.195	**82.0**	**1.31**		**5**	Changed 29° since 1830.	
15988	STF 2912		83.745	122.5	0.96	5.8– 7.1	1		
	22249N0355		83.783	118.1	0.83		1		
			84.524	120.5	0.83		1		
			84.017	**120.4**	**0.87**		**3**	Knipe, 1958:	+ 2.7, –0.12

Table 1. (continued)

ADS	Disc. IDS	Mult.	Epoch 1900+	P	ρ	Est. Mag.	n	Notes	
16185	STF 2934		83.704	73°.9	0″.93	8.8– 9.5	1		
	22370N2054		83.723	68.5	0.96		1		
			84.525	72.3	0.97		1		
			83.984	**71.6**	**0.95**		**3**	Heintz, 1960:	+ 4°.8 + 0″.00
16317	STF 2950	AB	84.856	285.4	1.44	5.7– 7.0	1		
	22474N6109		84.864	286.0	1.40		1		
			84.860	**285.7**	**1.42**		**2**	Changed 33° since 1832.	
16326	A 632		83.704	168.8	0.82	8.6– 9.1	1		
	22480N5712		83.723	166.8	0.78		1		
			84.864	171.8	0.82		1		
			84.097	**169.1**	**0.81**		**3**	Heintz, 1961:	+ 3.7, + 0.05
16649	BU 79	AB	83.704	21.8	1.48	8.5– 9.6	1		
	23125S0204		83.739	20.2	1.50		1		
			83.721	**21.0**	**1.49**		**2**	Heintz, 1959:	–1.9, –0.04
16951	A 1242		83.723	327.3	0.78	9.6– 9.6	1		
	23380N1117		83.739	325.7	0.78		1		
			83.731	**326.5**	**0.78**		**2**	Zulević, 1974:	–0.7, + 0.03
17149	STF 3050	AB	84.834	313.9	1.49	6.6– 6.6	1		
	23544N3310		84.864	313.1	1.54		1		
			84.869	315.6	1.50		1		
			84.856	**314.2**	**1.51**		**3**	Heintz, 1973:	–1.7, –0.08

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PRELIMINARY RESULTS OF PLANET OBSERVATIONS WITH THE BELGRADE VERTICAL CIRCLE

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SUMMARY: Account is given of the method, organization and results of observations o outer planets with the Belgrade Vertical Circle, carried out in the period April 1983 t November 1984. The O – C differences for all the observed planets, as well as the me errors of observations are given.

1. INTRODUCTION

Following the dermination of observations involved by the working out of the Bright Stars catalogue of declinations in the zone from +65° to +90°, performed with the Belgrade Vertical Circle (ASKANIA, 190/2578 mm) the instrument is currently employed on the project: „Determination of declinations of the solar system bodies". Two observers are taking part: Dj. Bozhichovich and the author. Preliminary (experimental) observations were made during 1982 by the first observer which demonstrated that the obtained planet and the Sun's declinations possessed a satisfactory accuracy.

In the present paper are exposed results of this author's own observations of the planets Mars, Jupiter, Saturn, Uranus and Neptune carried out in 1983 and 1984. These will, simultanously, be the very fisrt results of observation with this instrument to have ever been published.

2. METHOD ,ORGANIZATION AND RESULTS OF OBSERVATION

Declinations are observed differentially, the reference stars being selected from the FK4. The list of the observed stars is displayed in Table 1, where n – the number of observations, m – apparent magnitude. It goes without saying that the stars have been selected in such a way as to be as near, in right ascension and declination, to the observed planet as possible and, moreover, as symetrically distributed as only feasible. One usually took 4 to 6 stars to be linked with the planet under observation, but this number was, for the sake of better dependability, now and then increased. Each observing tour included determination of the horizontal flexure component, which took about 25 minutes.

Mars, Jupiter, and Saturn observations were executed by setting the micrometer threads on the north and south edges. When, on the E clamp, one started setting on the planet's north edge it was on the south edge that

Table 1. Reference stars actually observed with the planets

N°	N_{FK4}	m
1	1335	4.9
2	498	1.2
3	1348	5.6
4	1335	5.2
5	510	5.1
6	1365	6.4
7	523	4.3
8	1371	4.6
9	1374	6.3
10	1381	6.2
11	545	4.0
12	548	2.9
13	1390	5.6
14	556	3.4
15	559	4.7
16	564	2.7
17	1404	6.8
18	1405	6.7
19	1407	5.9
20	577	4.0
21	1413	5.0
22	1415	5.1
23	594	2.5
24	1419	5.5
25	597	2.9
26	607	3.1 var.
27	616	1.5–5.2 var.
28	1430	5.8
29	624	5.0
30	1437	7.6
31	1447	6.2
32	1449	6.1
33	644	3.4
34	1457	4.3
35	1463	4.9
36	682	4.0
37	687	2.8
38	1485	5.8
39	1493	6.2
40	706	2.1
41	710	3.6
42	1496	3.4
43	720	3.0
44	722	5.0
45	736	4.7
46	1517	5.1
47	753	4.6
48	1529	6.0

settings started on the W clamp, and vice – versa. There were in all four settings at each tranit in NSSN or SNNS orders. The planets Uranus and Neptune were observed by bisection. The verical micrometer fixed threads on which the observations were performed were: 1, 1.5, 2 and 3.

Over the period concerned Mars has been observed 13 times, Jupiter 18, Saturn 11, Uranus 16 and Neptune 9 times.

At reduction, it was the mean latitude, resulting from the observations of all stars on a given night, that was used. The latitude has been computed according to the well known formula:

$$\varphi = z + \delta_{app}$$

where z – the observed zenith distance and δ_{app} – the apparent star declination at the time of observation.

The zenith distance was determined from observation on two clamp positions: circle east (CE) and circle west (CW). The reduction was performed according to the formula:

$$z = \frac{1}{2}(C_W - C_E) + \frac{1}{2}(M_E - M_W)\mu + \frac{1}{4}(LU_E - LU_W)\lambda_U + \frac{1}{4}(LL_E - LL_W)\lambda_L + C_c + C_r + F + B + \rho$$

where:

C_E and C_W – circle readings on CE and CW positions; M_E and M_W – eye–piece micrometer readings on CE and CW positions; μ – mean eye–piece micrometer revolution μ = 19″.99; LU_E, LU_W, LL_E, LL_W – upper and lower level readings on E and W clamps. λ_u and λ_L – mean division values of the upper and lower lavels, resp. computed by the expressions: λ_u = 1″.0408–0.0063 (T–1970.0) + 0.0037 (t – 12°.0) – 0.0004 (*l*–22.0), λ_L = 1″.0615 – 0.0083 (T – 1970.0) + 0.0029 (t – 12°.0) + 0.0007 (*l*–22.0) (M. Mijatov, V. Trajkovska, 1984); C_c – correction to the circle division; C_r – correction for the run; F – correction for the curvature of the parallel; B – flexure (B = b sin z, b – horizontal flexure component measured on the particular night); ρ – refracton, computed according to the Pulkovo Tables.

The planet declination is deduced from the mean latitude furnished by the observed stars and the measured zenith distance using the familiar relation. Using these values and those obtained from the ephemeris (computed at the Pukovo Observatory according to VSOP–82 theory developed at the Bureau des Longitudes at Paris) one formed the (O–C) differences, exhibited in Table 2.

Table 2.

Date	JED	Initial instr. position	δ			O–C	Edge	Δπ	n	Note
			MARS							
	2445									
1984 5 18.91	839.41247	E	–17°	42′	13″.23	0″.36	N/S	14″.65	6	4)
1984 5 19.91	840.40872	E	17	39	4.44	0.43	N/S	14.64	5	4)
1984 7 10.76	892.25621	W	18	13	3.23	0.60	I/II	11.06	9	2)
1984 7 11.75	893.25418	E	18	18	26.12	0.61	II/I	11.00	11	
1984 7 12.75	894.25219	E	18	23	57.57	–0.16	I/II	10.92	12	2)
1984 7 13.75	895.25022	E	18	29	34.76	0.78	II/I	10.85	10	
1984 7 14.75	896.24829	E	18	35	20.27	0.54	II/I	10.78	9	
1984 7 15.75	897.24638	E	18	41	12.30	0.60	I/II	10.71	6	2)
1984 7 19.74	901.23899	E	19	05	43.23	0.28	II/I	10.44	10	
1984 7 20.74	902.23720	E	19	12	12.57	0.73	I/II	10.36	10	2)
1984 7 22.73	904.23372	E	19	25	3.08	0.72	II/I	10.25	11	
1984 10 19.65	993.14609	W	25	02	40.81	0.85	II/I	6.43	6	2)
1984 10 22.64	996.14445	W	24	49	43.48	–1.18	I/II	6.34	4	
			JUPITER							
	2445									
1983 7 9.81	525.31179	E	–19°	43′	32″.18	–0″.36	S/N	1″.73	4	4), 1)
1983 7 10.81	526.30889	W	19	3	4.33	–0.39	S/N	1.73	5	4)
1983 7 17.79	533.28886	E	19	40	46.84	0.31	I/II	1.69	3	
1983 7 18.79	534.28602	E	19	40	34.87	1.27	I/II	1.69	4	
1983 7 19.78	535.28321	E	19	40	26.05	1.30	N/S	1.68	4	4)
1983 7 20.78	536.28040	E	19	40	20.96	–0.21	I/II	1.68	0	1), 4)
1983 7 22.77	538.27480	W	19	40	13.58	0.64	I/II	1.67	3	2
1983 7 24.77	540.26924	E	19	40	15.73	0.83	I/II	1.66	2	2), 3)

Table 2. (continued)

Date	JED	Initial instr. position	δ			O–C	Edge	Δπ	n	Note
1983 7 27.76	543.26096	W	19	40	37.43	−0.75	I/II	1.65	3	2)
1984 7 10.91	892.41102	W	23	14	14.74	0.13	I/II	1.92	9	
1984 7 11.91	893.40791	W	23	14	44.50	0.62	II/I	1.92	11	
1984 7 12.90	894.40482	E	23	15	14.61	0.20	II/I	1.92	12	
1984 7 14.90	896.39864	E	23	16	11.84	0.59	II/I	1.92	9	
1984 7 19.88	901.38327	W	23	18	26.36	−0.50	II/I	1.92	10	
1984 7 20.88	902.38022	W	23	18	50.48	0.21	II/I	1.91	10	
1984 7 21.88	903.37716	W	23	19	15.11	−0.21	II/I	1.91	7	
1984 7 22.87	904.37410	E	23	19	38.87	−0.36	II/I	1.91	11	
1984 10 19.65	993.13609	E	−23	24	48.74	0.76	II/I	1.50	6	
				SATURN						
	2445									
1983 4 8.99	433.48604	E	− 9°	37'	35".82	0".19	S/N	0".81	2	
1984 4 19.90	839.39800	E	12	56	56.42	0.43	I/II	0.84	6	
1984 5 19.90	840.39508	W	12	55	45.61	0.66	I/II	0.84	5	
1984 5 21.89	842.38924	E	12	53	28.43	−0 67	II/I	0.83	7	
1984 5 26.87	847.37466	W	12	47	57.56	0.84	II	0.82	7	4)
1984 5 28.87	849.36885	E	12	45	55.38	−1.13	S/N	0.82	6	1)
1984 6 2.85	854.35437	E	12	41	6.13	−0.46	II/I	0.82	5	
1984 6 3.85	855.35149	E	12	40	11.81	0.15	II/I	0.82	4	
1984 6 17.81	869.31138	E	12	30	17.21	−0.71	I/II	0.81	5	
1984 6 23.79	875.29440	E	12	27	39.04	0.06	II/I	0.80	6	2)
1984 7 2.77	884.26922	W	−12	25	43.34	0.65	I/II	0.79	5	2)
				URANUS						
	2445									
1983 7 10.82	526.32003	E	−21°	08'	38".67	0".22	C	0".44	5	
1983 7 19.79	535.29483	E	21	06	28.68	1.84	C	0.44	4	4)
1983 7 22.79	538.28646	E	21	05	55.16	0.54	C	0.44	3	2),4)
1983 7 24.78	540.28091	W	21	05	35.32	−0.42	C	0.44	2	3), 4)
1983 7 27.77	543.27257	W	21	05	7.85	−0.51	C	0.44	3	
1984 5 26.96	847.46209	W	22	10	15.86	1.22	C	0.45	6	
1984 7 2.85	884.35395	W	21	58	37.94	1.03	C	0.45	7	
1984 7 10.83	892.33137	W	21	56	34.46	−0.45	C	0.44	9	
1984 7 11.83	893.32855	W	21	56	20.35	−0.71	C	0.44	11	
1984 7 12.83	894.32573	W	21	56	5.31	−0.28	C	0.44	12	
1984 7 13.82	895.32292	W	21	55	51.08	−0.77	C	0.44	10	
1984 7 14.82	896.32012	W	21	55	38.88	−0.46	C	0.44	9	1)
1984 7 15.82	897.31731	W	21	55	25.17	0.14	C	0.44	6	
1984 7 19.81	901.30609	E	21	54	36.51	−0 50	C	0.44	10	
1984 7 21.80	903.30050	E	21	54	12.98	0.37	C	0.44		
1984 7 22.80	904.29771	W	−21	54	2.65	−0.11	C	0.44	11	
				NEPTUNE						
	2445									
1984 7 10.89	892.38954	E	−22°	13'	47".92	0".99	C	0".28	9	3)
1984 7 12.88	894.38393	E	22	13	50.22	0.82	C	0.28	12	3)
1984 7 13.88	895.38113	E	22	13	50.99	1.17	C	0.28	10	3), 4)
1984 7 14.88	896.37833	E	22	13	51.53	1.79	C	0.28	9	3), 4)
1984 7 15.88	897.37553	E	22	13	53.75	0.76	C	0.28	6	3), 4)
1984 7 19.86	901.36432	W	22	13	59.27	0.18	C	0.28	10	3), 4)
1984 7 19.86	901.36432	W	22	13	59.27	0.18	C	0.28	10	
1984 7 21.86	903.35872	W	22	14	2.17	−0.17	C	0.28	7	
1984 7 22.86	904.35593	W	−22	14	3.30	−0.00	C	0.28	11	

The same Table gives also:

- Date according to universal time up to 0^d01;
- Julian ephemeris date up to 1.10^{-5};
- Initial instrument position (E or W);
- δ – Observed apparent geocentric declination, of the disc's centre
- Order of the observed edges (N, S, Center obtained from I – NSSN or II – SNNS orders of measurings);
- $\Delta\pi$ – correction for the parallax, computed by the formula:

$$\Delta\pi = 0.997\ \pi_0 \sin (44^o48'13 - \delta);$$

- n – the number of the reference stars for the given planet observation;
- Note on the circumstances of observation (1 – through the cluds, 2 – image unsteady, 3 – image indinstinct, 4 – settings dubious).

The differences of the observed apparent semi–diameter R_o and the ephemeris apparent semi–diameter R_e are listed in Table 3.

The mean square errors σ of the (O–C) values for each planet separately, as well as m.s. errors ϵ of the differences (R_o-R_e) are shown in Table 4. The $\overline{O-C}$ and $\overline{R_o-R_e}$ values, along with number of observation n are also given.

A comparison of the (O–C) values and their mean errors, resulting from the Belgrade Vertical Circle observations with those associated with the Wanschaff Vertical Circle at the Kiew Observatory (Harin et al., 1980) disclosed the former to be somewhat smaller. This might in part be attirbuted to the Belgrade instrument being geographically more favourably located (lower latitude). The problem of the site selection for the instruments involved in the solar system bodies observation (refraction getting larger with the higher latitudes) was pointed at by these same authors.

These observations of ours are continually going on. Complete analysis will ensue after the observing programme will have been finished.

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Table 3. Differences of the observed and ephemeris semi–diameters of the planets

MARS

Date	R_o-R_e	Date	R_o-R_e
18.5.1984	1.″96	14. 7.1984	0.″75
19.5.1984	2.65	15. 7.1984	1.70
		19. 7.1984	0.71
10.7.1984	1.11	20. 7.1984	0.83
11.7.1984	0.92	22. 7.1984	1.09
12.7.1984	1.26	19.10.1984	1.56
13.7.1984	1.18	22.10.1984	1.29

JUPITER

Date	R_o-R_e	Date	R_o-R_e
10.7.1983	–0.″58	10. 7.1984	3.″07
17.7.1983	2.28	11. 7.1984	3.48
18.7.1983	1.06	12. 7.1984	3.42
19.7.1983	1.08	14. 7.1984	3.93
20.7.1983	1.60	19. 7.1984	2.39
22.7.1983	1.94	20. 7.1984	2.32
24.7.1983	0.78	21. 7.1984	2.60
27.7.1983	1.95	22. 7.1984	2.66
		19.10.1984	0.53

SATURN

Date	R_o-R_e	Date	R_o-R_e
		28. 5.1984	2.″00
8.4.1983	1.″83	2. 6.1984	1.18
18.5.1984	1.00	3. 6.1984	2.12
19.5.1984	2.01	17. 6.1984	1.82
21.5.1984	1.52	23. 6.1984	1.54
26.5.1984	1.94	2. 7.1984	1.22

Table 4.

Planet	$\overline{O-C}$	σ	$\overline{R_o-R_e}$	ϵ	n
Mars	0.″40	±0.″54	1.″31	±0.″55	13
Jupiter	0.23	±0.61	2.19	±1.00	18
Saturn	0.00	±0.65	1.75	±0.49	11
Utanus	0.20	±0.73	–	–	16
Neptune	0.75	±0.65	–	–	9

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FUNDAMENTAL ASTEROID POSITIONS OBTAINED WITH THE BELGRADE ZEISS ASTROGRAPH

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SUMMARY: Presented are 147 geocentric positions of the „fundamental" asteroids observed in the period 1967 to 1983. The reduction was implemented by the method of dependences using 4 to 11 reference stars whose positions are taken from AGK3 and SAO catalogues.

1. INTRODUCTION

The present paper comprises 147 positions of the „fundamental" asteroids from the Leningrad programme (Orel'skaja, 1974) obtained with the short–focus Zeiss 16/80 astrograph of the Belgrade Observatory (1 mm = 257"83) in the period 1966–1983.

The plate measuring has been carried out with the Zeiss two–coordinate Pulfrich–type measuring engine (with a 0.001 mm graduation).

The whole of the computations have been performed on the „digital PDP 11/70" computer.

2. RESULTS

The positions of the rererence stars have been taken from the AGK3 and SAO catalogues, depending on declinations. The plates have been reduced according to Schlesinger method (method of dependences) using 4 to 11 reference stars. The same method provides also possibility for ulterior correcting the results. Moreover, the method proved in a paper of ours (Olević et al., 1986) more accurate than the Terner's one involving 6 coefficients, applied to observations with our instrument.

In Table 1 are given: The listing number of observation (common to both Table 1 and Table 2), object designation, plate designation, date, geocentric positions for 1950.0 and the corresponding residuals with respect to the ITA ephemeris.

No ephemeris were available for the period 1966–1976 (residuals from this interval are marked by asterisks).

Table 2 gives the listing number (common to both Tables), star designation, whereby: for AGK3 stars by zone and ordering number and by ordering number for the SAO stars, 1 denoting the AGK3 and 0 the SAO catalogue, final figures in α and δ and the corresponding dependences.

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Table 1.

Nº	OBJECT	PLATE	DATE	ALPHA 1950			DELTA 1950			O-C	O-C
				H	M	S	°	′	″	S	″
1.	1 CERES	24/68	1968 MAR 24.033609	14	26	44.279	- 0	6	43.79	*.***	*.**
2.		25/68	1968 MAR 24.043671	14	26	43.771	- 0	6	47.73	*.***	*.**
3.		34/68	1968 MAR 27.014179	14	25	8.884	+ 0	4	17.91	*.***	*.**
4.		50/68	1968 APR 1.004470	14	22	2.799	+ 0	22	50.52	*.***	*.**
5.		51/68	1968 APR 1.014890	14	22	2.224	+ 0	26	51.11	*.***	*.**
6.		56/68	1968 APR 18.961411	14	7	34.300	+ 1	18	41.96	*.***	*.**
7.		57/68	1968 APR 18.973930	14	7	33.833	+ 1	18	43.58	*.***	*.**
8.		62/68	1968 APR 23.931219	14	3	8.132	+ 1	28	21.48	*.***	*.**
9.		63/68	1968 APR 23.939541	14	3	7.639	+ 1	28	21.35	*.***	*.**
10.	2 PALLAS	10/68	1968 FEB 20.000347	11	47	56.558	- 6	6	31.50	*.***	*.**
11.		10/68	1968 FEB 20.010347	11	47	56.542	- 6	6	28.35	*.***	*.**
12.		11/68	1968 FEB 20.013519	11	47	56.331	- 6	6	21.48	*.***	*.**
13.		20/68	1968 MAR 23.937620	11	27	10.284	+ 7	5	32.63	*.***	*.**
14.		21/68	1968 MAR 23.946819	11	27	9.878	+ 7	5	43.01	*.***	*.**
15.		30/68	1968 MAR 26.934660	11	25	21.486	+ 8	13	52.22	*.***	*.**
16.		31/68	1968 MAR 26.945601	11	25	21.161	+ 8	14	2.53	*.***	*.**
17.		53/68	1968 APR 18.889910	11	17	29.459	+15	2	26.51	*.***	*.**
18.		8/78	1978 JUL 24.884392	16	40	55.145	+21	42	46.59	0.058	1.58
19.		8/78	1978 JUL 24.893750	16	40	54.965	+21	42	39.79	-0.017	0.47
20.		9/79	1979 JUL 19.019097	21	28	25.928	+14	41	44.53	0.045	0.91
21.		9/79	1979 JUL 19.027083	21	28	25.733	+14	41	42.25	0.141	0.21
22.		9/79	1979 JUL 19.036111	21	28	25.294	+14	41	40.50	0.031	0.24
23.		9/82	1982 MAR 25.002470	13	20	39.846	+12	1	32.56	-0.002	-0.84
24.		9/82	1982 MAR 25.016296	13	20	39.314	+12	1	49.10	0.014	-1.96
25.		9/82	1982 MAR 25.034340	13	20	38.531	+12	2	12.78	-0.053	-1.31
26.		10/82	1982 MAR 27.000185	13	19	18.974	+12	43	41.86	-0.092	-1.27
27.		10/82	1982 MAR 27.010000	13	19	18.635	+12	43	54.79	-0.027	-0.65
28.	3 JUNO	26/68	1968 MAR 24.063480	14	50	33.217	- 4	21	48.84	*.***	*.**
29.		27/68	1968 MAR 24.083611	14	50	32.656	- 4	21	42.82	*.***	*.**
30.		36/68	1968 MAR 27.055670	14	49	15.340	- 4	1	26.47	*.***	*.**
31.		37/68	1968 MAR 27.077890	14	49	14.764	- 4	1	18.37	*.***	*.**
32.		45/68	1968 MAR 30.037090	14	47	47.422	- 3	40	46.89	*.***	*.**
33.		52/68	1968 APR 1.036111	14	46	43.069	- 3	26	39.53	*.***	*.**
34.		58/68	1968 APR 18.996849	14	34	29.598	- 1	20	22.10	*.***	*.**
35.		59/68	1968 APR 19.016291	14	34	28.681	- 1	20	13.53	*.***	*.**
36.		64/68	1968 APR 23.958981	14	30	35.106	- 0	47	50.13	*.***	*.**
37.		77/68	1968 MAY 3.907292	14	22	37.912	+ 0	10	13.63	*.***	*.**
38.		78/68	1968 MAY 3.922610	14	22	37.134	+ 0	10	16.13	*.***	*.**
39.		9/78	1978 JUL 24.925347	19	59	37.630	- 4	57	17.26	-0.021	-0.14
40.		9/78	1978 JUL 24.935764	19	59	37.064	- 4	57	19.51	-0.037	0.81
41.		9/78	1978 JUL 24.946180	19	59	36.530	- 4	57	23.74	-0.021	-0.22
42.		1/80	1980 FEB 20.891840	7	1	28.720	+ 8	2	45.70	0.045	0.06
43.		1/80	1980 FEB 20.901736	7	1	28.818	+ 8	2	50.24	0.125	-1.21
44.		1/80	1980 FEB 20.909780	7	1	28.794	+ 8	2	55.09	0.086	-1.09
45.		14/82	1982 MAY 19.020498	18	32	51.148	- 5	50	55.82	0.068	1.86
46.		14/82	1982 MAY 19.029433	18	32	50.824	- 5	50	54.55	-0.036	1.22
47.		14/82	1982 MAY 19.038461	18	32	50.674	- 5	50	54.57	0.035	-0.72
48.	4 VESTA	124/68	1968 DEC 7.773180	1	26	21.918	- 0	30	33.76	*.***	*.**
49.		125/68	1968 DEC 7.796580	1	26	21.805	- 0	30	29.60	*.***	*.**
50.		126/68	1968 DEC 10.775750	1	26	16.663	- 0	17	14.17	*.***	*.**
51.		127/68	1968 DEC 10.803530	1	26	16.627	- 0	17	14.65	*.***	*.**
52.		31/79	1979 OCT 12.003760	3	4	7.071	+ 6	23	9.44	-0.039	-1.63
53.		31/79	1979 OCT 12.110070	3	4	3.261	+ 6	22	48.09	-0.161	-0.08
54.		18/82	1982 JUL 17.986516	21	46	6.628	-19	22	40.84	-0.048	-0.30
55.		18/82	1982 JUL 17.995856	21	46	6.305	-19	22	46.08	-0.061	-1.14
56.		18/82	1982 JUL 18.007153	21	46	5.962	-19	22	52.11	-0.030	-1.84
57.	6 HEBE	89/68	1968 JUN 9.016670	18	48	41.225	- 5	22	55.29	*.***	*.**
58.		90/68	1968 JUN 9.033339	18	48	41.048	- 5	22	52.35	*.***	*.**
59.		97/68	1968 JUN 26.933649	18	33	9.705	- 6	16	43.88	*.***	*.**

Table 1. (continued)

Nº	OBJECT	PLATE	DATE	ALPHA 1950	DELTA 1950	O-C	O-C
60.		3/78	1978 MAR 29.905586	10 22 37.283	+19 46 15.96	0.018	-1.54
61.		3/78	1978 MAR 29.919950	10 22 36.889	+19 46 19.56	0.053	-1.64
62.		3/78	1978 MAR 29.933333	10 22 36.434	+19 46 24.75	-0.003	0.11
63.		3/79	1979 JUN 6.909028	16 0 25.392	+ 2 2 56.81	-0.012	-0.35
64.		3/79	1979 JUN 6.919473	16 0 24.861	+ 2 2 56.52	0.026	-0.11
65.		3/79	1979 JUN 6.909028	16 0 25.475	+ 2 2 56.94	0.071	-0.21
66.		3/79	1979 JUN 6.919473	16 0 24.756	+ 2 2 56.81	-0.079	0.17
67.		24/83	1983 MAY 16.011603	18 5 51.031	- 3 56 59.15	-0.033	-0.38
68.		24/83	1983 MAY 16.023120	18 5 50.700	- 3 56 54.96	-0.067	1.62
69.		24/83	1983 MAY 16.032147	18 5 50.476	- 3 56 54.27	-0.059	0.58
70.		24/83	1983 MAY 16.033410	18 5 50.422	- 3 56 54.84	-0.080	-0.22
71.	7 IRIS	58/69	1969 SEP 8.997920	0 56 11.359	+17 7 35.42	*.***	*.**
72.		59/69	1969 SEP 9.025000	0 56 10.763	+17 7 37.50	-0.052	1.82
73.		68/69	1969 SEP 30.877840	0 43 34.421	+16 21 15.88	-0.071	0.07
74.		4/78	1978 MAR 30.844128	9 24 7.303	+ 7 0 25.98	0.081	-1.33
75.	11 PARTHENOPE	100/67	1967 NOV 28.126089	8 33 53.384	+16 51 46.93	*.***	*.**
76.		101/67	1967 NOV 28.154560	8 33 53.616	+16 51 45.47	*.***	*.**
77.		102/67	1967 NOV 28.199700	8 33 58.645	+17 1 24.79	*.***	*.**
78.		107/67	1967 DEC 0.117420	8 33 30.623	+16 51 43.50	*.***	*.**
79.		108/67	1967 DEC 0.135420	8 33 30.571	+16 51 44.78	*.***	*.**
80.		3/68	1968 FEB 5.902790	7 46 52.912	+20 49 35.09	*.***	*.**
81.		4/68	1968 FEB 5.917709	7 46 51.980	+20 49 42.31	*.***	*.**
82.		4/68	1968 FEB 5.928000	7 46 52.165	+20 49 37.11	*.***	*.**
83.		6/68	1968 FEB 19.858334	7 36 55.917	+21 36 6.06	*.***	*.**
84.		7/68	1968 FEB 19.877781	7 36 55.267	+21 36 8.57	*.***	*.**
85.		22/69	1969 APR 26.015093	15 3 11.006	- 9 14 33.21	*.***	*.**
86.		35/69	1969 MAY 23.906389	14 38 2.414	- 7 35 41.69	*.***	*.**
87.		23/78	1978 OCT 9.088542	4 41 12.833	+15 54 8.59	-0.033	0.07
88.		23/78	1978 OCT 9.097407	4 41 12.878	+15 54 7.98	-0.001	0.35
89.		24/78	1978 OCT 9.117025	4 41 12.932	+15 54 7.46	0.025	1.78
90.		24/78	1978 OCT 9.129525	4 41 12.797	+15 54 5.43	-0.127	1.01
91.		29/78	1978 OCT 11.101389	4 41 12.039	+15 50 41.26	0.045	-1.03
92.		29/78	1978 OCT 11.116667	4 41 11.976	+15 50 37.25	0.018	-3.43
93.		29/78	1978 OCT 11.131597	4 41 12.005	+15 50 37.99	0.082	-1.12
94.		3/80	1980 FEB 21.009872	11 27 51.107	+ 8 15 28.96	-0.093	0.85
95.		3/80	1980 FEB 21.028131	11 27 50.417	+ 8 15 35.46	0.035	-0.24
96.		43/82	1982 NOV 21.991134	5 46 32.424	+17 58 25.95	0.096	0.37
97.		43/82	1982 NOV 21.999815	5 46 31.948	+17 58 26.15	0.029	0.69
98.		43/82	1982 NOV 22.008495	5 46 31.484	+17 58 26.03	-0.025	0.68
99.		43/82	1982 NOV 22.017176	5 46 31.226	+17 58 26.00	0.127	0.77
100.		1/83	1983 JAN 13.849306	4 57 57.066	+18 33 32.22	0.013	-0.89
101.		1/83	1983 JAN 13.856944	4 57 56.681	+18 33 32.14	-0.130	-1.76
102.		1/83	1983 JAN 13.864236	4 57 56.565	+18 33 34.78	-0.015	0.13
103.		1/83	1983 JAN 13.871528	4 57 56.367	+18 33 36.22	0.019	0.81
104.		1/83	1983 JAN 13.879514	4 57 56.066	+18 33 35.61	-0.030	-0.62
105.	18 MELPOMENA	25/78	1978 OCT 9.151736	6 27 55.654	+10 21 5.31	0.003	1.01
106.		30/78	1978 OCT 11.158698	6 30 13.735	+10 10 6.10	-0.045	1.35
107.		4/80	1980 MAR 19.010764	13 57 35.483	- 0 13 29.26	0.043	-1.24
108.		4/80	1980 MAR 19.020660	13 57 35.029	- 0 13 22.47	-0.068	0.79
109.		4/80	1980 MAR 19.030729	13 57 34.819	- 0 13 17.51	0.071	0.92
110.		15/81	1981 JUL 3.019954	22 14 20.239	- 4 45 55.30	-0.026	0.09
111.		15/81	1981 JUL 3.028113	22 14 20.470	- 4 45 56.22	-0.012	-0.40
112.		15/81	1981 JUL 3.037141	22 14 20.739	- 4 45 55.71	0.015	0.57
113.		15/81	1981 JUL 3.047361	22 14 20.894	- 4 45 57.36	-0.102	-0.55
114.		9/83	1983 MAR 13.928171	10 41 52.761	+12 6 1.25	0.090	1.01
115.		9/83	1983 MAR 13.937917	10 41 52.085	+12 6 6.65	-0.081	1.61
116.		9/83	1983 MAR 13.948218	10 41 51.628	+12 6 9.80	-0.003	-0.31
117.	39 LAETITIA	16/78	1978 SEP 26.987500	2 7 53.399	+ 0 53 10.09	-0.059	0.43
118.		16/78	1978 SEP 26.999653	2 7 53.066	+ 0 53 3.71	-0.058	0.33
119.		16/78	1978 SEP 27.010775	2 7 52.926	+ 0 52 56.13	0.108	-1.51
120.		20/78	1978 OCT 8.958333	2 0 58.116	- 0 51 4.15	0.037	-1.26

Table 1. (continued)

Nº	OBJECT	PLATE	DATE	ALPHA 1950	DELTA 1950	O-C	O-C
121.		20/78	1978 OCT 8.968750	2 0 57.541	- 0 51 8.97	-0.113	-0.70
122.		20/78	1978 OCT 8.980556	2 0 57.331	- 0 51 15.19	0.159	-0.84
123.		26/78	1978 OCT 10.982292	1 59 33.798	- 1 8 20.14	-0.038	0.24
124.		27/78	1978 OCT 11.006250	1 59 32.909	- 1 8 32.88	0.088	-0.31
125.		27/78	1978 OCT 11.020139	1 59 32.230	- 1 8 39.47	-0.002	0.16
126.		15/82	1982 JUL 17.005405	20 34 48.553	- 8 57 47.53	0.022	-0.50
127.		15/82	1982 JUL 17.013912	20 34 48.289	- 8 57 49.96	0.131	-0.33
128.		15/82	1982 JUL 17.021550	20 34 47.734	- 8 57 52.05	-0.090	-0.10
129.	40 HARMONIA	77/67	1967 NOV 16.084730	7 45 46.644	+21 0 28.66	*.***	*.**
130.		78/67	1967 NOV 16.102091	7 45 47.241	+21 0 27.99	*.***	*.**
131.		98/67	1967 NOV 28.087549	7 47 2.038	+21 19 55.87	*.***	*.**
132.		99/67	1967 NOV 28.105610	7 47 1.920	+21 19 58.17	*.***	*.**
133.		105/67	1967 DEC 0.075390	7 46 19.754	+21 30 0.55	*.***	*.**
134.		106/67	1967 DEC 0.115320	7 46 19.652	+21 30 5.83	*.***	*.**
135.		1/68	1968 FEB 5.859280	6 48 18.015	+25 28 46.37	*.***	*.**
136.		2/68	1968 FEB 5.877070	6 48 17.374	+25 28 48.72	*.***	*.**
137.		13/77	1977 NOV 12.019184	5 2 30.337	+19 11 9.59	*.***	*.**
138.		13/77	1977 NOV 12.036719	5 2 30.907	+19 11 5.25	*.***	*.**
139.		11/80	1980 SEP 18.004478	0 30 15.505	- 5 18 1.01	*.***	*.**
140.		11/80	1980 SEP 18.013508	0 30 14.939	- 5 18 4.57	*.***	*.**
141.		11/80	1980 SEP 18.021494	0 30 14.679	- 5 18 6.98	*.***	*.**
142.	148 GALLIA	2/83	1983 JAN 13.897338	7 25 31.731	- 0 47 23.82	0.010	-0.19
143.		2/83	1983 JAN 13.904861	7 25 31.193	- 0 47 18.29	-0.113	0.24
144.		2/83	1983 JAN 13.913183	7 25 30.704	- 0 47 11.38	-0.141	1.50
145.	532 HERCULINA	3/69	1969 MAY 17.000404	17 35 16.948	- 8 7 20.75	*.***	*.**
146.		4/69	1969 MAY 17.055099	17 35 14.752	- 8 7 26.87	*.***	*.**
147.	704 INTERAMNIA	8/79	1979 JUL 18.977980	20 55 19.447	- 4 22 25.66	0.051	0.04

Table 2.

OBSERVATIONS	CATALOGUE	POSITIONS USED		DEPENDANCES
		S	η	
1	1 -0 1914	28.970	-0.638	0.1199990
	0 1748	59.681	32.853	0.0975477
	0 1751	12.687	58.222	0.0976432
	-0 1916	32.094	-1.312	0.1123574
	-0 1918	23.253	-47.412	0.1036359
	-0 1921	2.674	-6.504	0.1026656
	-1 1844	21.013	-28.841	0.1207894
	1 1654	30.463	37.198	0.0628210
	-0 1922	37.726	-58.863	0.0947771
	0 1759	50.459	-0.030	0.0877636
2	1 -0 1914	28.970	-0.638	0.1206919
	0 1748	59.681	32.853	0.0979222
	0 1751	12.687	58.222	0.0978468
	-0 1916	32.094	-1.312	0.1126877
	-0 1918	23.253	-47.412	0.1037555
	-0 1921	2.674	-6.504	0.1025322
	-1 1844	21.013	-28.841	0.1208078
	1 1654	30.463	37.198	0.0622234
	-0 1922	37.726	-58.863	0.0944751
	0 1759	50.459	-0.030	0.0870574
3	1 -0 1914	28.970	-0.638	0.1126226
	0 1745	35.765	29.599	0.1805885
	0 1748	59.681	32.853	0.1032147
	1 1644	28.224	2.440	0.0348127
	0 1751	12.687	58.222	0.1015327
	-0 1916	32.094	-1.312	0.1512833
	-0 1918	23.253	-47.413	0.1200683

Table 2. (continued)

OBSERVATIONS		CATALOGUE			POSITIONS USED		DEPENDANCES	
			1	1651	24.469	43.448	0.0181493	
			-0	1921	2.674	-6.504	0.1140561	
			1	1654	30.463	37.198	-0.0226031	
			-0	1922	37.726	-58.863	0.0862747	
4		1	0	1736	55.532	39.978	0.1983383	
			-0	1908	12.412	-35.950	0.1632854	
			1	1631	41.982	20.727	0.1630105	
			1	1641	22.958	4.182	0.1243012	
			-0	1914	28.970	-0.638	0.1168873	
			-0	1916	32.094	-1.313	0.0882079	
			-0	1918	23.253	-47.413	0.0771739	
			1	1653	17.399	3.074	0.0687954	
5		1	0	1736	55.532	39.978	0.1986203	
			-0	1908	12.412	-35.950	0.1517418	
			1	1631	41.982	20.727	0.1794239	
			1	1641	22.958	4.182	0.1373090	
			-0	1914	28.970	-0.638	0.1049222	
			-0	1916	32.094	-1.313	0.0774955	
			-0	1918	23.253	-47.413	0.0708421	
			1	1653	17.399	3.074	0.0796451	
6		1	2	1728	20.825	27.198	0.1421194	
			1	1606	6.095	49.666	0.1096807	
			0	1713	7.238	41.378	0.1611003	
			-0	1898	42.097	-48.110	0.0941699	
			2	1731	39.886	50.425	0.1523153	
			1	1616	4.086	15.081	0.1301882	
			0	1725	17.504	40.267	0.0977819	
			1	1619	43.019	3.221	0.1126443	
7		1	2	1728	20.825	27.198	0.1427391	
			1	1606	6.095	49.666	0.1099746	
			0	1713	7.238	41.378	0.1616798	
			-0	1898	42.097	-48.110	0.0940606	
			2	1731	39.886	50.425	0.1523507	
			1	1616	4.086	15.081	0.1298421	
			0	1725	17.504	40.267	0.0972367	
			1	1619	43.019	3.221	0.1121163	
8		1	1	1597	51.980	37.341	0.0864551	
			1	1600	12.534	55.948	0.0809196	
			0	1702	18.855	48.477	0.0963039	
			0	1710	17.552	57.684	0.1094425	
			2	1723	47.281	48.039	0.0909061	
			2	1727	11.114	44.324	0.1166918	
			1	1606	20.825	27.197	0.1286695	
			1	1607	18.218	26.705	0.1305979	
			1	1613	14.670	5.819	0.1600137	
9		1	1	1597	51.980	37.341	0.0862603	
			1	1600	12.534	55.948	0.0999159	
			0	1702	18.855	48.477	0.0830597	
			0	1710	17.552	57.684	0.1062126	
			2	1723	47.281	48.039	0.1388709	
			1	1606	20.825	27.197	0.1433239	
			1	1607	18.218	26.705	0.1600004	
			1	1613	14.670	5.819	0.1823562	
10	11	0		138406	59.976	-25.872	0.1130530	0.1129856
				138412	19.880	-0.807	0.0959182	0.0960110
				138422	33.203	-20.013	0.0676091	0.0679017
				138425	42.002	-1.980	0.1760034	0.1757008
				138443	22.575	-26.786	0.0740580	0.0743988
				138451	16.768	-1.074	0.1012225	0.1013583
				138453	30.300	-42.653	0.2105217	0.2101313
				138459	25.077	-33.825	0.1616141	0.1615126
12		0		138406	59.976	-25.872	0.1131261	
				138412	19.880	-0.807	0.0963422	
				138422	33.203	-20.013	0.0686346	
				138425	42.002	-1.980	0.1750933	
				138443	22.575	-26.786	0.0749897	
				138451	16.768	-1.074	0.1016758	
				138453	30.300	-42.653	0.2090683	
				138459	25.077	-33.825	0.1610701	
13		1	7	1537	36.024	44.706	0.0952477	
			7	1538	38.151	34.196	0.1397766	
			8	1489	12.311	23.562	0.0480440	

Table 2. (continued)

OBSERVATIONS			CATALOGUE			POSITIONS USED		DEPENDANCES		
				6	1438	38.841	26.265	0.1656259		
				7	1545	10.314	53.736	0.0814734		
				8	1491	5.066	22.300	0.0188317		
				7	1551	32.670	14.200	0.0399843		
				6	1445	22.729	22.768	0.1070575		
				6	1446	59.299	54.871	0.0847765		
14			1	7	1537	36.024	44.706	0.0958318		
				7	1538	38.151	34.196	0.1396331		
				8	1489	12.311	23.562	0.0487613		
				7	1540	46.326	59.672	0.1044171		
				7	1542	38.258	43.951	0.1145858		
				6	1438	38.841	26.265	0.1649278		
				7	1545	10.314	53.736	0.0815756		
				8	1491	5.066	22.300	0.0194090		
				7	1551	32.670	14.200	0.0401955		
				6	1445	22.729	22.768	0.1063969		
				6	1446	59.299	54.871	0.0842661		
15			1	8	1482	49.708	42.654	0.1604387		
				7	1537	27.201	3.273	0.1612518		
				8	1485	36.024	44.706	0.1449090		
				7	1540	46.326	59.672	0.1151889		
				8	1490	51.542	22.796	0.1320483		
				7	1545	10.314	53.736	0.1007263		
				9	1413	52.535	33.670	0.0992416		
				8	1491	5.066	22.300	0.0861955		
16			1	8	1482	49.708	42.654	0.1609115		
				7	1537	27.201	3.273	0.1623177		
				8	1485	36.024	44.706	0.1447884		
				7	1540	46.326	59.672	0.1143667		
				8	1490	51.542	22.796	0.1326261		
				7	1545	10.314	53.736	0.0998255		
				9	1413	52.535	33.670	0.0995538		
				8	1491	5.066	22.300	0.0856103		
17			1	15	1221	48.196	9.980	0.0433010		
				15	1224	5.928	14.022	0.0827868		
				14	1191	6.904	45.322	0.1083311		
				16	1185	36.866	38.406	0.0695259		
				14	1195	45.182	56.124	0.1759182		
				16	1188	4.521	17.203	0.1081727		
				15	1233	16.828	26.985	0.1827516		
				14	1198	18.137	51.258	0.2292127		
18	19		1	21	1620	42.840	4.348	0.1270304	0.1271885	
				21	1623	35.217	56.650	-0.0957078	-0.0926260	
				21	1626	17.287	11.800	0.2383210	0.2371304	
				21	1627	37.191	58.190	0.2638325	0.2622513	
				21	1628	27.363	0.871	0.1748501	0.1745228	
				21	1629	31.695	57.811	0.1817666	0.1813757	
				21	1631	40.738	55.641	0.1099072	0.1101572	
20	21	22	1	14	2394	16.680	38.027	0.1337751	0.1340789	0.1346512
				15	2403	48.964	21.594	0.0037859	0.0037565	0.0039786
				14	2405	45.127	36.576	0.1351222	0.1351794	0.1352409
				14	2407	52.814	19.436	0.0259946	0.0259149	0.0260855
				14	2406	58.265	51.332	0.1624354	0.1625132	0.1625038
				14	2414	38.012	41.236	0.2608980	0.2610537	0.2609488
				15	2412	2.490	18.900	0.0477225	0.0476271	0.0475395
				15	2418	27.684	51.374	0.0842593	0.0840686	0.0836922
				15	2424	46.334	51.161	0.1460071	0.1458077	0.1453595
23	24	25	1	12	1475	29.798	27.576	0.0837862	0.0845496	0.0856440
				11	1490	10.086	37.591	0.0609024	0.0604826	0.0598911
				11	1491	16.806	51.142	0.0761784	0.0764065	0.0767708
				12	1479	10.258	1.322	0.0989307	0.0997485	0.1009187
				10	1620	44.847	0.763	0.0665400	0.0658000	0.0647000
				12	1480	3.817	49.067	0.0898148	0.0900153	0.0903058
				13	1317	14.223	28.724	0.1175898	0.1185403	0.1198853
				11	1496	11.777	25.108	0.0937861	0.0934334	0.0929572
				11	1498	54.239	56.358	0.0851302	0.0842317	0.0829551
				12	1486	53.590	57.604	0.1155741	0.1155831	0.1155906
				11	1503	37.673	43.172	0.1117672	0.1112090	0.1103813
26	27		1	12	1475	29.798	27.576	0.0560878	0.0562566	
				13	1310	33.837	47.225	0.0565503	0.0573055	
				11	1491	16.806	51.142	0.0675105	0.0671257	
				12	1479	10.258	1.322	0.0934443	0.0935558	

Table 2. (continued)

OBSERVATIONS		CATALOGUE	POSITIONS USED		DEPENDANCES	
		13 1313	24.931	6.965	0.0962650	0.0970278
		12 1480	3.817	49.067	0.1066005	0.1060400
		12 1481	25.736	13.408	0.1112498	0.1111145
		13 1315	26.803	47.920	0.1247872	0.1252953
		13 1317	14.223	28.724	0.1362305	0.1363073
		11 1496	11.777	25.108	0.1512541	0.1499715
28	0	140154	32.140	-41.744	0.0830202	
		140157	40.345	-42.934	0.1310545	
		140168	40.235	-3.216	0.0389685	
		140189	27.756	-45.296	0.1423605	
		140192	41.039	-50.444	0.0310590	
		140213	46.297	-49.349	0.1185626	
		140217	59.150	-52.979	0.2014528	
		140219	20.733	-41.968	0.0746146	
		140232	44.543	-8.665	0.1789074	
29	0	140154	32.140	-41.744	0.0835309	
		140157	40.345	-42.934	0.1312211	
		140168	40.235	-3.216	0.0397745	
		140189	27.756	-45.296	0.1421404	
		140192	41.039	-50.444	0.0317388	
		140213	46.297	-49.349	0.1183765	
		140217	59.150	-52.979	0.2005496	
		140219	20.733	-41.968	0.0746543	
		140232	44.543	-8.665	0.1780139	
30	0	140154	32.140	-41.744	0.1526423	
		140157	40.345	-42.933	0.1253381	
		140168	40.235	-3.217	0.1679768	
		140189	27.756	-45.296	0.0980341	
		140192	41.039	-50.444	0.1570569	
		140213	46.297	-49.349	0.0934921	
		140217	59.150	-52.979	0.0466864	
		140219	20.733	-41.968	0.1131206	
		140232	44.543	-8.665	0.0456525	
31	0	140154	32.140	-41.744	0.1531629	
		140157	40.345	-42.933	0.1253918	
		140168	40.235	-3.217	0.1689364	
		140189	27.756	-45.296	0.0977233	
		140192	41.039	-50.444	0.1578967	
		140213	46.297	-49.349	0.0932869	
		140217	59.150	-52.979	0.0456017	
		140219	20.733	-41.968	0.1133207	
		140232	44.543	-8.665	0.0446796	
32	0	140132	6.296	-36.209	0.2062818	
		140143	1.695	-56.190	0.1927375	
		140154	32.140	-41.744	0.1721217	
		140189	41.039	-50.444	0.1313381	
		140192	46.297	-49.349	0.1027842	
		140213	59.150	-52.979	0.0990040	
		140219	20.733	-41.968	0.0957328	
33	0	140111	15.597	-4.461	0.1181164	
		140132	6.296	-36.209	0.1854629	
		140141	35.963	-32.505	0.0333128	
		140143	1.695	-56.190	0.0784046	
		140154	32.140	-41.744	0.0526057	
		140168	40.235	-3.218	0.1645404	
		140189	27.756	-45.297	0.1018871	
		140192	41.039	-50.444	0.2656702	
34	1	-1 1845	28.206	-7.555	0.1392682	
		-2 8760	5.999	-47.552	0.1008946	
		-1 1848	13.413	-38.614	0.1454236	
		-0 1931	51.979	-6.045	0.1603581	
		-2 8790	12.691	-17.832	0.0945420	
		-0 1935	38.277	-3.960	0.1562440	
		-2 8820	26.915	-31.842	0.0809216	
		-1 1851	1.152	-30.806	0.1223481	
35	1	-1 1845	28.206	-7.555	0.1402673	
		-2 8760	5.999	-47.552	0.1007968	
		-1 1848	13.413	-38.614	0.1461454	
		-0 1931	51.979	-6.045	0.1611443	
		-2 8790	12.691	-17.832	0.0937738	
		-0 1935	38.277	-3.960	0.1565941	
		-2 8820	26.915	-31.842	0.0795627	

Table 2. (continued)

OBSERVATIONS				CATALOGUE	POSITIONS USED		DEPENDANCES		
				-1 1851	1.152	-30.806	0.1217155		
36			1	-0 1920	51.944	-26.706	0.0804020		
				-0 1921	2.673	-6.500	0.0855044		
				-1 1844	21.013	-28.843	0.1173975		
				-1 1845	28.206	-7.555	0.1433587		
				0 1759	50.459	-0.030	0.1108917		
				-0 1927	12.050	-20.992	0.1255904		
				-1 1848	13.413	-38.614	0.1659433		
				-0 1931	51.979	-6.046	0.1709120		
37			1	0 1736	55.532	39.973	0.0951825		
				1 1628	12.159	39.515	0.0963599		
				-0 1908	12.412	-35.950	0.0977181		
				0 1741	0.200	25.047	0.0983812		
				0 1745	35.765	29.592	0.0999438		
				-0 1914	28.969	-0.639	0.1011019		
				0 1748	59.681	32.851	0.1014064		
				0 1751	12.687	58.222	0.1026969		
				-0 1916	32.094	-1.318	0.1031985		
				-0 1918	23.252	-47.416	0.1040108		
38			1	0 1736	55.532	39.973	0.0960204		
				1 1628	12.159	39.515	0.0968867		
				-0 1908	12.412	-35.950	0.0982298		
				0 1741	0.200	25.047	0.0986601		
				0 1745	35.765	29.592	0.0998845		
				-0 1914	28.969	-0.639	0.1010068		
				0 1748	59.681	32.851	0.1010946		
				0 1751	12.687	58.222	0.1021804		
				-0 1916	32.094	-1.318	0.1027095		
				-0 1918	23.252	-47.416	0.1033271		
39	40	41	0	143985	10.378	-59.931	0.0940768	0.0954812	0.0966116
				143987	16.518	-54.197	0.0956500	0.0970168	0.0981933
				143990	29.221	-20.594	0.0965520	0.0980646	0.0997591
				144009	31.646	-47.856	0.1266861	0.1266293	0.1266216
				144010	31.706	-45.649	0.1276307	0.1275470	0.1274202
				144018	5.317	-0.994	0.1388222	0.1383036	0.1381032
				144029	35.146	-19.583	0.1570691	0.1554507	0.1538435
				144031	46.245	-32.506	0.1635131	0.1615068	0.1594476
42	43	44	1	8 889	11.585	5.108	0.1019629	0.1019347	0.1022640
				8 893	41.919	13.729	0.1105296	0.1106377	0.1109655
				7 914	0.067	35.830	0.0898275	0.0888989	0.0878944
				7 915	4.889	13.405	0.1084820	0.1080319	0.1076169
				8 902	18.462	29.989	0.1381490	0.1385249	0.1388910
				8 903	47.646	26.792	0.1449541	0.1453868	0.1457812
				7 924	2.104	15.112	0.1466770	0.1467335	0.1466079
				8 906	7.814	36.451	0.1594179	0.1598516	0.1599791
45	46	47	0	142359	14.381	-58.411	0.0519179	0.0522299	0.0523466
				142415	28.142	-32.324	0.0542134	0.0544502	0.0545628
				142367	7.673	-6.234	0.0623766	0.0625231	0.0626262
				142370	17.268	-5.810	0.0651721	0.0653017	0.0653921
				142380	27.325	-4.071	0.0823490	0.0825011	0.0825424
				142426	26.214	-1.961	0.1216334	0.1214500	0.1213910
				142430	1.400	-53.537	0.1301082	0.1299250	0.1298382
				142457	11.964	-54.122	0.1340528	0.1339108	0.1338313
				142446	6.038	-3.958	0.1469929	0.1468283	0.1467028
				142457	31.941	-40.682	0.1511837	0.1508799	0.1507665
48			1	-1 126	49.648	-42.331	0.1034422		
				-0 140	51.592	-13.357	0.0885566		
				-0 144	50.052	-4.475	0.0843428		
				-0 149	2.667	-18.988	0.0982261		
				0 129	12.036	12.320	0.0803328		
				-0 150	14.991	-54.031	0.1369444		
				0 130	19.082	59.660	0.1084653		
				-0 151	35.089	-46.191	0.1374859		
				-1 133	0.505	-44.002	0.1622039		
49			1	-1 126	49.648	-42.331	0.0846812		
				-0 140	51.592	-13.357	0.0687740		
				-0 144	25.164	-47.455	0.0693821		
				-0 146	50.052	-4.475	0.0687378		
				-0 149	2.667	-18.988	0.0892790		
				0 129	12.036	12.320	0.0706335		
				-0 150	14.991	-54.031	0.1365164		
				0 130	19.082	59.660	0.1061695		

Table 2. (continued)

OBSERVATIONS				CATALOGUE	POSITIONS USED		DEPENDANCES		
				-0 151	35.089	-46.191	0.1386138		
				-1 133	0.505	-44.002	0.1672127		
50			1	-1 126	49.648	-42.331	0.0325668		
				-0 140	51.592	-13.357	0.0576565		
				-0 144	25.164	-47.455	0.0821210		
				-0 146	50.052	-4.475	0.0993182		
				-0 149	2.667	-18.988	0.1205224		
				0 129	12.036	12.320	0.1549374		
				-0 150	14.991	-54.031	0.1016800		
				0 130	19.082	59.660	0.1498491		
				-0 151	35.089	-46.191	0.1128917		
				-1 133	0.505	-44.002	0.0884569		
51			1	-1 126	49.648	-42.331	0.0327093		
				-0 140	51.592	-13.357	0.0577659		
				-0 144	25.164	-47.455	0.0821791		
				-0 146	50.052	-4.475	0.0994065		
				-0 149	2.667	-18.988	0.1205123		
				0 129	12.036	12.320	0.1548787		
				-0 150	14.991	-54.031	0.1016218		
				0 130	19.082	59.660	0.1497502		
				-0 151	35.089	-46.191	0.1128073		
				-1 133	0.505	-44.002	0.0883689		
52	53		1	6 315	49.306	55.172	0.1236042	0.1281602	
				5 327	11.714	18.169	0.1407552	0.1448290	
				7 337	17.843	13.690	0.0174768	0.0210555	
				5 329	59.601	27.970	0.1763378	0.1776656	
				7 342	0.594	16.850	0.0914016	0.0891505	
				7 343	16.414	53.871	0.0951269	0.0925968	
				6 326	45.428	57.699	0.1623332	0.1591525	
				6 329	16.816	56.882	0.1929642	0.1873898	
54	55	56	0	164593	52.143	-42.770	0.1867399	0.1874474	0.1882477
				164654	53.420	-36.573	0.2266434	0.2273337	0.2280939
				164657	58.777	-43.645	0.1070214	0.1065774	0.1060147
				164674	33.785	-11.144	0.1153157	0.1147754	0.1141798
				164697	55.335	-27.606	0.1258213	0.1251745	0.1244921
				190716	59.605	-40.306	0.2384583	0.2386916	0.2389717
57			0	142631	36.336	-20.702	0.0519420		
				142632	42.397	-28.917	0.1054466		
				142661	0.358	-15.491	0.1894092		
				142670	23.343	-42.342	0.1228625		
				142738	54.507	-12.315	0.1284139		
				142754	5.062	-38.973	0.2142580		
				142798	41.981	-20.216	0.1876677		
58			0	142631	36.336	-20.702	0.0523341		
				142632	42.397	-28.917	0.1056303		
				142661	0.358	-15.491	0.1892458		
				142670	23.343	-42.342	0.1229834		
				142738	54.507	-12.315	0.1285265		
				142754	5.062	-38.973	0.2139126		
				142798	41.981	-20.216	0.1873672		
59			0	142370	17.267	-5.866	0.1525208		
				142380	27.324	-3.834	0.0122289		
				142386	42.177	-0.253	0.1225324		
				142415	26.213	-1.836	0.2447481		
				142260	1.398	-53.148	0.1975595		
				142430	11.966	-53.761	0.0184132		
				142436	42.721	-28.510	0.1497793		
				142482	26.190	-13.588	0.1022180		
60	61	62	1	20 1173	9.942	45.118	0.1274093	0.1281957	0.1291529
				19 1053	15.792	2.035	0.1072696	0.1075755	0.1078353
				19 1054	11.077	18.534	0.1175246	0.1178712	0.1182767
				19 1055	48.592	23.998	0.0917539	0.0914052	0.0909126
				19 1056	20.783	21.866	0.1080929	0.1079483	0.1077679
				20 1181	28.079	52.087	0.1314086	0.1316323	0.1320255
				19 1058	10.922	3.206	0.1093554	0.1091170	0.1088471
				20 1183	27.546	10.269	0.1169161	0.1167553	0.1166400
				19 1062	35.376	5.982	0.0902695	0.0894994	0.0885419
63	64		1	2 1881	13.899	3.700	0.1184427	0.1191051	
				2 1881	57.032	11.783	0.2399259	0.2408168	
				2 1882	58.853	54.576	0.1247446	0.1251881	
				3 1885	4.702	47.864	-0.0652087	-0.0656461	
				2 1777	25.137	9.007	0.3385443	0.3390894	

Table 2. (continued)

OBSERVATIONS		CATALOGUE	POSITIONS USED		DEPENDANCES			
		2 1890	50.354	7.168	0.0180796	0.0174373		
		2 1779	42.628	41.903	0.1967553	0.1962092		
		2 1891	52.160	56.700	0.0287162	0.0278002		
65 66	1	2 1881	57.032	11.783	0.3880447	0.3900743		
		1 1777	25.137	9.007	0.3721481	0.3736551		
		2 1890	50.354	7.168	0.1144379	0.1131666		
		1 1779	42.628	41.903	0.1253694	0.1231040		
67 68 69 70	0	142059	14.650	-55.964	0.0691643	0.0694776	0.0696895	0.0696885
		142067	0.874	-13.957	0.0954210	0.0955347	0.0956520	0.0956841
		142072	28.402	-3.744	0.0441434	0.0445880	0.0447169	0.0447513
		142079	3.594	-0.507	0.1236427	0.1234831	0.1235281	0.1236192
		142092	18.086	-25.783	0.0593816	0.0596655	0.0597362	0.0597013
		142108	40.606	-9.457	0.1313046	0.1309953	0.1309419	0.1309845
		142117	7.579	-0.834	0.1031259	0.1030297	0.1030041	0.1029881
		142137	56.659	-37.591	0.1151797	0.1149404	0.1148283	0.1148145
		142135	4.735	-52.713	0.0556829	0.0558360	0.0558066	0.0557431
		142153	58.272	-57.507	0.0871912	0.0870512	0.0869154	0.0868627
		142159	31.430	-32.602	0.1157628	0.1153987	0.1151811	0.1151626
71	1	16 83	29.613	22.309	0.0840958			
		17 75	1.117	23.548	0.1170125			
		17 79	32.132	2.712	0.1104817			
		17 80	17.736	26.596	0.1325759			
		16 88	22.320	15.783	0.1218724			
		16 89	42.137	26.709	0.1403133			
		16 91	13.824	31.070	0.1358510			
		17 83	25.806	10.017	0.1577975			
72	1	16 83	29.613	22.309	0.0861038			
		17 75	1.117	23.548	0.1181518			
		17 79	32.132	2.712	0.1112879			
		17 80	17.736	26.596	0.1329527			
		16 88	22.320	15.783	0.1215739			
		16 89	42.137	26.709	0.1392138			
		16 91	17.824	31.070	0.1344248			
		17 83	25.806	10.017	0.1562911			
73	1	16 69	15.513	21.814	0.1546451			
		17 61	55.669	56.928	0.1657797			
		15 64	11.620	24.283	0.1385367			
		14 64	41.050	33.674	0.1205892			
		17 64	26.388	9.360	0.1661694			
		15 71	49.823	44.718	0.1133037			
		16 77	59.816	5.632	0.1409761			
74	1	7 1327	49.955	43.510	0.0840659			
		6 1216	50.193	58.343	0.1171779			
		6 1217	44.203	28.363	0.1333873			
		6 1220	56.985	51.484	0.1504356			
		6 1224	38.545	5.913	0.1656053			
		7 1333	4.120	9.939	0.1589663			
		7 1339	50.491	39.450	0.1903616			
75	1	17 909	10.849	51.681	0.1418671			
		17 914	32.257	11.284	0.1615343			
		17 917	19.441	10.242	0.0965460			
		16 914	35.056	56.850	0.1472711			
		16 918	21.760	52.864	0.1701884			
		17 930	39.217	10.145	0.0595439			
		16 920	50.940	8.387	0.1564517			
		16 921	5.593	41.197	0.0856247			
		17 934	9.653	17.658	-0.0190273			
76	1	17 909	10.849	51.681	0.1416697			
		17 914	32.257	11.284	0.1614089			
		17 917	19.441	10.242	0.0962989			
		16 914	35.056	56.850	0.1473062			
		16 918	21.760	52.864	0.1702748			
		17 930	39.217	10.145	0.0595686			
		16 920	50.940	8.387	0.1565644			
		16 921	5.593	41.197	0.0859261			
		17 934	9.653	17.658	-0.0190177			
77	1	17 909	10.849	51.681	0.1607314			
		17 914	32.257	11.284	0.1394752			
		17 917	19.441	10.076	0.1299310			
		16 914	35.056	56.850	0.1207694			
		16 918	21.760	52.864	0.1058788			
		17 930	39.217	10.145	0.0990198			

Table 2. (continued)

OBSERVATIONS		CATALOGUE	POSITIONS USED		DEPENDANCES	
		16 920	50.940	8.387	0.0920830	
		16 921	5.593	41.197	0.0783187	
		17 934	9.653	17.658	0.0737928	
78		1 17 909	10.849	51.681	0.1675478	
		17 914	32.257	11.284	0.1845881	
		17 917	19.441	10.242	0.1059616	
		16 914	35.056	56.850	0.1410482	
		16 918	21.760	52.863	0.1783971	
		17 930	39.217	10.145	0.0492064	
		16 920	50.940	8.387	0.1562483	
		16 921	5.593	41.197	0.0691942	
		17 934	9.653	17.658	-0.0521918	
79		1 17 909	10.849	51.681	0.1676626	
		17 914	32.257	11.284	0.1846429	
		17 917	19.441	10.242	0.1061229	
		16 914	35.056	56.850	0.1409615	
		16 918	21.760	52.863	0.1783058	
		17 930	39.217	10.145	0.0491746	
		16 920	50.940	8.387	0.1561025	
		16 921	5.593	41.197	0.0691100	
		17 934	9.653	17.658	-0.0520827	
80		1 20 888	20.196	35.119	0.1184156	
		20 889	20.388	16.853	0.1026793	
		21 868	13.555	26.411	0.1042706	
		22 925	40.694	0.377	0.0847398	
		19 761	18.276	44.488	0.1584423	
		21 874	28.773	56.153	0.1243313	
		20 903	9.159	32.589	0.1637585	
		20 904	26.917	4.034	0.1433627	
81	82	1 20 888	20.196	35.119	0.1190490	0.1190766
		20 889	20.388	16.853	0.1036006	0.1034200
		21 868	13.555	26.411	0.1047887	0.1045520
		22 925	40.694	0.377	0.0855218	0.0850324
		19 761	18.276	44.488	0.1578530	0.1583275
		21 874	28.773	56.153	0.1239722	0.1238737
		20 903	9.159	32.589	0.1626331	0.1630316
		20 904	26.917	4.034	0.1425817	0.1426862
83		1 22 905	11.818	33.848	0.1141445	
		21 840	5.286	35.131	0.1283031	
		22 909	33.870	21.256	0.1278572	
		20 877	30.591	21.759	0.1482927	
		21 852	15.060	52.446	0.1547230	
		21 854	18.515	42.334	0.1666102	
		21 855	35.787	4.857	0.1600693	
84		1 22 905	11.818	33.848	0.1151811	
		21 840	5.286	35.131	0.1290455	
		22 909	33.870	21.256	0.1282184	
		20 877	30.591	21.759	0.1483064	
		21 852	15.060	52.446	0.1542308	
		21 854	18.515	42.334	0.1657907	
		21 855	35.787	4.857	0.1592270	
85		0 140266	41.917	-16.876	0.1118248	
		140277	57.832	-56.912	0.1078279	
		126760	9.037	-48.380	0.1174182	
		159023	29.790	-4.265	0.1178846	
		140323	54.708	-33.855	0.1048195	
		140331	28.476	-12.479	0.1081334	
		140341	36.949	-57.637	0.1123638	
		140350	52.834	-12.945	0.1078127	
		140362	39.422	-49.533	0.1119151	
86		0 140017	45.799	-27.799	0.0967489	
		140029	51.820	-28.015	0.1105950	
		140043	26.422	-34.010	0.1070245	
		140058	25.689	-36.622	0.1327682	
		140077	2.873	-10.983	0.1200611	
		140080	18.269	-16.802	0.1426974	
		140089	21.799	-42.906	0.1339823	
		140117	38.125	-49.972	0.1561226	
87	88	1 16 404	38.659	40.682	0.1214998	0.1214111
		15 399	18.097	32.495	0.1555268	0.1555207
		15 400	9.148	49.034	0.1726513	0.1727232
		16 408	11.790	13.916	0.1265057	0.1264350

Table 2. (continued)

OBSERVATIONS						CATALOGUE	POSITIONS USED		DEPENDANCES				
						15 402	34.023	0.399	0.1238683	0.1238687			
						15 404	39.062	58.085	0.1323693	0.1324493			
						16 410	57.161	45.189	0.0819728	0.0819460			
						15 406	3.455	0.726	0.0856059	0.0856459			
89	90				1	16 404	38.659	40.682	0.1213049	0.1211668			
						15 399	18.097	32.495	0.1555142	0.1557538			
						15 400	9.148	49.034	0.1727973	0.1732928			
						16 408	11.790	13.916	0.1264338	0.1264063			
						15 402	34.023	0.399	0.1238242	0.1238425			
						15 404	39.062	58.085	0.1325224	0.1326510			
						16 410	57.161	45.189	0.0819614	0.0815302			
						15 406	3.455	0.726	0.0856418	0.0853566			
91	92	93			1	15 399	18.097	32.494	0.2126531	0.2126672	0.2127121		
						15 400	9.150	49.034	0.1916092	0.1924270	0.1922536		
						16 408	11.790	13.916	0.1885681	0.1881164	0.1881950		
						15 402	34.023	0.399	0.1534529	0.1532706	0.1532977		
						15 404	39.062	58.085	0.1002247	0.1008897	0.1007973		
						16 410	57.161	45.189	0.0908982	0.0902311	0.0903574		
						15 406	3.455	0.726	0.0625938	0.0623980	0.0623868		
94	95				1	8 1488	43.619	30.777	0.1275580	0.1285433			
						8 1489	12.292	23.491	0.1212147	0.1218132			
						8 1490	51.522	22.433	0.1358882	0.1368852			
						7 1545	10.343	53.879	0.1086492	0.1082012			
						8 1491	5.010	22.121	0.1242688	0.1238905			
						8 1492	17.897	53.760	0.1380543	0.1381610			
						7 1551	32.620	14.081	0.1159909	0.1148734			
						8 1494	57.268	18.682	0.1283760	0.1276321			
96	97	98	99		1	17 524	44.575	57.276	0.1749622	0.1762249	0.1774732	0.1781962	
						17 527	34.153	3.799	0.2039392	0.2039757	0.2040412	0.2040657	
						18 499	49.001	40.270	0.1476383	0.1484918	0.1493016	0.1497598	
						18 500	28.996	13.295	0.1256569	0.1264125	0.1270852	0.1274742	
						17 532	12.238	24.066	0.1945966	0.1928795	0.1912718	0.1903482	
						18 509	31.831	55.750	0.1532068	0.1520156	0.1508271	0.1501559	
100	101	102	103	104	1	18 403	8.994	57.421	0.1258785	0.1263110	0.1264704	0.1267169	0.1270523
						17 437	50.388	43.985	0.1119137	0.1123793	0.1124167	0.1125973	0.1129865
						19 413	12.576	16.518	0.1302409	0.1303948	0.1305876	0.1307391	0.1308356
						18 406	46.165	12.775	0.1181678	0.1183717	0.1184422	0.1185484	0.1187081
						17 440	5.140	52.411	0.0998049	0.0999529	0.0998634	0.0998696	0.1000205
						18 409	50.545	20.972	0.1114499	0.1112997	0.1112877	0.1112450	0.1111050
						19 417	2.574	50.547	0.1160312	0.1155681	0.1155946	0.1154423	0.1150466
						17 441	19.723	13.080	0.0903149	0.0901200	0.0899172	0.0897275	0.0896059
						18 411	54.988	9.186	0.0961982	0.0956024	0.0954202	0.0951138	0.0946397
105					1	10 754	23.926	22.124	0.0874099				
						10 755	31.732	48.917	0.1013376				
						10 761	55.538	58.377	0.1358923				
						10 762	32.535	21.244	0.1309043				
						10 763	36.650	52.310	0.1147184				
						10 765	26.868	15.203	0.1243449				
						10 770	53.324	40.400	0.1588088				
						10 772	2.931	14.387	0.1465838				
106					1	10 754	23.926	22.124	0.0278125				
						10 755	55.538	58.377	0.1312003				
						10 761	32.535	21.244	0.1171782				
						10 762	36.650	52.310	0.0801818				
						10 763	26.868	15.203	0.0982806				
						10 765	46.605	13.147	-0.0068082				
						10 770	51.136	45.110	0.0527321				
						10 772	33.038	24.053	0.0416662				
						9 730	39.776	31.817	0.0444978				
						10 781	32.217	45.510	0.1779442				
						10 784	23.946	36.617	0.2353144				
107	108	109			1	-8 1882	9.719	-30.963	0.2196672	0.2202942	0.2207054		
						8 1695	43.216	1.149	0.3389541	0.3399765	0.3405179		
						-1 1800	50.189	-4.742	0.0683956	0.0683486	0.0683302		
						-1 1803	5.697	-28.849	-0.0363547	-0.0368886	-0.0372904		
						-1 1804	12.636	-54.340	0.0085938	0.0082720	0.0079285		
						-0 1887	50.656	-17.661	0.1503018	0.1502187	0.1501718		
						-0 1888	28.360	-23.089	0.1822483	0.1821465	0.1822667		
						-8 1890	20.885	-52.865	0.0681938	0.0676322	0.0673699		
110	111	112	113			145955	17.907	-33.415	0.1214768	0.1211848	0.1208351	0.1206541	
						145969	18.453	-49.366	0.0790466	0.0787474	0.0784728	0.0782091	
						145973	35.538	-1.277	0.1882958	0.1883396	0.1881893	0.1883388	

Table 2. (continued)

OBSERVATIONS		CATALOGUE	POSITIONS USED		DEPENDANCES			
		145986	41.630	-22.358	0.0834354	0.0833024	0.0831728	0.0830824
		145995	39.735	-22.298	0.1233134	0.1232890	0.1233696	0.1234114
		145998	8.336	-36.879	0.0491433	0.0490389	0.0490685	0.0489183
		146000	13.713	-3.856	0.1094794	0.1095984	0.1097007	0.1097104
		146022	13.323	-3.992	0.1044518	0.1047402	0.1050477	0.1052247
		146021	24.913	-54.417	0.1413575	0.1417593	0.1421434	0.1424507
114 115 116	1	12 1251	58.589	24.432	0.1982091	0.2001085	0.2013672	
		11 1245	3.474	4.614	0.1631648	0.1632003	0.1632751	
		13 1070	40.717	41.579	0.3496907	0.3495710	0.3494300	
		11 1252	58.663	54.919	0.2889353	0.2871202	0.2859277	
117 118 119	1	0 188	7.531	34.146	0.1729585	0.1738941	0.1742729	
		1 228	6.725	12.863	0.1782032	0.1780196	0.1775880	
		0 189	9.766	40.149	0.1424507	0.1430730	0.1434879	
		0 190	38.649	31.288	0.1191787	0.1197842	0.1204271	
		1 230	47.965	52.625	0.1357767	0.1351145	0.1343628	
		1 232	10.248	-39.115	0.0713672	0.0716719	0.0723966	
		-0 229	26.000	0.289	0.1114371	0.1106760	0.1101727	
		0 195	39.983	20.714	0.0686278	0.0677666	0.0672920	
120 121 122	1	-0 207	54.267	-40.765	0.1028312	0.1032596	0.1031054	
		-1 186	48.160	-34.071	0.1919883	0.1928016	0.1936713	
		-0 212	1.259	-56.600	0.1379146	0.1381634	0.1382693	
		-1 192	47.691	-30.092	0.2182597	0.2190444	0.2199118	
		-0 216	8.701	-48.995	0.0631871	0.0628220	0.0621256	
		-0 219	36.682	-21.977	0.0576426	0.0570039	0.0563239	
		-0 221	41.313	-33.949	0.0844481	0.0836789	0.0831704	
		-0 223	1.326	-9.548	0.1437284	0.1432262	0.1434222	
123	1	-0 210	16.626	-52.108	0.1676653			
		-1 177	38.644	-59.668	0.1480514			
		-1 186	48.160	-34.071	0.1489637			
		-1 188	7.632	-52.045	0.1231675			
		-0 213	34.916	-17.800	0.1534996			
		-1 192	47.691	-30.093	0.1330179			
		-1 194	40.424	-27.115	0.1256346			
124 125	1	-0 210	16.626	-52.108	0.1046673	0.1052047		
		-1 177	38.644	-59.668	0.2373630	0.2396619		
		-1 186	48.160	-34.071	0.1715794	0.1723897		
		-0 212	1.259	-56.600	0.0917597	0.0907572		
		-0 213	34.916	-17.800	0.0462249	0.0443856		
		-1 192	47.691	-30.093	0.1934040	0.1937286		
		-1 194	40.424	-27.115	0.1550018	0.1538723		
126 127 128	0	144535	23.459	-30.850	0.1077437	0.1079042	0.1083355	
		144554	18.153	-10.725	0.1334516	0.1337129	0.1341267	
		144581	0.774	-35.714	0.0814381	0.0814062	0.0814705	
		144595	20.881	-12.093	0.1608230	0.1610763	0.1614160	
		144671	46.223	-35.624	0.0924794	0.0922384	0.0919258	
		144691	17.013	-18.420	0.1083469	0.1081093	0.1077351	
		144696	24.561	-21.528	0.1751935	0.1752012	0.1750080	
		144716	13.070	-7.428	0.1405239	0.1403514	0.1399826	
129	1	20 889	20.388	16.856	0.1107846			
		21 865	50.046	37.730	0.0967709			
		21 866	52.675	56.481	0.0924718			
		21 867	59.135	35.202	0.0952466			
		21 868	13.555	26.420	0.0923704			
		22 925	40.695	0.378	0.0851051			
		20 894	49.036	5.465	0.0925059			
		19 761	18.276	44.494	0.0973387			
		19 764	43.104	43.480	0.0898595			
		20 900	22.537	55.109	0.0783190			
		21 874	28.774	56.154	0.0692275			
130	1	20 889	20.388	16.856	0.1098511			
		21 865	50.046	37.730	0.0964719			
		21 866	52.675	56.481	0.0922447			
		21 867	59.135	35.202	0.0949886			
		21 868	13.555	26.420	0.0922001			
		22 925	40.695	0.338	0.0851275			
		20 894	49.036	5.465	0.0926114			
		19 761	18.276	44.494	0.0972854			
		19 764	43.104	43.480	0.0901728			
		20 900	22.537	55.109	0.0789041			
		21 874	28.774	56.154	0.0701423			
131	1	21 865	50.046	37.730	0.0983702			
		21 866	52.675	56.481	0.0467423			

Table 2. **(continued)**

OBSERVATIONS		CATALOGUE	POSITIONS USED		DEPENDANCES		
		21 867	59.135	35.202	0.0929508		
		21 868	13.555	26.418	0.0790530		
		22 925	40.695	0.378	0.0282604		
		20 894	49.036	5.464	0.1381665		
		22 931	58.507	2.947	0.0665874		
		22 932	4.414	34.927	0.0587436		
		20 900	22.537	55.109	0.2015285		
		21 874	28.774	56.154	0.1895973		
132	1	21 865	50.046	37.730	0.0985357		
		21 866	52.675	56.481	0.0470494		
		21 867	59.135	35.202	0.0930024		
		21 868	13.555	26.418	0.0790508		
		22 925	40.695	0.378	0.0285096		
		20 894	49.036	5.464	0.1379318		
		22 931	58.507	2.947	0.0666710		
		22 932	4.414	34.927	0.0589087		
		20 900	22.537	55.109	0.2012255		
		21 874	28.774	56.154	0.1891152		
133	1	20 889	20.388	16.855	0.1151404		
		22 922	9.509	47.406	0.0969382		
		21 866	52.675	56.481	0.1160150		
		22 925	40.695	0.378	0.1110052		
		20 894	49.036	5.463	0.1384718		
		22 931	58.507	2.946	0.1195606		
		20 900	22.537	55.109	0.1532241		
		21 874	28.774	56.154	0.1496448		
134	1	20 889	20.388	16.855	0.1154811		
		22 922	9.509	47.406	0.0976095		
		21 866	52.675	56.481	0.1162556		
		22 925	40.695	0.378	0.1113247		
		20 894	49.036	5.463	0.1381838		
		22 931	58.507	2.946	0.1196123		
		20 900	22.537	55.109	0.1525283		
		21 874	28.774	56.154	0.1490047		
135	1	25 758	25.775	46.366	0.0911982		
		25 760	38.296	33.531	0.1212156		
		24 728	40.142	48.558	0.0893189		
		25 762	41.241	31.375	0.1147008		
		25 763	54.803	17.881	0.1626732		
		25 773	40.975	50.550	0.1111453		
		25 774	49.132	34.736	0.1704759		
		25 775	1.575	25.908	0.1392722		
136	1	25 758	25.775	46.366	0.0927150		
		25 760	38.296	33.531	0.1222671		
		24 728	40.142	48.558	0.0891090		
		25 762	41.241	31.375	0.1148732		
		25 763	54.803	17.881	0.1633593		
		25 773	40.975	50.550	0.1098177		
		25 774	49.132	34.736	0.1697776		
		25 775	1.575	25.908	0.1380810		
137 138	1	18 409	50.540	20.899	0.1148572	0.1140912	
		19 417	2.579	50.604	0.2075859	0.2067178	
		18 411	54.989	9.279	0.0382270	0.0384308	
		19 419	35.062	22.324	0.2380824	0.2378166	
		17 412	6.983	3.301	0.0260617	0.0263839	
		19 421	16.574	11.528	0.1746793	0.1746473	
		18 413	30.560	47.972	0.0819792	0.0827605	
		18 415	15.691	44.529	0.1185274	0.1191519	
139 140 141	0	128766	32.310	-48.724	0.0379145	0.0384710	0.0387976
		128770	53.076	-6.321	0.1147097	0.1149481	0.1150505
		128781	43.610	-8.247	0.0218496	0.0225047	0.0227628
		128805	58.762	-26.655	0.2044294	0.2040817	0.2038224
		128810	24.295	-33.476	0.0567445	0.0570606	0.0572508
		128830	54.691	-44.977	0.1041778	0.1041291	0.1041983
		128850	56.544	-19.546	0.2576346	0.2568121	0.2564180
		128831	17.684	-27.977	0.2025399	0.2019927	0.2016996
142 143 144	1	-1 1014	13.859	-44.044	0.1048410	0.1053317	0.1056421
		-0 1026	14.423	-39.441	0.1145627	0.1151444	0.1156974
		-0 1027	31.179	-40.253	0.1208523	0.1215664	0.1223474
		-0 1034	43.437	-29.551	0.1246819	0.1252703	0.1260008
		-1 1031	34.590	-24.984	0.0983792	0.0979807	0.0974226
		-0 1042	12.990	-27.032	0.1102489	0.1098838	0.1095640

Table 2. (continued)

OBSERVATIONS		CATALOGUE	POSITIONS USED		DEPENDANCES		
	-1	1041	21.567	-35.088	0.1013072	0.1006387	0.0999041
	-0	1045	57.613	-28.529	0.1169247	0.1166105	0.1164411
	-1	1043	13.233	-54.069	0.1082022	0.1075736	0.1069807
145	0	141725	20.120	-34.898	0.1358486		
		141732	3.837	-1.848	0.1213235		
		141737	37.283	-38.540	0.1060017		
		141756	56.379	-55.313	0.1264414		
		141787	35.754	-11.017	0.1165040		
		141792	6.882	-7.524	0.0746392		
		141807	27.152	-50.311	0.0683400		
		141817	31.153	-54.119	0.0858032		
		141818	40.728	-9.578	0.0989022		
		141845	52.487	-15.119	0.0661962		
146	0	141725	20.120	-34.898	0.1373253		
		141732	3.797	-1.848	0.1225852		
		141737	37.283	-38.540	0.1071050		
		141756	56.379	-55.313	0.1270045		
		141787	35.754	-11.017	0.1163845		
		141792	6.882	-7.524	0.0743203		
		141807	27.152	-50.311	0.0676902		
		141817	31.153	-54.119	0.0849096		
		141818	40.728	-9.578	0.0979965		
		141845	52.487	-15.119	0.0646790		
147	0	144948	52.992	-14.501	0.0577505		
		144950	5.347	-28.767	0.0836895		
		144958	42.380	-16.173	0.1535685		
		144967	7.657	-1.343	0.0794831		
		144983	12.384	-27.710	0.0955212		
		144994	8.745	-33.384	0.1544249		
		145003	32.464	-50.184	0.1748114		
		145012	2.098	-42.989	0.2007509		

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INSTRUMENTAL SYSTEMS OF THE BELGRADE LARGE MERIDIAN CIRCLE IN THE PERIOD 1981–84

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SUMMARY Results are exposed of determination of the Belgrade Large Meridian Circle's instrumental systems in right ascension and declination from the Küstner series observations performed in the period 1981–1984.
Comparison is also made of the collimation error and of the flexure values as furnished by the Küstner series observations during 1984 to those rezulting from the laboratory measurements.

INTRODUCTION

The instrumental system in either right ascension or declination is embodied by the systematic differences between the star positions in a fundamental catalogue and those supplied by the observations with a particular instrument. That instrumental system is commonly brought out by observing transits of stars taken from some fundamental catalogue (presently from the FK4), i.e. by observing the so called Küstner series (Podobed, 1968). One is thus enabled to deduce the systematic differences $\Delta\alpha\cos\delta$ and $\Delta\delta$ for each star. These differences – persuant to a generally adopted procedure – are meaned by declination zones and smoothed in such a way as to weaken the effect of the observational random errors. The meaned systematic differences $\Delta\alpha_\delta \cos\delta$ and $\Delta\delta_\delta$ constitute then what is called instrumental system in α or δ.

The systematic differences $\Delta\alpha\cos\delta$ and $\Delta\delta$ are known to evolve from the defects in the instrument's construction and its defective setting: improper horizontal axis position, non–perpendicularity of the line–of–sight and the horizontal axis, flexure etc., to which are added the deficiencies of the registering equipment, local circumstances, errors in the fundamental catalogue and the like. The parameters reflecting the improper horizontal axis position (m, n), the line–of–sight non–perpendicularity with the horizontal axis – the collimation error(c), tube flexure (a, b) and the inaccurate observed time clock correction (u) are deduced from the Küstner series – passing the remark, however, that the quantities m and u cannot separately be determined but solely as the sum (u + m). Apart from these parameters one has to determine also the variation in time of (u + m), and of the equator point M_0, in the course of the observing tour due to the changes in the instrument itself, in the equipment and the environment.

The collimation error and the flexure parameters, as furnished by the astronomical observations, may be compared with those resulting from the laboratory measurements carried out interstitially.

Previously, the LMC instrumental system has been determined, both in α and δ, in the periods 1973–1975 and 1977 -- 1978 when observations were made for the North Photographic Zenith Tubes (NPZT) catalogue (Dačić, 1984).

OBSERVATIONS

In the period 1981–1984 the observation was carried out with the LMC of 25 Küstner series. On the average, the series embraced 27 fundamental stars from the FK4. One abided by the rule of as even a distribution as possible of stars all along the meridian from $-30^\circ < \delta < 80^\circ$ and of each series comprising a few stars at the lower transit.

The rationale behind oru LMC instrumental system determination is its being associated with the regular programmewise observations of double stars (DS) and of stars near radio sources (RS), interspersed with daily observations of the Sun and the planets, all carried out in the period 1981–1984.

The number of the Küstner series observed according to years in uneven: while their total in the years 1981–83 is but 13, there are as many as 12 in 1984 alone. This is due to the circumstance that this author was charged, in 1984, with the specific task of studying the LMC instrumental system with a view of harnessing it in the forthcoming data handling, once the current observing programme is completed.

Of the total number of the Küstner series observations, 5 have been made in teh spring, 12 in summer, 7 in autumn and 1 in winter. The temperatures at which the observations were made ran from −2.6 C to +25.6 C. There were in all 14 observations on clamp E 11 on clamp W.

Since May 1984 systematic laboratory measurements are carried out of the collimation error and the flexure using horizontally mounted collimators in the LMC pavilion. One performed, until November 1984, 45 collimation error and 44 flexure measurements. In that same period one carried out 11 Küstner series observations. The laboratory measurements were performed at temperatures ranging from +5.0 C to +28.6 C, mostly between 10^h a.m. and 2^h p.m., largely with the open pavilion. Some of the measurements have been executed in the early morning or late evening hours or at the closed pavilion.

DATA PROCESSING AND DISCUSSION

The processing of the Küstner series observations implied the derivation of the parameters (u + m), n, Δc and τ for the right ascension and M_o, a, b and τ' for the declination by the formulae

$$-\Delta\alpha \cos\delta = -(\alpha - T)\cos\delta + \Delta c + (u + m)\cos\delta +$$

$$+ n \sin\delta + \tau(\alpha - \alpha_o)\cos\delta \qquad (1)$$

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

$$\Delta\delta = -(M - \delta) + M_o + a\cos z + b\sin z + \tau'(\alpha - \alpha_o) \qquad (2)$$

where $\Delta\alpha = \alpha - \alpha'$ and $\Delta\delta = \delta - \delta'$, i.e. the differences of the right ascension and declination (α, δ) found in FK 4 and their observed values (α', δ'), T – the observed time of star transit; (u + m) and **n** Bessel formula's parameters; $\Delta c = c - c_o$ correction to the collimation error measured with the collimatory; M – circle reading; M_o – equator point; **a** and **b**, vertical and horizontal flexure components, respectively, τ and τ' – coefficients of the linear variation in time, respectively; α_o – initial time of the Küstner series observation.

The mean unit wight error, in right ascension was $\sigma_o = 0^s.0296$ and that in declination was $\sigma'_o = 0''.503$

The instrument's parameters (u + m) and M_o assume different values from one series to another. The variation in time of (u + m) in the course of a series' observation turned non-conspicuous in only 5 series, while being sometimes, in the rest of them, very significant. The coefficient of the linear variation in the τ varied within the $0^s.015$ and $0^s.090$ bounds. The variation of M_o in the course of a Küstner series' observation is not as pronounced as the one of (u + m); none at all is found in 12 series. The coefficient τ' of the linear variation in time varied within $0''.17$ and $1''.05$ limits.

During 1981 and 1982 the parameter **n** had small values from $-0^s.352$ to $+0^s.466$. During 1983 and 1984 its value grew above $0^s.5$, to attain even $0^s.915$.

Table 1. Mean collimation and flexure values resulting from the Küstner series observations in the period 1981–1984

Clamp	c_o	Δ_c	c	n_1	a	b	n_2
E	$-0^s.038$	-0^s030	$-0^s.068$	12	$+2^s.66$	$-1^s.67$	13
	± 5	± 52	± 52		± 55	± 21	
W	−0.067	−0.004	+0.063	8	−0.84	−2.22	11
	± 4	± 52	± 52		± 55	± 20	

Table 1 gives the mean values of the collimation error ($c = c_o + \Delta c$) and the coefficients (a, b) in the formula for the fluxure, obtained from the Küstner series observation, where c_o – the collimation furnished by the laboratory measurements; a – vertical fluxure component; b – horizontal fluxure component; n_1 – the number of the Küstner series from which Δc has been computed; n_2 – the number of the series serving for the computation of **a** and **b**.

The c_o and c values have opposite signs on clamps E and W, a consequence of the horizontal axis occupying opposite positions at those clamps. Therefore, we are going to employ in the further presentations their absolute values when it comes to comparing their amounts on the two clamps.

The c_o values on clamp E are nearly double less than those on clamp W, but the respective **c** values on both clamps are accordant, which might be taken as evidence of dependability of the employed method of their determination.

The **a** and **b** values in their turn are also different on the two clamps, whereby the **a** value on the clamp E is in excess by $3''.5$, and the one of **b** by more than $0''.5$, in reference to their respective values on the clamp W. We see from equation (2) the factor of M_o is unity and the one of **a** is cosz. In some of the Küstner series the star distribution was not exactly an even one since some stars proved unobservable or had to be discarded on account of excessive errors of observation. This made itself felt at separating the coefficients of M_o and **a**.

An inquiry pertaining to the parameters, **c**, **a** and **b** being dependent on the temperature revealed this dependence being absent, which is also realized from the Figs. 1 and 2.

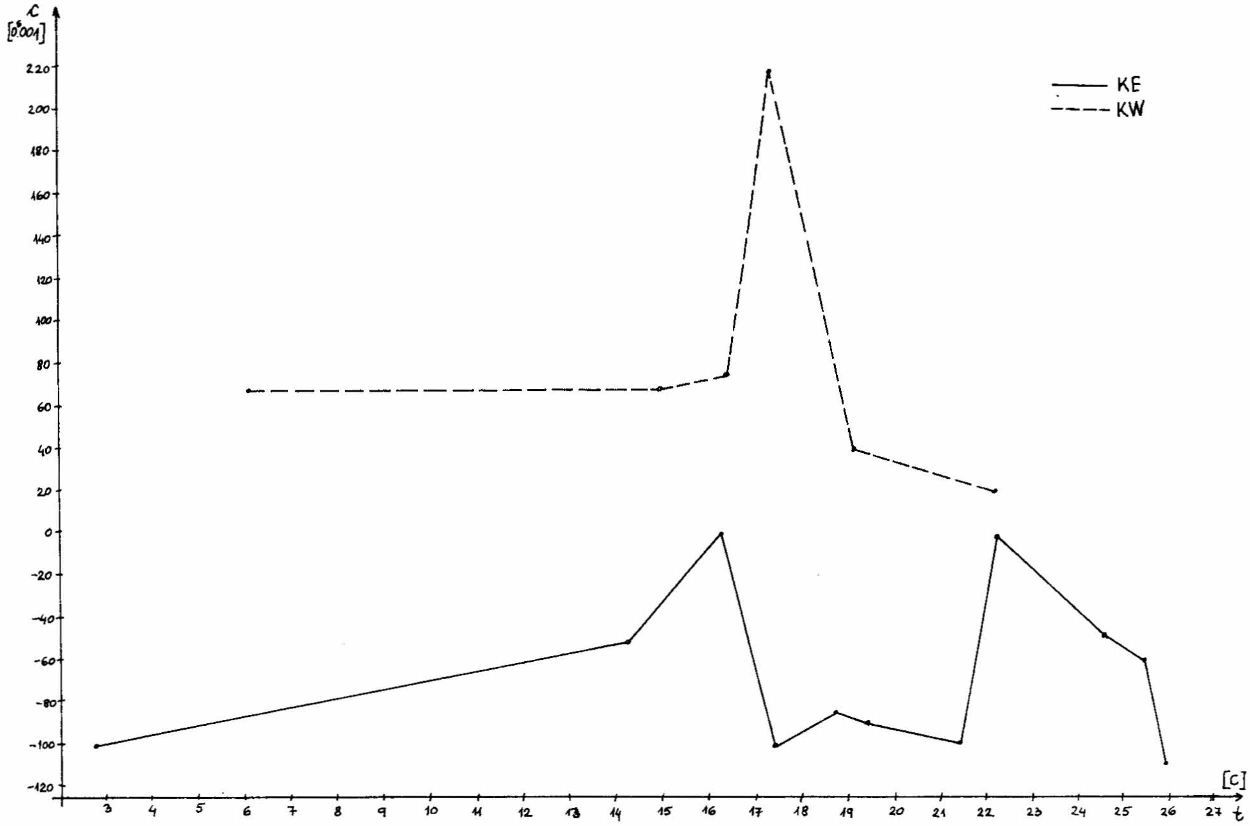

Fig. 1. Collimation c dependence on temperature during observation

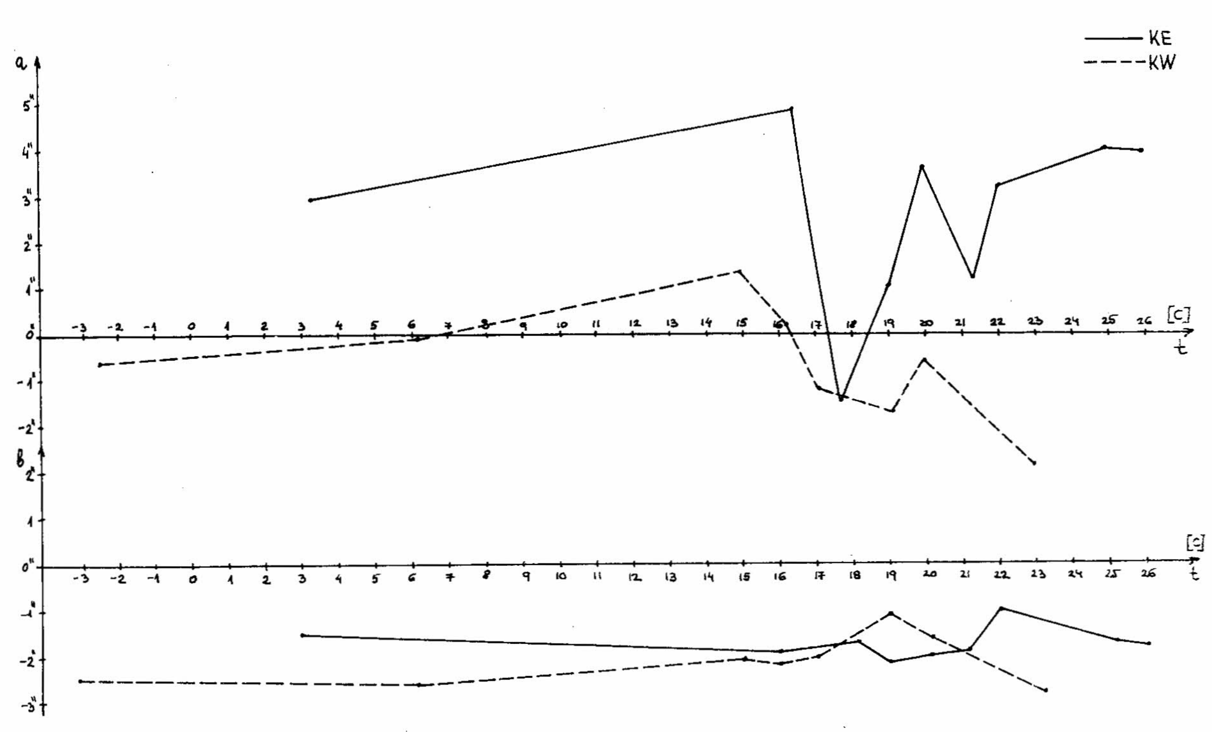

Fig. 2. Fluxure coefficients a and b dependence on temperature during observation

Fig. 1 illustrates the collimation error versus temperature.

Fig. 2 illustrates the flexure coefficients **a** and **b** versus temperature.

Table 2. Mean collimation and flexure values resulting from the Küstner series and laboratory measurements in 1984

Küstner series					
Clamp	c	n_1	a	b	n_2
E	−0ˢ.065 ± 32	6	+2″.61 ± 59	−1″.81 ± 22	7
W	+0.092 ± 25	2	−0.71 ± 46	−2.15 ± 18	4
Laboratory measurements					
Clamp	c	n'_1	a	b	n'_2
E	−0ˢ.013 ± 6	30		−1″.51 ± 14	30
W	+0.036 ± 7	15		−0.73 ± 24	14

The mean values of the collimation error and the fluxure coefficients, resulting from the Küstner series and the laboratory measurements. are displayed in Table 2, where c – the collimation error; n_1 and n_2 – the number of Küstner series involved; n'_1 and n'_2 – the number of laboratory measurements involved; a – vertical fluxure component; b – horizontal fluxure component.

A comparison of data in Table 1 with those in the upper half of Table 2 reveals the clamp E collimation errors to be well accordant while the one at clamp W in the Table 2 appear signally greater over its homologous in Table 1. As for the **a** and **b** coefficients they are found fairly consistent.

The c values obtained from the Küstner series and the ones resulting from the laboratory measurements in Table 2 for both clamps differ among themselves by the same amount: 0ˢ.05, which might be considered as betraying an actual difference inherent in this quantity on the two instrument clamps. A disparity of 0″.3 on the clamp E is stated in the quantity **b**, but a rather significant one of 1″.4 on the clamp W.

Relevant to the right ascension observations, the accuracy of the parameters (u + m) and Δc determination is runing between 0ˢ.040 and 0ˢ.060, the one of **n** between 0ˢ.020 and 0ˢ.040, while that of τ is between 0ˢ.010 and 0ˢ.020. In declination, the parameter M_o and **a** accuracy is confined between 0″.30 and 0″.70, the one of the parameter **b** between 0″.15 and 0″.25, and that of the parameter τ' between 0″.15 and 0″.30.

The flexure and the collimation errors, as obtained from the laboratory measurements have also been, like their homologous obtained from the Küstner series, inquired after their possible dependence on the temperature but none could be established.

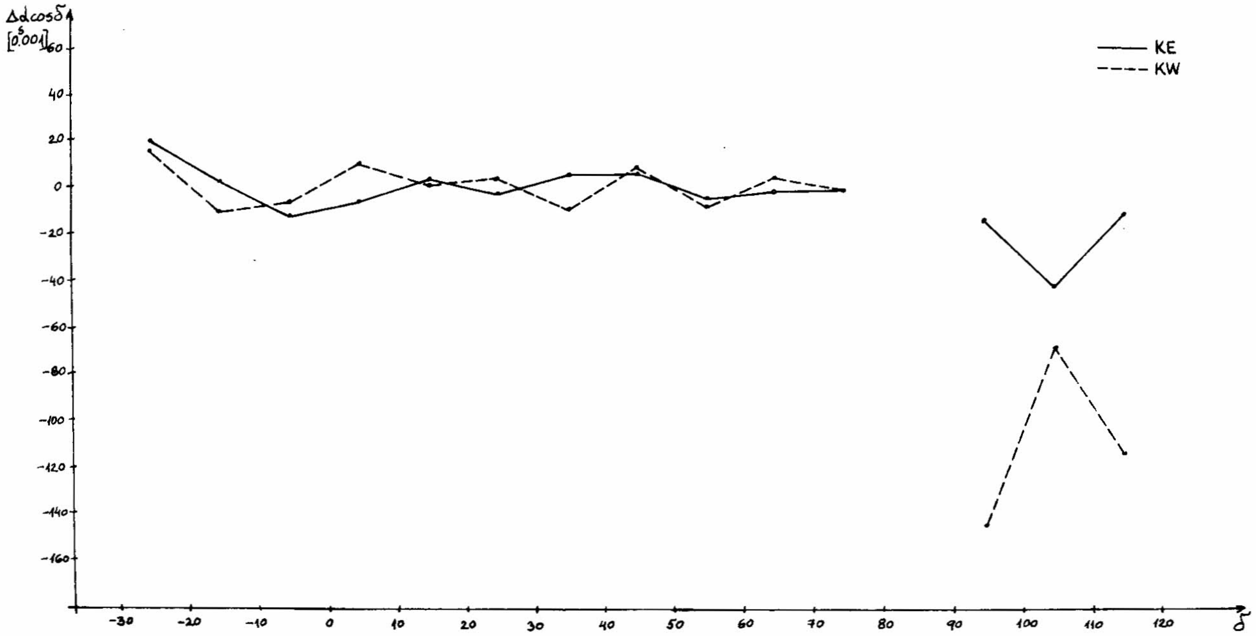

Fig. 3. LMC system in right ascension

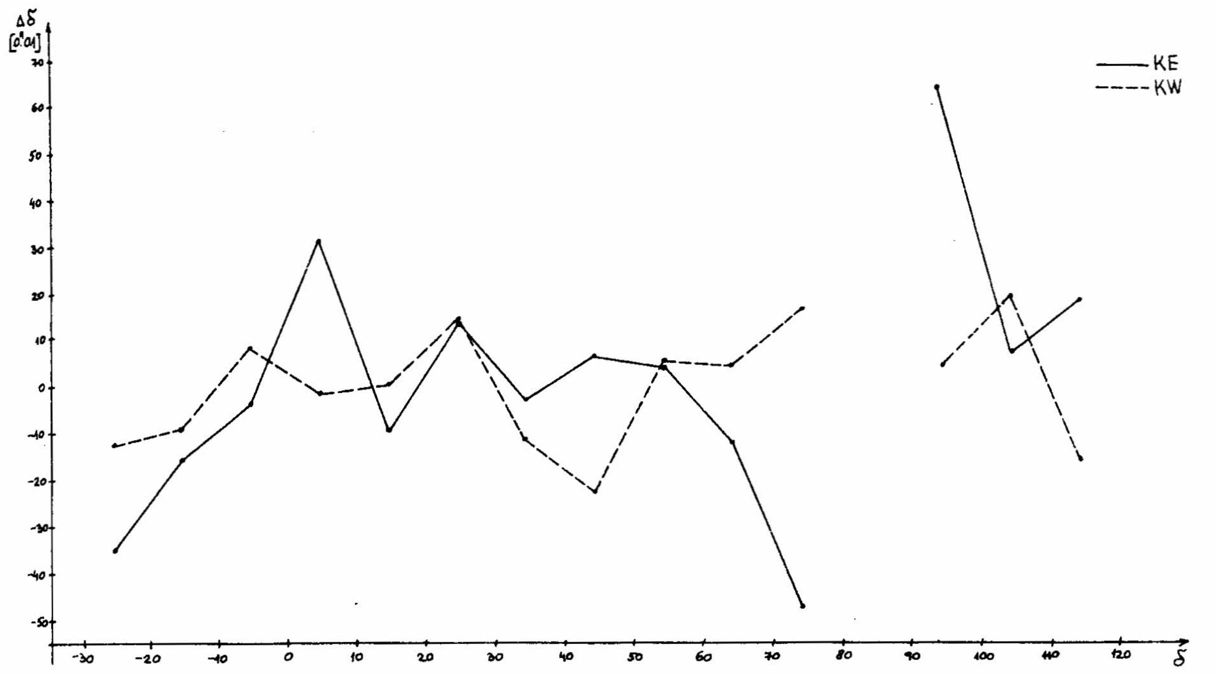

Fig. 4. LMC system in declination

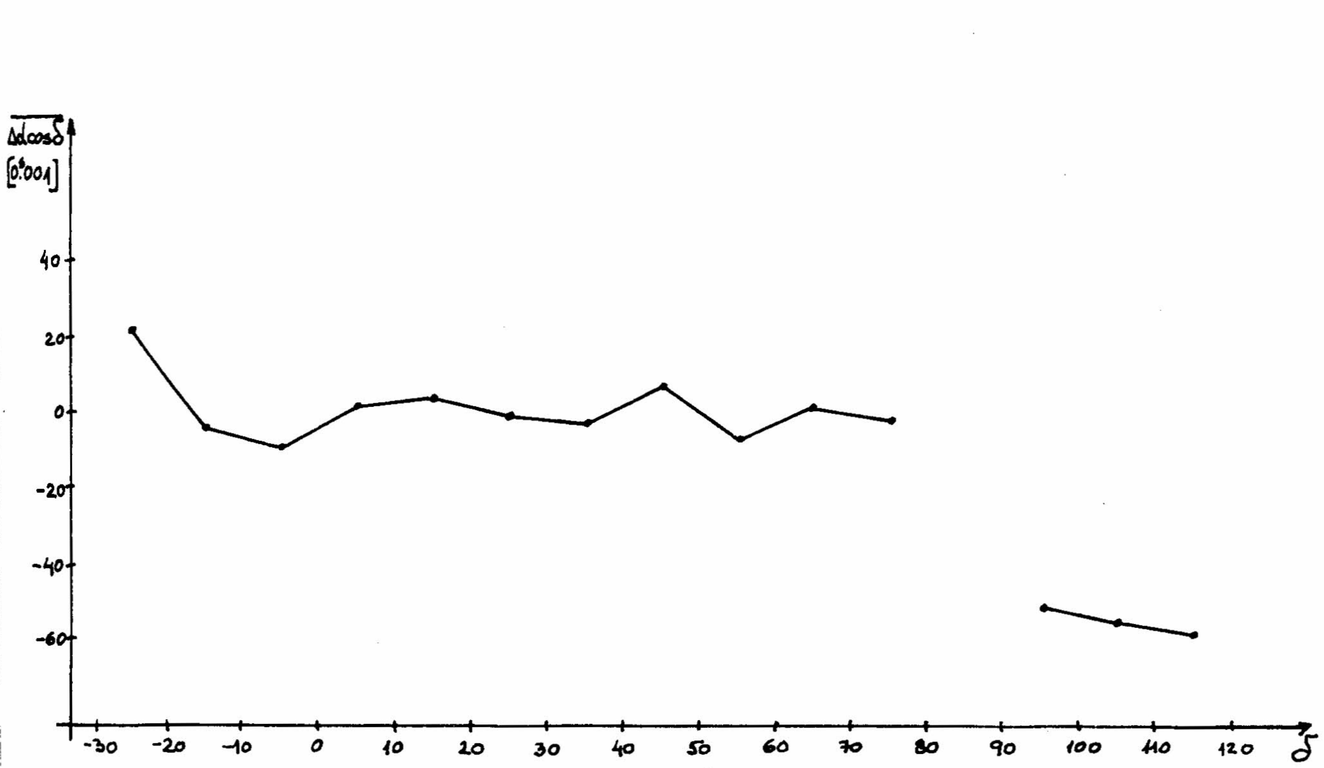

Fig. 5. LMC mean system in right ascension

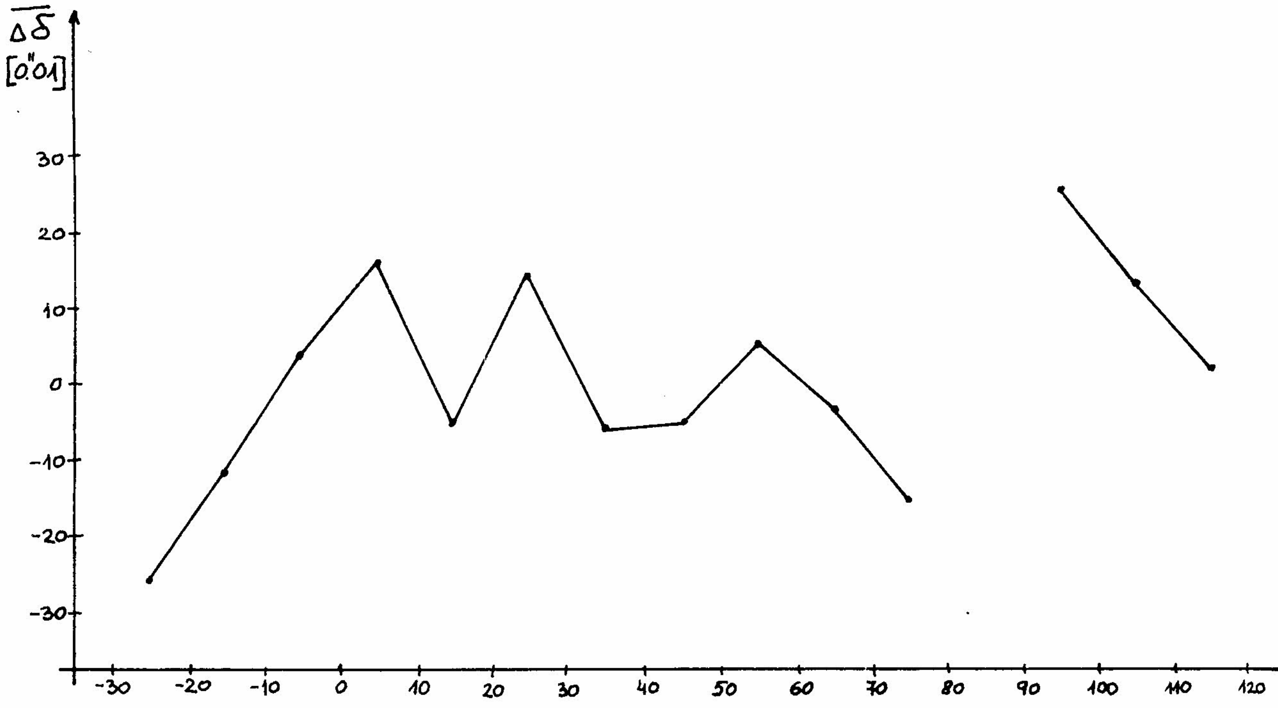

Fig. 6. LMC mean system in declination

THE LMC MEAN INSTRUMENTAL SYSTEM

The systematic differences $\Delta\alpha\cos\delta$ and $\Delta\delta$, computed according to equations (1) and (2) by employing known instrument's parameters, enabled a picture to be gained of the LMC mean instrumental system for the period 1981–1984. The grouping in declination of the systematic differences was performed according to 10° zones (Figs. 3, 4, 5 and 6).

Figs. 3 and 4 illustrate the right ascension and declination systems according to declination for the E and W clamps.

Figs. 5 and 6 illustrate the meaned right ascension and declination systems according to declination.

Remarkable consistency is evident in Figs. 3 and 4 of the right ascension and declination systems on both clamps. More pronounced deflections do occur in the lower transits, but no interpretation can be offered before additional study is made.

From the comparison of the curves illustrating the mean insturmental systems in right ascnesion and declination for the period 1973–1975 and 1977–1978 (Dačić, 1984) with their counterparts in Figs. 5 and 6 we get apprised of the following: 1) the right ascension curves exhibit virtually the same course over the declinations 0° through 70°. Small departures arise in the negative δ and at the lower transits; 2) the curve associated with the declinations, follow virtually th same course over the entire declination range.

CONCLUSIONS

No appreciable changes, in either right ascnesion o in declination, are apparent over longer time intervals i the LMC instrumental system. This is to say that th LMC is a rather steady instrument, capable of yieldin reliable results, a momentous fact in the Sun, planet and stras observations which are on programme of ou LMC for already 20 years.

Good accordance is stated of the collimation errors furnished by the Küstner series observations, on bot clamps, while there is a discrepancy of about 0."5 in th coefficient **b** values on the two clamps. No reliabilit may be accorded to the coefficient a values.

The divergence is confirmed of the collimation erro values and of those of the flexure, provided by th laboratory measurements and of those resulting from th Küstner series observation. This divergence for th collimation error might, partially, be interpreted as bein due to its varying with the zenith distance. The deviation in the flexure values, to be explained, calls for supplementary inquiry, this above all with the laboratory measurements under various circumstances.

No temperature dependence vould be stated of the collimation error or flexure values whether obtained from the Küstner series observation or from the laboratory measurements.

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INVESTIGATION OF THE GRADUATION ERROR OF THE BELGRADE MERIDIAN CIRCLE

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SUMMARY. Account is given of the organization and analysis of investigation of tl graduation of the Belgrade Meridian Circle performed in 1977. Measurements are made half–degree spacing, Bruns' method having been applied. Inquiry is made for possib temperature effects on the measurements.

1. INTRODUCTION

During June and July, 1977, the graduation has been investigated of the Belgrade Meridian Circle (Askania, 190/2578 mm,cicle diameter D = 800 mm) at 0.5 separation. These measurements were first partially processed, the settings at 4° spacing only having been employed, whereby a global notion of the corrections to the graudation and the circle's quality could be provided (Trajkovska, 1979).

Next, the measuring material as a whole was treated, the results obtained being reported in the present paper. The idea followed was to compare the graudation errors as we obtained them with those deduced earlier (Sadžakov, Šaletić, 1968), the latter arrived at by the same (Bruns') method, with the settings having been made also at 0.5 spacing. The incitement to this investigation of ours was presented by the fact that in some circle graduations time dependent systematic displacements have been established, even such in the course of a year (Hφg, 1960).

The periodicity of the circle graduation errors was shown in a separate paper (Trajkovska, 1981) by making use of the spectral analysis.

2. METHOD AND ORGANIZATION OF MEASUREMENTS

The investigation of the cicle graduation at 0.5 spacing was carried out according to the Bruns' method, which allows the use of the rosette R (360, x) as a combination of three rosettes:

$$R(9, x); R(8, x); R(5, x);$$

where

$$n = p\,q\,r = 9 \cdot 8 \cdot 5 = 360$$

with x representing anyone of the diameters.

The number of the diameter readings is:

$$2pqr\,(p + q + r - 3) = 13\,680$$

with the weight $g = 17.6$

The number of the constant angles at which th measurements were made over the graduation is specif ed by the relation

$$f = \frac{1}{2}\,(p + q + r - 2) = 10$$

Concerning the rosette R(9, x) the angles are th following:

$$20^\circ, 40^\circ, 60^\circ, 80^\circ$$

while the ones for the rosette R(8, x) –

$$22^\circ\!.5, 45^\circ, 67^\circ\!.5, 90^\circ,$$

and for the rosette R(5, x) – 36° and 72°

The application principle was the following: wit the rosette R(9, x) the angles 20°, 40°, 60° and 80 were employed 40 times starting from

$$0^\circ, 0^\circ 30', \quad , 19^\circ 30';$$

With the rosette (R(8, x) the angles 22°.5, 45°, 67°.5 an 90° were used 45 times starting from

$$0^\circ, 0^\circ\!.30', \ldots , 22^\circ$$

and with the rosette R(5, x) the angles 36° and 72° hav been used 72 times, starting from

$0^o, 0^o30', \ldots, 35^o30'$.

The measurements were carried out by series, which took 25 minutes on the average (any series involving measurements in both senses). For homogeneity, all the measurements were perfomed by the same observer (the author), the note taking having been made by several persons.

The measurements are visual, having been executed by settings of the movable micrometer thread on the „junior" and the „senior" divisions, twice on each one. It took about 250 effective hours to accomplish the measurements and about 20 extra hours for proper installing and adjusting the microscopes.

The measurements were all performed in the closed MC pavilion. The temperature during these meas rements kept about 20°.0 C, its variation in the course of a series reaching 0°.9 C. The instrument was in the CW position, the same it occupied in the previous investigations, the purpose being to ensure, as much as possible, the same circumstances, thus providing as legitimate a base as possible for the intended comparison.

3. DEDUCTION OF THE CORRECTIONS TO THE DIAMETER AND THE ACCURACY

The determination of the corrections to the circle diameter from the observational material was carried out according to the scheme suggested by Zverev (1954). First, the means were derived of the micrometer readings by the I and III, as well as by the II and IV microscopes. Next, one found the quantities $D_{x,x+f}$ (differences of the diameters x and x + f readings) in both senses of measurements by series. Then, the quantities d_x^f were calculated, which are the differences between the contiguous angles:

$$d_x^f = D_{x,x+f} - D_{x-f,x},$$

the subscripts denoting the particular diameter and the superscript the constant angle.

These values enter in the normal equations of the form:

$$22\,E_x - S_x^5 - S_x^8 - S_x^9 = d_x^{20} + d_x^{40} + d_x^{60} + d_x^{80} +$$

$$+ d_x^{22.5} + d_x^{45} + d_x^{67.5} + d_x^{90} + d_x^{36} + d_x^{72} = F_x$$

solvable on the basic condition that the sum of corrections to all the diamters of the rosette is equal to zero, i.e.

$$\sum_{i=o}^{n} E_x = 0$$

The elimination of the sums S_x^5, S_x^8, S_x^9 and the quantity F_x was achieved by introducing new quantities G_x, H_x, K_x, L_x, M_x and N_x the result being the values of the corrections E_x.

The note–book recordings were checked by making summation of the quantities d_x^f, whose sum in any series must be zero. The cheking of quantities featuring on the processing cheme was made in adequate manner.

The estimate of accuracy of the obtained corrections is made by

$$\epsilon_E = \pm \frac{\epsilon_d}{g}$$

where

ϵ_d – rms error of one diameter,
g – the weight associated with the determined corrections, amounting to 17.6 in the present case.

The rms error of a diameter reading in these measurings is

$$\epsilon_d = \pm\, 0''.25$$

while $\epsilon_E = \pm\, 0''.06$ is the r m s error of the diameter corrections.

4. ANALYSIS AND CONCLUSION

The numerical values of the circle corrections obtained vary between +1".51 and –1".53. The maximum positive corrections appear around 130° and 160°, whereas those negative are found around 70°.

The comparison ot these corrections with those found previously (Fig. 1) reveals the following: while no significant changes in the positions of the circle divisions do exist, there nevertheless a small displacement of one curve with respect to the other is evident. For it to be accounted for one has to give consideration to the fact that the two investigations have been made at markedly differing temperatures (the measurements in 1968 have been carried out in March and April, the average temperature being about 10°C while those in 1977 are accomplished in June and July at an average temperature about 20° C). To this must be added the all–out „agening" of the circle, its illumination and, certainly, personal error.

It is important to ascertain the possible temperature effect, this all the more so as besides night observations with this instrument, those by day–time (high day–time

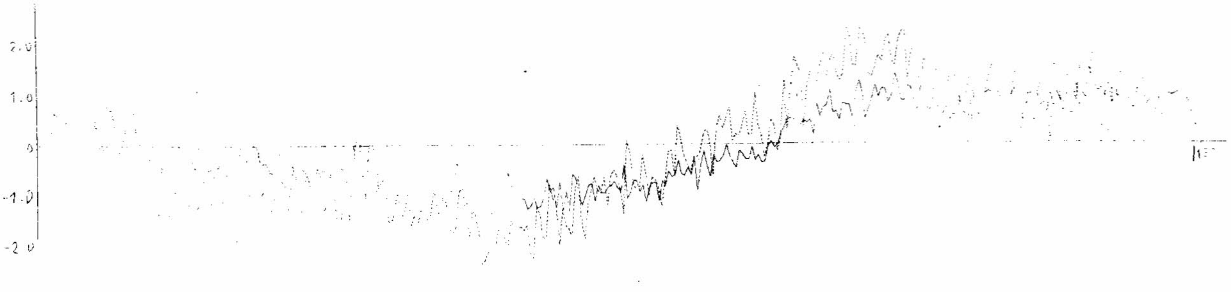

Fig. 1. The graduation errors of the Belgrade Meridian Circle, at 0°5 separation, obained by measurements in 1968 (– – – –) and in 1977 (———).

temperature over the summer months) are also made. However, for the diameter corrections dependence on temperature to be brought out, greater number of their determinations at various temperatures is necessary. Since we are lacking such extensive measurements, it being difficult to provide them for the classical, unautomated, instruments, decision was taken to extract from the available material at least some notion about the temperature effect. With this in mind we analysed the quantities $D_{x,x+f}$ (which constitute the basis in the circle corrections calculation) in terms of temperature. Therefore, in using the observational material from 1968 and 1977, we formed the temperature differences Δt and the differences of the qunatities $D_{x,x+f}$ for the sets of measurements at the angles 20°, 36°, 45° and 60°.

The question arises whether there exist, and if, what sort of mutual dependence of these quantities. In order to establish what form of relation is the most convenient, we supposed the following dependences (linear, quadratic, third power and logarithmic)

$$\Delta D_{(x,x+f)_i} = D_{01} + \alpha_1 \Delta t_i \qquad (1)$$

$$\Delta D_{(x,x+f)_i} = D_{02} + \alpha_2 \Delta t_i + \beta_2 \Delta t_i^2 \qquad (2)$$

$$\Delta D_{(x,x+f)_i} = D_{03} + \alpha_3 \Delta t_i + \beta_3 \Delta t_i^2 + \gamma \Delta t_i^3 \qquad (3)$$

$$\Delta D_{(x,x+f)_i} = D_{04} \exp(\alpha_4 \Delta t_i) \qquad (4)$$

Table 1. The results obtained using the formulae (1), (2), (3) and (4)

Angle of measur.	k	D_{ok}	α_k	β_k	γ	σ_{D_o}	$\sigma_{\alpha k}$	$\sigma_{\beta k}$	σ_γ	σ_o	r
	1	7.752	0.531	–	–	0.991	0.060	–	–	1.715	0 82
	2	13.585	–0.360	0.030	–	3.580	0.529	0.018	–	1.674	0.83
20°	3	36.166	–5.361	0.375	–0.008	13.858	3.015	0.206	0.004	1.634	0.85
	4	9.315	0.034	–	–	1.061	0.004	–	–	0.102	0.84
	1	22.380	0.332	–	–	1.346	0.094	–	–	1.113	0.54
	2	22.758	0.280	0.002	–	6.922	0.953	0.032	–	1.132	0.54
36°	3	165.058	–28.561	1.908	–0.041	42.135	8.494	0.560	0.012	0.968	0.71
	4	22.809	0.012	–	–	1.050	0.003	–	–	0.040	0.54
	1	0.901	0.175	–	–	0.638	0.059	–	–	1.218	0.43
	2	4.562	–0.584	0.036	–	1.792	0.354	0.016	–	1.162	0.53
45°	3	1.763	0.273	–0.045	0.002	6.435	1.925	0.179	0.005	1.175	0.53
	4	0.560	0.125	–	–	1.445	0.034	–	–	1.307	0.30
	1	–1.159	0.305	–	–	1.527	0.168	–	–	1.172	0.38
	2	–13.176	3.223	–0.171	–	5.539	1.311	0.076	–	1.069	0.57
60°	3	–35.567	11.533	–1.163	0.038	28.282	10.373	1.231	0.047	1.079	0.59
	4	0.090	0.827	–	–	6.202	0.201	–	–	2.376	0.48

where

D_{01}, D_{02} D_{03} and D_{04} are the most probable values of the quantites $D_{x,x+f}$ at temperature diff. $\Delta t = 0$;

$\Delta D_{x,x+f}$ – differences of the quantities $D_{x,x+f}$ for 1968 and 1977 of the for the i-th measurements within at angles 20°, 36°, 45° and 60°;

$\alpha_k, \beta_k, \gamma$ – the searched for coefficients of the temperature terms. The solution by the least square method supplied the looked for values of D_{ox}, α_x, β_k and γ (Table 1). Given are also the r m s error of σ_{D_o}, $\sigma_{\alpha x}$, $\sigma_{\beta k}$ and σ_γ, as well as σ_o– r m s error of one equation of condition and the correlation coefficient r.

These results enable one to state that there existed a temperature dependence of the quantities $D_{x,x+f}$. It is most suitably expressed by the form (3). The measurement series at angle 20° discloses a closer correlation than those furnished by measurements at 36°, 45° and 60° angles. This might be a consequence of the smaller temperature differences with the latter measurements (average temperature differences with them are 3°.4 C, 5°.7 C and 2°.4 C respectively, while the one associated with 20° angle measurements is notable greater – 9°.0 C)

From this analysis it transpires that the systematic shift of the Fig. 1. curves might partially be accounted for by the temperature effect.

The author takes the opportunity to thank Dr. S. Sadžakov and ing. D. Šaletic for their advice concerning the use of the Bruns method, Dr. G. Teleki for being helpful at analysing the results, as well as all the colleques who have rendering service at recording the enormous observational material.

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A SURVEY OF MERIDIAN OBSERVATIONS CARRIED OUT WITH THE TRANSIT INSTRUMENT OF THE BELGRADE OBSERVATORY IN THE PERIOD 1952 TO 1983

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SUMMARY: Presented are data on the frequency of observations in the Belgrade Time and Longitude Service, tabular survey of the number of observations performed by individual observers and a graphich illustration of the monthly average number of observations in the period 1952–1983.

Table 1 Broj posmatranih serija+ zvezda pojedinih posmatrača 1952.–1983.g.
Number of series observed by individual observers 1952–1983.

Posmatrač Godine	ZB	LjM	MJ	DĐ	RM	DV	ML	DM	LĐ	BJ	Broj serij.
1952	122	140	–	–	–	–	–	–	–	–	262
1953	141	161	–	–	–	–	–	–	–	–	302
1954	104	52	–	–	–	–	–	–	–	–	156
1955	107	66	–	–	–	–	–	–	–	–	173
1956	81	84	8	–	–	–	–	–	–	–	173
1957	51	65	20	–	–	–	–	–	–	–	136
1958	62	73	66	–	–	–	–	–	–	–	201
1959	88	31	94	–	–	–	–	–	–	–	213
1960	40	46	110	10	–	–	–	–	–	–	206
1961	1	2	108	148	–	–	–	–	–	–	259
1962	87	–	72	94	–	–	–	–	–	–	253
1963	122	–	133	124	71	–	–	–	–	–	450
1964	105	–	95	144	100	–	–	–	–	–	444
1965	77	–	88	104	79	–	–	–	–	–	348
1966	90	–	126	131	–	–	–	–	–	–	347
1967	10	–	149	168	–	–	–	–	–	–	327
1968	–	–	115	135	–	–	–	–	–	–	250
1969	–	–	177	14	–	61	57	60	–	–	369
1970	–	–	178	–	–	81	22	–	–	–	281
1971	–	–	144	–	–	121	12	–	–	–	277
1972	–	–	102	–	–	113	–	–	–	–	215
1973	–	–	103	–	–	114	–	–	–	–	217
1974	–	–	98	–	–	107	–	–	–	–	205
1975	–	–	147	–	–	31	–	–	49	–	227
1976	–	–	118	–	–	–	–	–	69	–	187
1977	–	–	135	–	–	–	–	–	83	–	218
1978	–	–	59	–	–	–	–	–	65	–	124
1979	–	–	114	–	–	–	–	–	43	–	157
1980	–	–	118	–	–	–	–	–	39	–	157
1981	–	–	103	–	–	–	–	–	67	–	170
1982	–	–	75	–	–	–	–	–	71	–	146
1983	–	–	77	31	–	–	–	–	78	18	204
Prosek:											239

+ Serija je sastavljena od 10–12 zvezda
A series comprises 10–12 stars

More intensive observational activity aimed at pursuing clock correction and longitude started at the Belgrade Observatory's soon as this institution was established at its present location, i.e. since 1934. Great efforts were necessary to overcome difficulties and to master both working technique and scientific achevements involved by regular research work.

It is, however, not until 1951 that regular observations with the transit instrument „Bamberg" were started, but the acquired material was used only for deriving the instrument's constants.

The processed observational material aimed at systematic pursuing of the clock correction and the longitude from 1952 and 1953 conditioned the Belgrade Observatory's Time Service admission to the International Time Service (B.I.H.). The processing and analysis of this observing material is authored by Z.M.Brkić and Lj.A. Mitić.

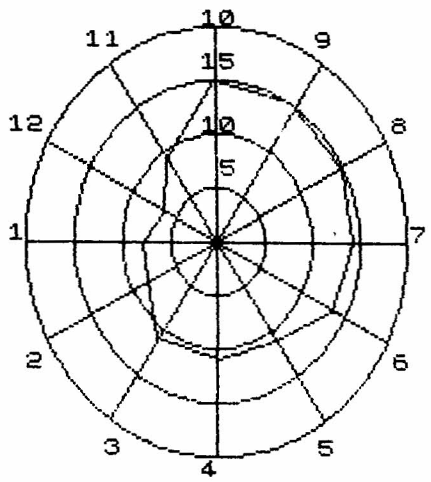

Fig. 1

Tabela II Pregled broja posmatračkih večeri u periodu 1952.–1983.g
Number of observing niglts in the period 1952.–1983.

Mesec God.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Br. posm. večeri
1952	7	3	10	14	7	16	22	16	14	14	13	7	143
1953	7	11	22	13	17	15	21	18	20	16	13	19	192
1954	2	8	12	11	16	14	15	21	15	17	7	7	145
1955	9	10	13	19	19	17	13	15	17	13	9	12	166
1956	14	7	8	12	14	13	16	26	19	23	6	11	169
1957	11	15	15	8	5	12	–	8	14	21	10	3	122
1958	13	12	13	8	19	14	22	19	16	12	5	14	167
1959	12	13	12	12	10	15	13	18	16	16	12	4	153
1960	10	13	5	11	12	15	15	18	18	15	11	13	156
1961	11	12	16	18	10	19	21	24	27	23	12	7	200
1962	9	8	10	7	9	8	9	28	16	20	6	11	141
1963	12	11	20	16	18	21	23	12	12	12	16	7	180
1964	12	12	10	19	19	15	24	22	19	18	11	9	190
1965	15	11	20	14	12	22	27	19	21	22	10	9	202
1966	5	11	12	8	16	14	14	16	21	11	10	5	143
1967	17	11	6	12	15	16	24	17	16	12	6	5	157
1968	4	8	16	13	7	8	11	8	7	17	3	3	105
1969	13	7	6	15	10	11	20	15	18	20	15	1	151
1970	10	5	11	10	9	13	12	19	15	16	14	7	141
1971	5	5	6	15	16	16	14	23	12	18	11	10	151
1972	2	8	22	15	13	12	6	6	10	6	12	11	123
1973	9	5	5	7	11	12	10	11	16	20	14	7	127
1974	12	11	15	11	7	8	14	14	13	6	14	6	131
1975	17	14	10	10	8	4	16	3	19	9	8	5	123
1976	4	9	6	6	3	11	12	11	15	11	6	6	100
1977	6	1	18	9	9	9	7	14	11	19	6	7	116
1978	3	–	3	2	1	7	10	17	8	10	2	4	67
1979	–	11	11	8	4	8	10	6	12	8	2	5	85
1980	1	4	9	7	4	12	5	10	14	9	7	–	82
1981	–	6	12	14	10	11	8	1	8	11	9	–	90
1982	–	7	9	10	8	10	6	1	10	7	8	6	82
1983	6	2	7	4	8	3	10	9	15	15	7	2	88
S/32	8	8	11	11	11	13	14	15	15	15	9	7	137

The observers in the Time Service over the period 1952 to 1983 are: Z.Brkić (ZB), Lj.Mitić (LjM), M.Jova nović (MJ), D.Djurović (DĐ), R.Momčilović (RM), D.Vesić (DV), M.Lončarević (ML), D.Mandić (DM), L.Djurović (LĐ) i B.Jovanović (BJ).

Graphic illustration of the avarege number of observing nights by months in the period 1952 – 1983.

The reduction of the observations to the same coordinate system–zero point, is performed by the chain method in various versions. The application of thi method assumes the same accuracy level in all of it „links". Such an accuracy is provided inasmuch as th observation frequency is evenly distributed in time. A planing researches involving the application of th method (working out of catalogues from observation made in time services, derivation of the local Z–term) is necessary to known the frequency distribution of th clear nights. This just was the task we set up in th present statement.

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