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Original scientific paper

LONG–TERM CHANGES OF LINEAR OPTICAL POLARIZATION OF Be STARS

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SUMMARY: As a part of a more extensive research program at Belgrade Astronomical Observatory, the first results of ten–year optical polarization measurements of o And, 88 Her, κ Dra and γ Cas have been shown. The existence of slow changes of polarization parameters has been established in all four stars. For two of them, 88 Her and κ Dra, the intrinsic polarization has been determined. A further analysis of these results is in preparation.

INTRODUCTION

Almost all characteristic phenomena simultaneously occuring in Be stars such as Balmer emission, quasi stationary shell absorption, infrared emission excess and high–velocity and high–ionization stellar wind can result in the apparition of an intrinsic stellar polarization. Indeed, the intrinsic optical polarization has been statistically established in 50% of all Be stars. Very often the degree of this polarization is less than 2% and most probably it originates in the extended stellar envelope. Some of the polarization characteristics, e.g. its dependence on the radiation wevelength, or the emission line polarizaton, are very intensively studied world–wide. But, they will not be reviewed in detail on this occasion because our interest is concentrated on time–dependent changes of stellar polarization. It is thought that they are mainly low–amplitude, irregular and that they consist of the superposed both short–period (less than a day) and long–period (of the order of hundred days) changes. However, due to the scarcity of such stellar data – especially those for periods longer than three years – conclusions are usually reached on the basis of few measurements.

Besides, no one scenario can successfully explain the polarization changes and, even more, the complex photometric, spectral and polarization characteristics. For example, in any star the behaviour of polarization parameters during the activity phases (B, Be, and Be + shell), probably existing in all Be stars, is not known. The same is valid for the connection of polarization parameters with photometric quantities – at the first place the brightness of a star. There are two good review papers concerning the optical polarization of Be stars where the reader can get informed about these problems in more detail, namely: Coyne (1976) and Coyne and Mc Lean (1982).

Taking our fair possibilities for astronomical observations (small–apperture telescope, bad astroclimatic condistions) into account, and, on the other hand, the ability to observe in very long series with the same telescope available at Belgrade Astronomical Observatory, a program of studying long–term optical polarization changes of some selected Be stars has been set up in 1974. The aim was to obtained reliable long-term (certainly longer than a year) data on polarization changes in V–spectral region and the examine the possible connection of these changes with different activity phases of Be stars – principally with the shell–phase. In addition, having in mind the long–lasting photometryc observations of these stars at Ondrejov and Hvar, a search for correlations of polarization with the corresponding photometric, or perhaps spectral, characteristics was planned.

In this paper we present only some results of the polarimatric measurements of o And, 88 Her, and γ Cas during the period 1974 – 1984, and of κ Dra during the period 1979 – 1984. The further analysis of these results will be published subsequently.

OBSERVATIONS

Polarimetric observations at Belgrade Astronomical Observatory from 1974 till 1984 were carried out with

Table 1. Annual mean values of the polarization parameters

Star	Year	P_O(%)	θ_O(o)	P_S(%)	θ_S(o)	n
o And	1974	0.43	96	–	–	15
	1975	0.56	104	–	–	19
	1976	0.34	130	–	–	14
	1977	0.15	117	–	–	57
	1978	0.17	120	–	–	6
	1979	0.18	76	–	–	15
	1980	0.35	74	–	–	2
	1981	0.27	85	–	–	12
	1982	0.30	85	–	–	43
	1983	0.42	94	–	–	82
88 Her	1974	0.18	112	0.20	97	2
	1975	0.15	177	0.09	16	4
	1976	0.14	149	0.06	105	7
	1977	0.09	147	0.03	100	14
	1978	0.13	116	0.17	97	17
	1979	0.28	60	0.38	62	19
	1980	0.25	68	0.35	68	16
	1981	0.22	68	0.33	68	21
	1982	0.24	46	0.33	56	36
	1983	0.21	43	0.29	51	35
	1984	0.12	34	0.18	50	57
κ Dra	1979	0.28	17	0.30	5	5
	1980	0.18	37	0.14	16	18
	1981	0.23	29	0.21	14	23
	1982	0.50	30	0.45	24	3
	1983	0.50	28	0.47	22	48
	1984	0.65	27	0.62	22	12
γ Cas	1974	1.09	105	–	–	15
	1975	0.96	114	–	–	1
	1976	0.84	111	–	–	1
	1977	–	–	–	–	–
	1978	0.97	112	–	–	9
	1979	0.78	104	–	–	4
	1980	–	–	–	–	–
	9181	0.68	107	–	–	4
	1982	0.68	105	–	–	33
	1983	0.61	105	–	–	22
	1984	0.68	106	–	–	34

the 65–cm Zeiss refractor and the stellar polarimeter (Kubičela *et al.*, 1976) was modified in 1979 to enable one to obtain digital magnetic records suitable for further computer processing. The measurements were done in the V–spectral region. Integration of the raw polarimatric signal was done in 4–second intervals. The angular velocity of the analyzer was one turn per minute. In most cases under „one measurement" we understand up to 8 one–minute polarimetric sine–wave signals phase–averaged.

The measurements were always done when sky polarization and brightness were low. Observing a program of bright stars, that was easily achieved during moonless nights. In the case of a fainter star, 88 Her, the observations with a sky signal higher than an adopted value have been rejected in the course of the numerical reduction.

Several stars of zero–polarization and non–zero polarimetric standards were in the usual way observed in order to determine the telescope constants. The instrumental polarization was always very close to zero, what was proved measuring the polarization of zero–polarization stars.

Mean annual values of the polarization parameters have been prepared for the further analysis. A typical r.m.s. error of polarization percentage derived in that way, amounts to ± 0.03%. The mean annual values of the observed polarization percentage, P_O, and polarization postion angle, θ_O, together with the corresponding intrinsic quantities, P_s and θ_s, have been given in Table I comprising the data of all four stars. In Table I n is the number of measurements included in the tabulated mean values.

POLARIMETRIC CARACTERISTICS OF INDIVIDUAL STARS

o And (HD 217675)

This is a very famous star more or less intensively observed for 90 years. Various forms of variability have been noticed in this star, but not discussing all of them, we'll mention only the existence of photometric changes that, according to Harmanec (1984), have a period of about 8.5 years. We take this period only as a rough estimation. It would be more appropriate to state than there are some long–term variations that can not be established as periodic yet. What is improtant and has to be mentioned in the o And polarimetry is an alternation of shell–phases in cycles of variable length.

The results of polarimetric observation of o And at the Belgrade Astronomical Observatory in the period 1974 – 1983 indicate the presence of long–term variations. It is clearly seen in Figure 1a and 1b, were the observed polarization parameters, p_o and θ_o, are shown versus time. We discuss here the observed polarization parameters as the interstellar component and hence the intrinsic polarization of this star can not be determined with sufficient certainty. The most prominent feature is the low polarization percentage (less than 0.2%) during three years, 1977–1979. It seems that these three years are just those with no observed shell obsorption and, at the same time, this is the period of high brightness of the star.

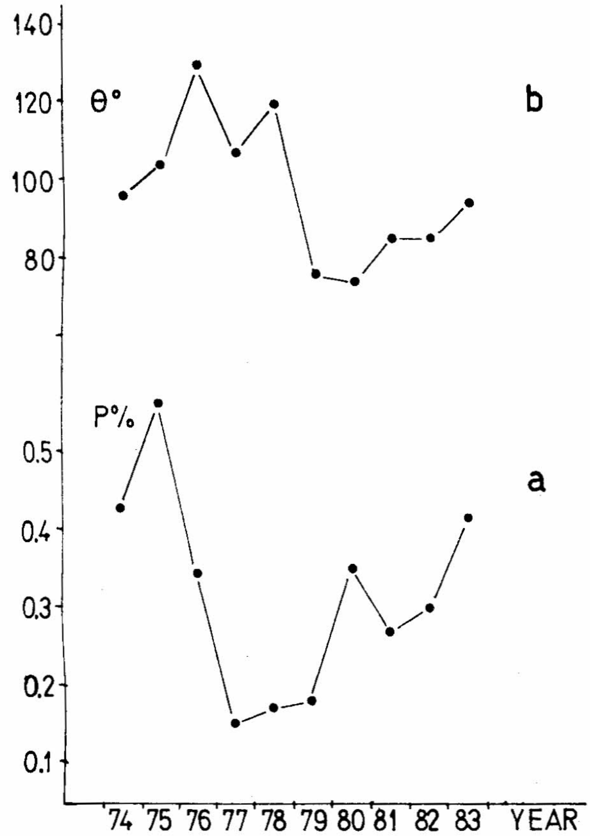

Fig. 1. Annual mean values of the observed polarization parameters of o And versus time: a) percentage of polarization P_o; b) position angle θ_o.

High degree of polarization was found in the period 1974 – 1976 when a shell phase was present. Perhaps something similar was going on in the period 1980 – 1983, but with a small polarization change and with a less conspicious shell phenomenon. Some peculiarities of the polarization of o And in the former time interval have been considered elsewhere (Arsenijević *et al.*, 1979, and Arsenijević, 1981). It can be guessed that the observed long–term polarization changes are connected with the observed shell absorption or emission. However, these questions will be quantitatively considered later on, using more data on the shell phases.

The changes of polarization position angle are large, but not so obviously connected to the photometric characteristics or to the shell obsorption. It is, however, seen that, after some considerable variations during 1975 – 1982 interval, both polarization parameters have almost the same values in 1974 and 1983. That might indicate the completion of a variability cycle – the fact that can be very important in the analysis of physical and dynamical properties of the star's envelope.

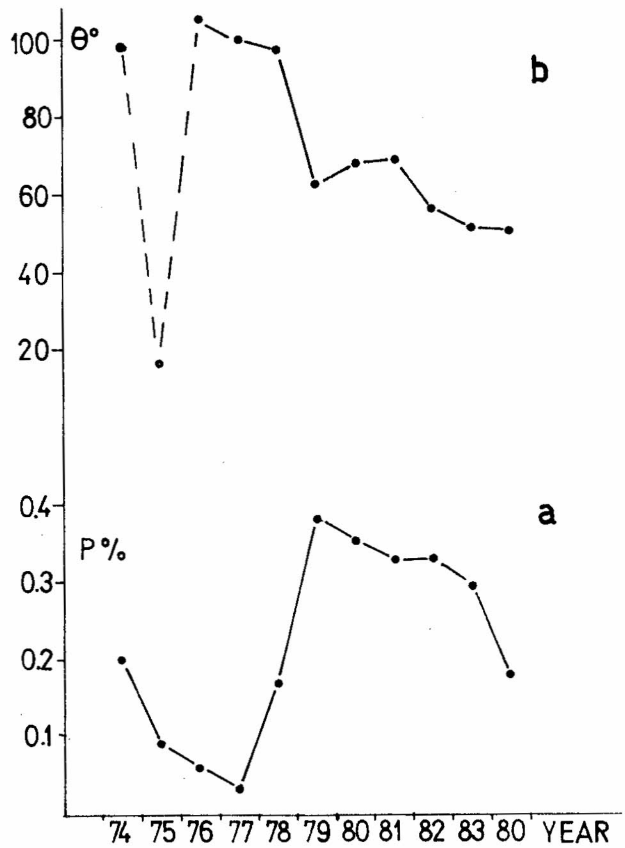

Fig. 2. Annual mean values of the intrinsic polarization parameters of 88 Her versus time: a) percentage of polarization P_s; b) position angle θ_s

88 Her (HD 162732)

The observations of optical polarization of this star were carried out in the period 1974 – 1984. The mean annual values of the observed polarization percentage and postion angle, p_o and θ_o, are shown in Table I. Due to some favorable circumstances, it was possible to estimate the interstellar polarization in the direction of 88 Her. The following preliminary values of interstellar polarization parameters have been accepted: p_i = 0,1% and θ_i = 158°. By eliminating the interstellar polarization out of the observed one, the intrinsic polarization parameters, p_s and θ_s, have been found. They are also shown in Table I and in Figure 2a and 2b as functions of time. It can be seen in Figure 2 that small but obvious variations of the polarization are present. Their amplitude is about 0.3%. It is, however, interesting to notice that all values below 0.1% (period 1975 – 1977) were measured when the star was bright and its spectrum was a quasi–normal B. The data concerning the light–variations have been taken from a diagram in Doazan *et al.*, (1982) paper, and they are exploited for a rough estimation of the phenomenon progress only. A strong shell phase, with decreasing the star brightness in the presence of a shell absorption, commenced abruptly in 1978 – when the degree of polarization increased too.

During the period of our polarimetric measurements of this star, some other kinds of observations in a wide wavelength range, 155 nm – 550 nm, were carried out. These cicumstances were anticipated when the selection of stars in our observing program was planned. They will enhance importance of the polarimetric data contributing to the explanation of the event that has taken place in the star (Doazan *et al.*, 1986).

κ Dra (HD 109387)

The star was observed in the period 1979 – 1984. The first results are shown in Table I where, similarly to the other stars, p_o and θ_o are the annual mean polarization percentage and position angle. The values of the intrinsic polarization parameters, p_s and θ_s, given in the corresponding columns, have been evaluated using the assumed interstellar polarization component: p_i = 0.12% and θ_i = 62°. The procedure of observing the interstellar polarization component is thoroughly described in the paper Arsenijević *et al.* (1986). The parameters of the intrinsic polarization are shown versus time in Figure 3a and 3b, where one can clearly notice continuous changes of the polarization percentage during the whole observed period. The minimum polarization percentage, of about 0.13%, has been found in 1980. Later on, the degree of polarization increases up to the value of about 0.62% in 1984. The polarization position angle changes from about 5° in 1979, to about 22° in 1983 and 1984. It seems that these changes are discontinuous exhibiting a leap of about 10° in the interval between the observations in 1979 and 1980 and another one, again of about 10°, during 1981 and 1982.

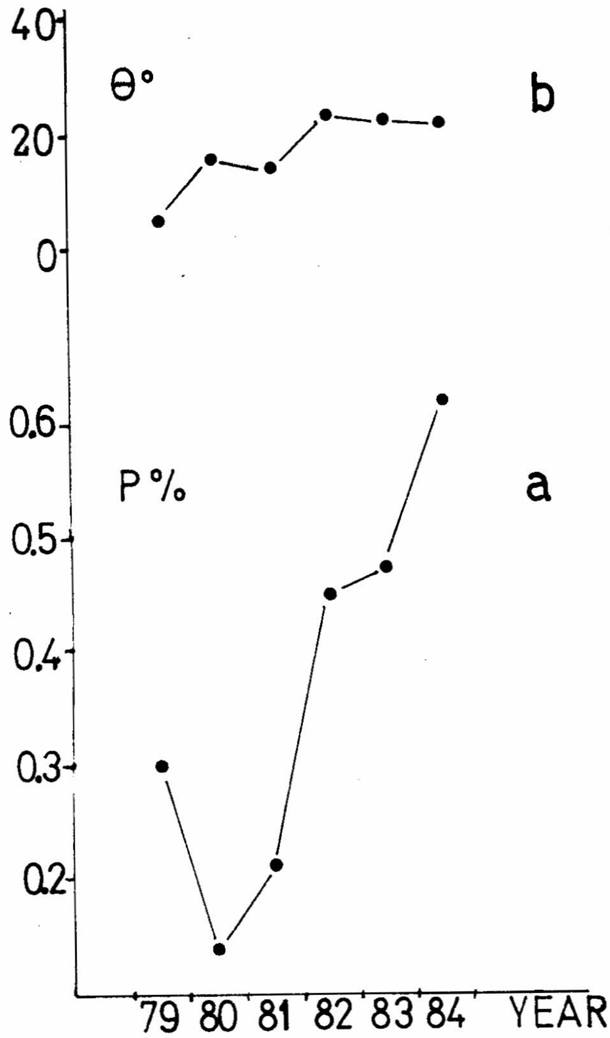

Fig. 3. Annual mean values of the intrinsic polarization parameters of κ Dra versus time: a) percentage of polarization P_s; b) position angle θ_s.

The highest changes of the both polarization parameters happened between 1979 and 1980 observing seasons.

κ Dra is a bright star and it is known as being photometrically and spectrally observed with the results not extensively published yet. It is expected that our polarimetric results will incite the other authors to publish their own findings. If the progress of long–term changes in κ Dra is similar to the variation in o And and 88 Her, a conclusion can be drawn from our polarimetric results that an active phase or formation of a non–spherical envelope has taken place in 1980 and has lasted up to 1984.

γ Cas (HD 5394)

This extremely interesting star is being observed in different ways for many years. An analysis of long–term changes in γ Cas has been given by Doazan *et al*, (1983). That was the first star for which the intrinsic polarization has been discovered. It is present in our observational program since 1974, and the results of its measurements up to 1984 are going to be discussed here. The annual mean values of the observed polarization parameters are given in Table I. The general changes of the polarization parameters during the whole observed interval can be seen in Figure 4a and 4b. A decreasing trend of polarization percentage from the value of about 1% in 1974 up to 0.6% in 1983 is clearly seen. The changes of polarization position angle are very small. Actually, the position angle in the period 1975 – 1978 is for about 11° larger than in the remaining observed interval – in 1974 and from 1979 till 1984.

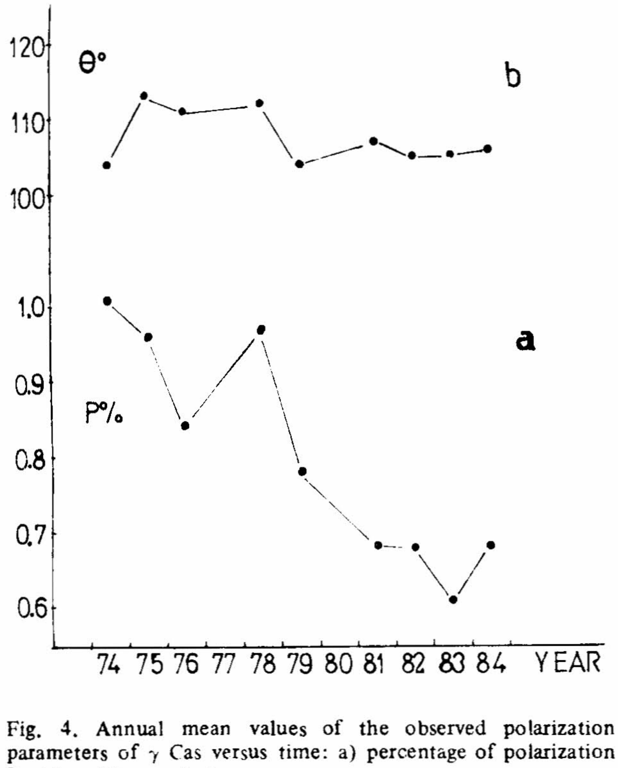

Fig. 4. Annual mean values of the observed polarization parameters of γ Cas versus time: a) percentage of polarization P_0; b) position angle θ_0.

The Poeckert's and Marlbrough's (1978) polarization measurements of γ Cas in the period 1973 – 1977 lead to the conclusion that decreasing of the degree of polarization has started before 1973 as a long–lasting (more than a decade) process, possibly correlated with the equivalent width of H_{alfa} emission.

Poeckert and Marlborough (1978) have also noticed in 1976 a deviation of polarization percentage from its general decreasing trend. It is seen in Figure 4a. In 1977, the same authors measured an opposite digression of the observed polarization and one could probably take that the polarization percentage found in 1978 – again deviating from the general trend – (Figure 4a) was a result of the disturbance occuring in 1977. It seems that these 1976 – 1978 changes can be understood as a disturbance of the long – term phenomenon. A similar case was with the polarization position angle, except that ,the disturbance started already in 1975. These short–term position angle changes seem to be unconnected to the equivalent widths of hydrogen emission lines.

There are different estimations of interstellar polarization component in the direction of γ Cas. Some authors declare it to be zero, while some others, measuring polarization of the field stars, find p_i = 0.66% and θ_i = 95° or, measuring the polarization in the spectral lines and in the continuum, p_i = 0.27% and θ_i = 96°. According to our estimation, the most realistic is the value obtained by measuring the polarization of the field stars. Untill the exact values of interstellar polarization parameters are obtained for γ Cas, we use only the observed ones. As the observed and interstellar polarization vectors are nearly colinear, the time–variation of the polarization percentage are in both cases the same, while the position angle remains approximetaly constant.

Accepting the highest value of the interstellar polarization percentage, p_i = 0.66%, one finds the intrinsic polarization of γ Cas in 1983 to be very close to zero. Hence, according to the behaviour of the other stars, one would assume that 1983 was a year of minimal activity in γ Cas, and that some new changes (Be or shell phase) could be expected.

INSTEAD OF A CONCLUSION

The results of Belgrade Astronomical Observatory research program on long–term polarization changes in V–spectral region in for selected Be stars since 1974 have been briefly presented here. The basic assumption of our 1973–program on the existence of long–term variations of optical polarization in these stars was fruitful. The first results already indicate some changes of both polarization parameters and their anticorrelation with the star brightness. However, they might be in correlation with the shell phases of the corresponding star and even with the intensity of its hydrogen emission lines.

Similar measurments of other program stars are in preparation. Besides, a further study of the noticed polarization changes and a search for the best parameters that would reveal and enable the correlation of polarimetric and photometric or spectral parameters to be obtained are in progress. A contribution of theorists to this task is necessary. We expect that our young colleagues will more intensively devote themselves to this research field.

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REFERENCES

Arsenijević, J. : 1981, *Bull. Obs. Astron. Beograd,* **131**, 13.

Arsenijević, J., Vince, I., Kubičela, A.: 1979, *Publ. Astron. Obs. Beograd,* **26**, 125.

Arsenijević, J., Jankov, S., Djurašević, G., Vince, I.: 1986, *Bull. Obs. Astron. Beograd,* **136**, 6.

Barylak, M., Doazan, V.: 1986, *Astron. Astrophys.,* **159**, 65.

Coyne, G.V.: 1976, IAU Symp. 70, *Be and Shell Stars,* ed. A. Slettebak, D.Reidel, Dordrecht, 233.

Coyne, G.V. and McLean, I.S.: 1982, *IAU Symp. 98, Be Stars,* eds. M.Jaschek and H–G.Groth, D.Reidel, Dordrecht, 77.

Doazan,V., Harmanec, P., Koubsky, P., Krpata, J., Zdarsky, F.: 1982, *Astron. Astrophys.* **115**, 138.

Doazan, V. Franco, M., Rusconi, L., Sedmak, G., Stalio, R.: 1983, *Astron. Astrophys.,* **128**, 171.

Doazan, V., Thomas, R.N., Barylak, M.: 1986, *Astron. Astrophys,* **159**, 75.

Harmanec, P.: 1984, *IBVS,* 2506.

Kubičela, A., Arsenijević, J., Vince, I.: 1976, *Publ. Dept. Astron. Univ. Beograd,* **6**, 25.

Poeckert, R. and Marlborough, J.M.: 1978, *Astrophys. J.,* **220**, 940.

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Original scientific paper

MODIFIED SEMIEMPIRICAL STARK WIDTHS AND SHIFTS OF Ar II LINES

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(Received: December 28, 1988)

SUMMARY: The modified semiempirical approach (Dimitrijević and Konjević, 1980; Dimitrijević and Kršljanin, 1986) was used for calculation of Stark widths and shifts for ArII lines. Comparison has been made with semiclassical results of Jones et al., (1971) as well as with critically selected experimental data. Since the good average accuracy of the present results has been achieved, tabulation of modified semiempirical Stark broadening parameters for 50 ArII multiplets is also given.

1. INTRODUCTION

In many astrophysical problems (e.g. eveluation and modeling of the stellar atmospheric physical properties, abundance determinations) Stark broadening data for a large number of transitions for many atoms are needed. Stark broadening is the dominant pressure broadening mechanism in atmospheres of O, B and A type stars, and hot white dwarfs. Even in solar like atmospheres Stark broadening may compete with other broadening mechanisms in line wings or for higher spectral series members (Vince *et al.*, 1985a). Moreover, Stark shift is one of the important causes of solar and stellar spectral line asymmetries (Vince *et al.*, 1985b; Vince, 1986), therefore it can serve for more precise determination of other causes of asymmetry, e.g. granular motion (Vince and Dimitrijević, 1989; Kršljanin, 1989b). Knowledge of Stark shifts can make possible accurate determination of the gravitational red shifts in spectra of white dwarfs (e.g. Wiese and Kelleher, 1971; Grabowski *et al.*, 1986; Kršljanin, 1989a).

Quantum mechanical or semiclassical theories are able to provide data of high accuracy but they require considerable computations and knowledge of numerous atomic data. For large scale calculations in astrophysics and rough estimates for experimental needs, simple approaches with good average accuracy (e.g. Griem, 1968; Griem, 1974; Hey and Bryan, 1977; Dimitrijević and Konjević, 1980; 1981; 1986; 1987; Dimitrijević and Kršljanin, 1986; Seaton, 1987) are more appropriate.

The modified semiempirical approach (Dimitrijević and Konjević, 1980; 1981a; 1987; Dimitrijević and Kršljanin, 1986) is tested several times (Dimitrijević and Konjević, 1981a,b,c; Dimitrijević, 1982a,c; 1983; 1988b,c; Dimitrijević and Kršljanin, 1986; Konjević *et al.*, 1984; Kršljanin and Dimitrijević, 1989; Lanz *et al.*, 1988; El–Farra and Hughes, 1983; Ackerman *et al.*, 1985) and on the average gives a satisfactory agreement with experiments. Recently, the modified semiempirical approach was applied to the Stark broadening of spectral lines from 127 astrophysicaly important multiplets of doubly and triply charged ions (Dimitrijević, 1988a), and the results are verified via comparison with some other approximate approaches (Dimitrijević, 1988c). This approach achieved reliable results also in the case of lines of heavy ions such as TiII and MnII in the solar spectrum (Dimitrijević, 1982a) and FeII in the spectrum of Am 15 Vulpeculae (Dimitrijević, 1988b).

Kršljanin and Dimitrijević (1989) showed that modified semiempirical approach gives good average accuracy even in the case of Stark shifts for such a complex ion as ArII. The aim of this paper is to examine reliability of modified semiempirical Stark widths and shifts of ArII lines via comparison with representative experimental and more sophysticated theoretical data and to provide extensive Stark broadening data set, suitable for fast estimates in astrophysics and laboratory plasma spectroscopy.

Absorption lines of ArII are observed in spectra of B and A type stars. The cosmic abundance of Ar is not very well determined (e.g. Grevesse, 1984). Argon is one of the important costituents of the Earth's atmosphere, and is frequently used in laboratory plasmas.

2. THEORY

According to the modified semiempirical approach (Dimitrijević and Konjević, 1980, 1987; Dimitrijević and Kršljanin, 1986), the half–halfwidth w and the shift d of an ion spectral line broadened by Stark effect are given by the following expression

$$w + id = N \frac{4\pi}{3} \frac{\hbar^2}{m^2} \left(\frac{2m}{\pi kT}\right)^{1/2} \frac{\pi}{\sqrt{3}} \sum_{j=i,f}$$

$$\{\mathbf{R}^2_{k,k+1} [g(x_{k,k+1}) + i\epsilon_j g_{sh}(x_{k,k+1})] + \mathbf{R}^2_{k,k-1} \cdot$$

$$\cdot [g(x_{k,k-1}) - i\epsilon_j g_{sh}(x_{k,k-1})]\} + \sum_{j'} (\mathbf{R}^2_{jj'})_{\Delta n \neq 0} [g(x_j) +$$

$$+ i\epsilon_j g_{sh}(x_j)] - 2i\epsilon_j [\sum_{\Delta E_{jj'} < 0} (\mathbf{R}^2_{jj'})_{\Delta n \neq 0} g_{sh}(x_{jj'})] \quad (1)$$

In this expression $\mathbf{R}^2_{j',j}$ (in units of the Bohr radius a_0^2) is the square of the coordinate operator matrix element summed over all components of the operator and the magnetic substates of total angular momentum J', and averaged over the magnetic substates of J.

$$\sum_{j'} (\mathbf{R}^2_{jj'})_{\Delta n \neq 0} = \left(\frac{3n_j^*}{2Z}\right)^2 \frac{1}{9} (n_j^{*2} + 3\ell_j^2 + 3\ell_j + 11)$$
$$\mathbf{R}^2_{jj'} = \left(\frac{3n_j^{*2}}{2Z}\right) \frac{\ell_>}{2\ell + 1} (n_\ell^{*2} - \ell_>^2) \phi^2 (n^*_{\ell-1}, n^*_\ell, \ell) \quad (2)$$

The cases where the one– electron model (i.e. only one energy level for each $n\ell$ electron) assumed in equation (2) is not satisfied, are analysed in detail by Dimitrijević (1982b). e.g. for a multiplet as a whole, $\mathbf{R}^2_{j,j}$ should be multiplied by $R^2_{\mathrm{mult}} (2\ell + 1)/(2L + 1)$ The multiplet factor R^2_{mult} can be found in tables of Shore and Menzel (1965). The parameter $\epsilon_j = +1$ if $j = i$, and -1 if $j = f$, $k = \ell_j$ (the orbital quantum number of the valence electron, i and f denote the initial and final energy states, $x_{jj'} = 3kT/2|\Delta E_{jj'}|$, $x_j = 3kTn_j^{*3}/4Z^2E_H$, E_H is the hydrogen ionization energy, E_{ion} is the appropriate spectral series limit (In case that the term in question belongs to a series converging on an excited state of the resulting ion, the excitation energy of this state is added to the usual ionization energy). The resuidual ionic charge is denoted as Z, $\Delta E_{j'j} = E_{j'} - E_j$, $\ell = \max(\ell_j', \ell_j)$, N is electron density, $n_j^* = [E_H Z^2/(E_{\mathrm{ion}} - E_j)]^{1/2}$ the effective principal quantum number, and ϕ^2 is the Bates–Damgaard (1949) factor, tabulated e.g. in Oertel and Shomo's (1968) paper.

All Gaunt factors g, g, g_{sh} and g_{sh} are given in Dimitrijević and Kršljanin (1986). At high temperatures, say $3kT/2\Delta E > 50$, all Gaunt factors in equation (1) may be calculated in accordance with the GBKO high temperature limit (Griem *et al.*, 1962).

Equation (1) is obtained assuming the LS coupling approximation, separating the transitions with $\Delta n = 0$ and $\Delta n \neq 0$ and supposing that the nearest perturbing level in the $\Delta n \neq 0$ group may be obtained in the hydrogenic approximation as:

$$|\Delta E_{n,n+1}| \approx 2Z^2 E_H / n^{*3}$$

In the cases when perturbing levels exist which strongly violate the assumed approximations, i.e. if there are levels with $|\Delta E_{j'j}| \ll |\Delta E_{n,n+1}|$, a correction of equation (1) may be done by summing equation (3) and equation (1). Here, m' is the number of such perturbing levels and $\epsilon_k = +1$ if $k = i$ and -1 if $k = f$.

$$w_c + id_c = N \frac{4\pi}{3} \frac{\hbar^2}{m^2} \left(\frac{2m}{\pi kT}\right)^{1/2} \frac{\pi}{\sqrt{3}} \cdot$$
$$\cdot \sum_{m'} \mathbf{R}^2_{j'j} [g(x_{j'j}) - g(x_{n_i, n_i+1}) \pm$$
$$\pm i\epsilon_k (g_{sh}(x_{j'j}) \mp g_{sh}(x_{n_i, n_i+1}))] \quad (3)$$

3. RESULTS

On the basis of critical reviews of experimental data (Konjević and Wiese, 1976; Konjević *et al.*, 1984) and from inspection of current literature, one can list 20 references with reliable experimental data on ArII Stark widths and shifts, covering about 50 ArII multiplets. For all these multiplets we calculated modified semiempirical widths and shifts. Data on relevant atomic energy levels were taken from Bashkin and Stoner (1975). Our results are presented in Table 1. Several representative cases are shown in figures 1–9, together with epxerimental data and with semiclassical results of Jones *et al.*, (1971).

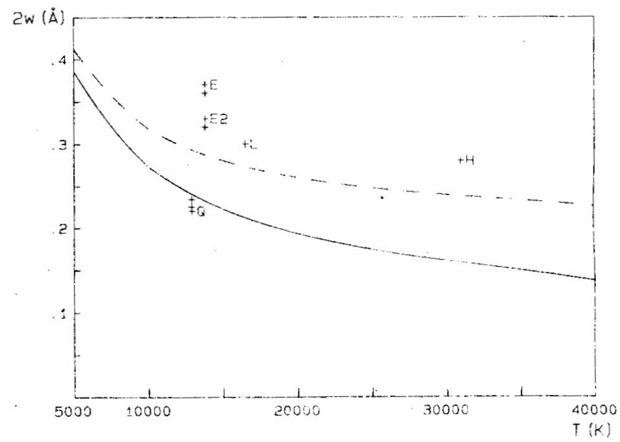

Fig. 1. Stark widths for ArII $3d^4D - 4p^4p^0$ multiplet. Calculations: MSE–modified semiempirical; SC–semiclassical, Jones et al. (1971). Experimental points: A–Popenoe and Shumaker (1965), A'–Popenoe and Shumaker (1965) corrected according to Nick and Helbig (1986), B–Jalufka et al. (1966), C–Murakawa (1966), D–Roberts (1966), E–Chapelle et al. (1967, 1968a), F–Blandin et al. (1968), G–Chapelle et al. (1968b), H–Roberts (1968), J–Powel (1966), K–Konjević et al. (1970), L–Labat et al. (1974), M–Morris and Morris (1970), N–Klein (1973), O–Baker and Burges (1979), P–Vaessen et al. (1985), Q–Nick and Helbig (1986), S–Vitel and Skowronek (1987), X–Behringer and Thoma (1978), Y–Pittman and Konjević (1986), Numerals near the experimental points denote numbers of line widths (shifts) with the same measured values.

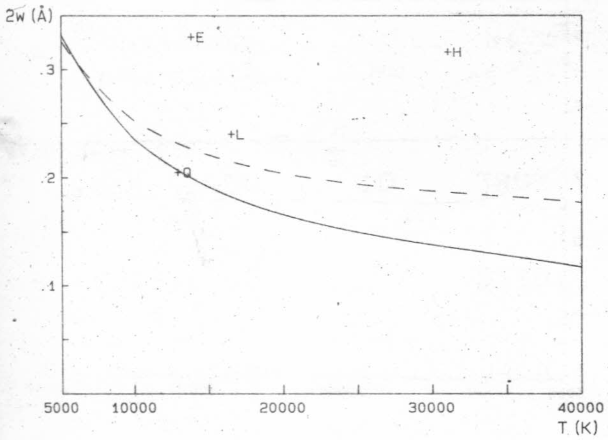

Fig. 2. Stark widths for ArII $3d^4D-4p^4D^0$ multiplet. Notation is the same as in Fig. 1.

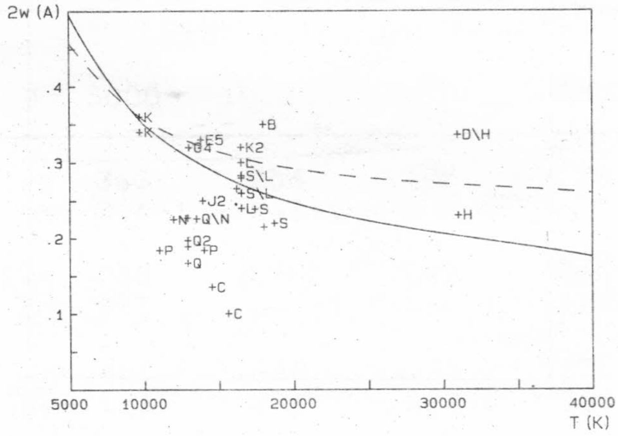

Fig. 5. Stark widths for ArII $4s^4P-4p^4D^0$ multiplet. Notation is the same as in Fig. 1.

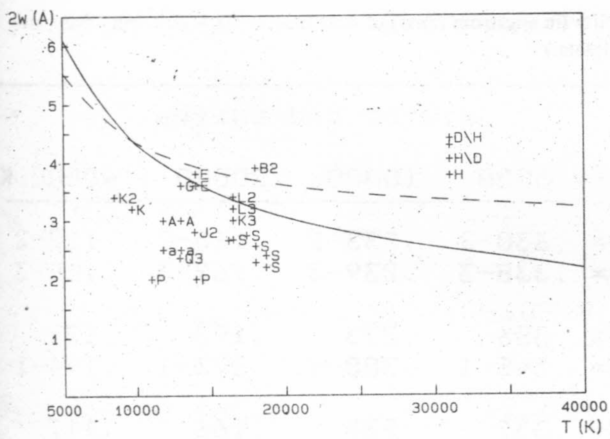

Fig. 3. Stark widths for ArII $4s^4P-4p^4P^0$ multiplet. Notation is the same as in Fig. 1.

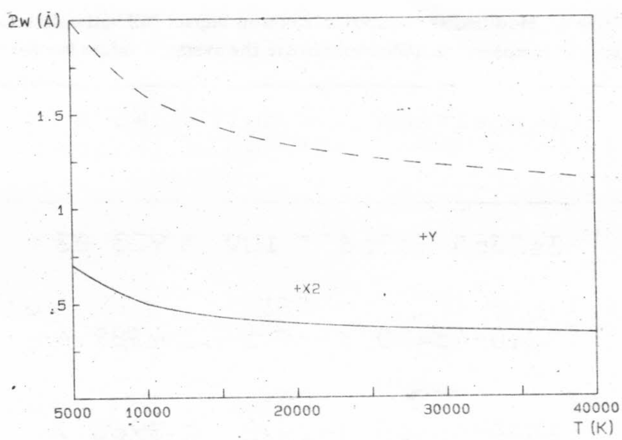

Fig. 6. Stark widths for ArII $4p^2P^0-4d^2P$ multiplet. Notation is the same as in Fig. 1.

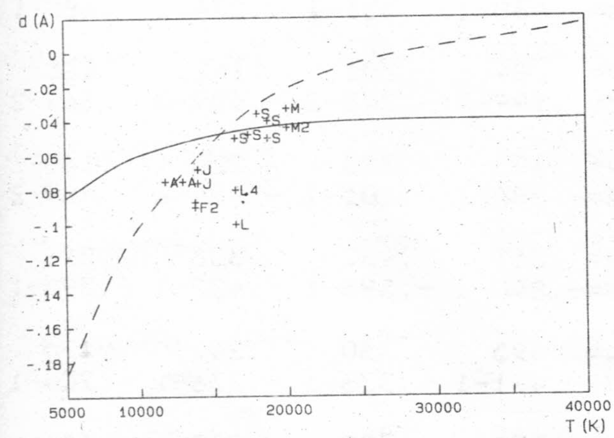

Fig. 4. Stark shifts for ArII $4s^4P-4p^4P^0$ multiplet. Notation is the same as in Fig. 1.

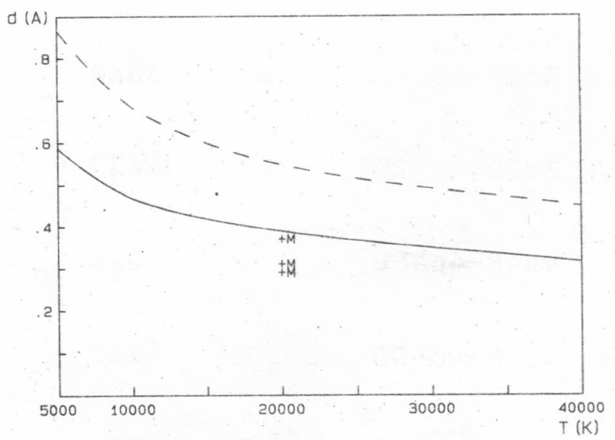

Fig. 7. Stark shifts for ArII $4p^2P^0-4d^2P$ multiplet. Notation is the same as in Fig. 1.

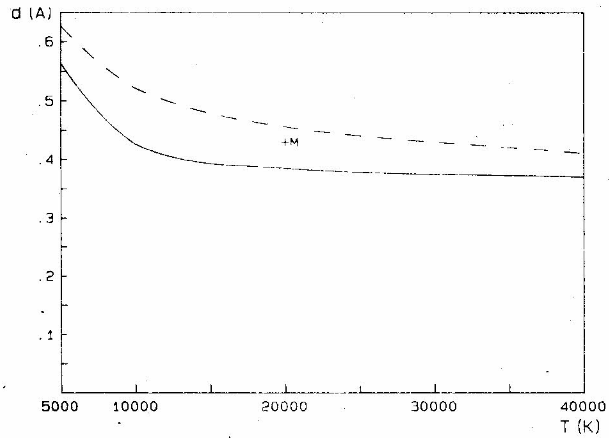

Fig. 8. Stark shifts for ArII $4p^2D^o$–$5s^2P$ multiplet. Notation is the same as in Fig. 1.

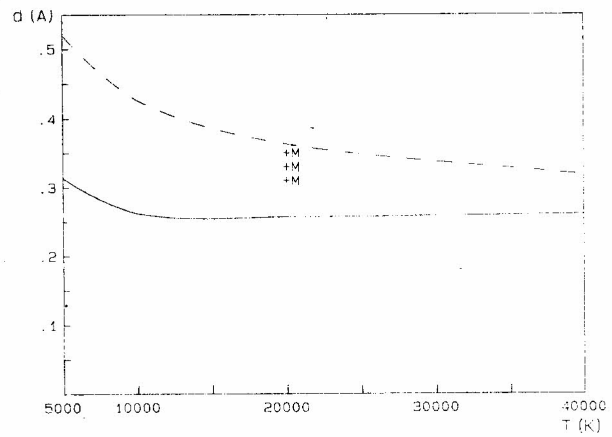

Fig. 9. Stark shifts for ArII $4p^4S^o$–$4d^4P$ multiplet. Notation is the same as in Fig. 1.

Table 1. Modified semiempirical electron impact full halfwidths and shifts (in angstrom units) of ArII lines at Ne = 10^{17} cm^{-3} as functions of temperature. (Wavelengths are the averaged values for the multiplets.)

	Transition	Mult. No.	Wave-length	Widths and shifts				
				T=	5000	10000	20000	40000 K
1.	3s23p5-3s3p6	1UV	923.83	2w=	.330-2	.233-2	.165-2	.117-2
				d=	.338-3	.239-3	.169-3	.119-3
2.	3d4D-4p4PO	1	4389.4	2w=	.386	.273	.193	.137
				d=	.548-1	.388-1	.273-1	.194-1
3.	3d4D-4p4DO	2	3968.7	2w=	.332	.235	.166	.117
				d=	.610-1	.434-1	.307-1	.235-1
4.	3d4D-4p4SO	5	3499.7	2w=	.260	.184	.130	.919-1
				d=	.468-1	.331-1	.234-1	.189-1
5.	3d2P-4p'2DO	30	3568.1	2w=	.284	.201	.142	.100
				d=	.199-2	-.340-2	-.409-3	-.149-2
6.	3d2D-4p'2DO	39	4437.9	2w=	.453	.320	.226	.160
				d=	-.380-2	-.101-1	-.984-2	-.489-2
7.	4s4P-4p4PO	6	4876.4	2w=	.611	.432	.305	.216
				d=	-.840-1	-.595-1	-.422-1	-.393-1
8.	4s4P-4p4DO	7	4362.6	2w=	.495	.350	.247	.175
				d=	-.471-1	-.333-1	-.236-1	-.204-1
9.	4s4P-4p2DO	8	4124.4	2w=	.436	.309	.218	.154
				d=	-.727-1	-.514-1	-.365-1	-.313-1

Table 1. (continued)

Transition	Mult. No.	Wave-length	Widths and shifts T= 5000	10000	20000	40000 K
10. 4s4P-4p4S0	10	3802.4	2w= .363	.256	.181	.128
			d=-.344-1	-.243-1	-.172-1	-.124-1
11. 4s2P-4p4D0	13	5238.3	2w= .755	.534	.377	.267
			d=-.915-1	-.647-1	-.460-1	-.415-1
12. 4s2P-4p2D0	14	4898.6	2w= .651	.460	.325	.231
			d=-.123	-.871-1	-.622-1	-.553-1
13. 4s2P-4p2P0	15	4655.5	2w= .563	.398	.281	.199
			d=-.151	-.107	-.756-1	-.492-1
14. 4s2P-4p2S0	17	4443.1	2w= .511	.362	.256	.181
			d=-.127	-.896-1	-.637-1	-.522-1
15. 4s2P-4p'2P0	19	2955.7	2w= .237	.167	.118	.837-1
			d=-.520-2	.393-2	.928-2	.766-2
16. 4s2P-4p'2D0	16UV	2674.1	2w= .197	.139	.983-1	.696-1
			d=-.462-1	-.354-1	-.260-1	-.208-1
17. 4s'2D-4p'2F0	31	4603.8	2w= .541	.382	.270	.191
			d=-.731-1	-.506-1	-.350-1	-.312-1
18. 4s'2D-4p'2P0	32	4226.4	2w= .453	.320	.227	.160
			d= .505-2	.191-1	.270-1	.241-1
19. 4s'2D-4p'2D0	33	4061.6	2w= .420	.297	.210	.149
			d=-.115	-.922-1	-.745-1	-.561-1
20. 4p4P0-4d4D	44	3500.3	2w= .566	.400	.283	.207
			d= .209	.156	.140	.149
21. 4p4P0-4d4P	47	3182.3	2w= .536	.379	.271	.207
			d= .227	.187	.180	.180
22. 4p4D0-4d4D	54	3823.5	2w= .706	.499	.353	.258
			d= .225	.170	.156	.168
23. 4p4D0-4d4F	56	3576.3	2w= .650	.460	.326	.246
			d= .255	.199	.191	.198
24. 4p4D0-4d4P	57	3447.2	2w= .627	.443	.316	.242
			d= .275	.226	.216	.214

Table 1. (continued)

Transition	Mult. No.	Wave-length		Widths and shifts T= 5000	10000	20000	40000
25. 4p4DO-4d2F	59	3392.7	2w=	.642	.454	.325	.250
			d=	.247	.203	.203	.206
26. 4p2DO-4d4D	65	4027.4	2w=	.760	.537	.380	.278
			d=	.288	.216	.192	.202
27. 4p2DO-4d2D		2974.2	2w=	.655	.510	.432	.392
			d=	.515-1	.292-1	.112-1	.886-1
28. 4p2DO-4d2F	70	3552.3	2w=	.698	.494	.354	.273
			d=	.293	.238	.233	.235
29. 4p2DO-4d2P	71	3187.0	2w=	.651	.461	.363	.309
			d=	.554	.441	.366	.296
30. 4p2PO-4d2P	83	3299.1	2w=	.706	.500	.393	.334
			d=	.587	.467	.389	.314
31. 4p4SO-4d4P	90	3901.4	2w=	.850	.601	.429	.324
			d=	.314	.262	.257	.261
32. 4p2SO-4d2P	96	3414.8	2w=	.765	.542	.426	.361
			d=	.620	.495	.412	.333
33. 4p2PO-4d'2P		2535.7	2w=	.332	.235	.167	.126
			d=	.140	.111	.105	.106
34. 4p'2FO-4d'2D	107	3409.9	2w=	.590	.418	.297	.226
			d=	.244	.194	.186	.190
35. 4p'2FO-4d'2F	109	3366.4	2w=	.583	.412	.295	.225
			d=	.249	.200	.194	.195
36. 4p'2PO-4d'2D	116	3651.5	2w=	.699	.494	.352	.267
			d=	.217	.167	.165	.176
37. 4p'2DO-4d'2D	129	3784.2	2w=	.763	.540	.384	.291
			d=	.314	.245	.243	.242
38. 4p'2DO-4d'2F	131	3730.6	2w=	.751	.531	.379	.288
			d=	.318	.261	.251	.248
39. 4p4PO-5s4P	42	3735.1	2w=	.997	.705	.538	.483
			d=	.425	.323	.298	.284

Table 1. (continued)

Transition	Mult. No.	Wave-length		Widths and shifts T= 5000	10000	20000	40000
40. 4p4PO-5s2P	43	3557.7	2w=	.932	.659	.501	.449
			d=	.415	.314	.285	.274
41. 4p4DO-5s4P	.52	4105.4	2w=	1.22	.864	.658	.590
			d=	.496	.378	.351	.336
42. 4p2DO-5s2P	64	4103.6	2w=	1.25	.884	.671	.601
			d=	.564	.426	.385	.370
43. 4p2PO-5s2P	77	4291.3	2w=	1.35	.957	.727	.653
			d=	.617	.465	.415	.395
44. 4p2PO-5s'2D	17UV	2793.1	2w=	.548	.387	.293	.262
			d=	.252	.189	.169	.162
45. 4p'2FO-5s'2D	105	3938.6	2w=	1.09	.774	.585	.522
			d=	.458	.346	.314	.304
46. 3d'2F-(P)4f(4)O		3166	2w=	.515	.374	.277	.234
			d=	.118	.773-1	.701-1	.895-1
47. 3d'2D-(D)4f(3)O		2724	2w=	.404	.286	.203	.169
			d=	.846-1	.568-1	.523-1	.653-1
48. 3d'2D-(D)4f(2)O		2748	2w=	.394	.278	.197	.162
			d=	.892-1	.595-1	.537-1	.656-1
49. 3d'2P-(D)4f(2)O		2909	2w=	.444	.314	.223	.183
			d=	.122	.953-1	.887-1	.969-1
50. 3d'2P-(D)4f(1)O		2937	2w=	.435	.307	.218	.177
			d=	.127	.991-1	.907-1	.978-1

Results of Kršljanin and Dimitrijević (1989) and of the present work show that the average agreement of modified semiempirical results with experiments for both widths and shifts is approximately within 50%. This is a fairly good result because of the large scattering of the experimental data, and particularly in the light of the fact that our computations cover a number of forbidden multiplets and multiplets where j ℓ coupling perturbing levels play an important role (for more details see Kršljanin and Dimitrijević, 1989).

One can conclude on the basis of Kršljanin and Dimitrijević (1989) and of the results presented here, that modified semiempirical approach might be treated as usefull method for simple and fast estimation of Stark broadening parameters with good average accuracy, even in the case of complex atoms,

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REFERENCES

Ackermann, U., Finken, K.H. and Musielok, J.: 1985, *Phys. Rev.* **A31**, 2597.

Baker, E.A.M. and Burges, D.D.: 1979, *J.Phys.* **B12**, 2097.

Bashkin, S. and Stoner Jr., J.O.: 1975, Atomic Energy Levels and Grotrian Diagrams, Vol. II, North Holland, Amsterdam.

Bates, D.R. and Damgaard, A.: 1949, *Phil. Trans. R. Soc. London*, Ser. **A242**, 101.

Behringer, K. and Thoma, R.: 1978, *JQSRT* **20**, 615.

Blandin, J., Sahal–Brechot, S., Chapelle, J. and Sy, A.: 1968, *Phys, Lett*, **26A**, 487.

Chapelle, J., Sy, A., Cabannes, F. and Blandin, J.: 1967, *C.R.H. Acad. Sci.* **B264**, 853.

Chapelle, J., Sy, A., Cabannes, F. and Blandin, J.: 1968a, *JQSRT* 8, 1201.

Chapelle, J., Sy, A., Cabannes, F. and Blandin, J.: 1968b, *C.R.H. Acad, Sci.* **B266**, 1513.

Dimitrijević, M.S.: 1982a, in Sun and Planetary System, Eds. W. Fricke, G. Teleki, D. Reidel, Dordrecht, p. 101.

Dimitrijević, M.S.: 1982b, *Astron. Astrophys*, **112**, 251.

Dimitrijević, M.S.: 1982c, in The Physics of Ionized Gases (Inv. Lectures of SPIG–82), Ed. G. Pichler, Inst. Phys. Univ. Zagreb, p. 397.

Dimitrijević, M.S.: 1983, *Astron. Astrophys.*, **127**, 68.

Dimitrijević, M.S.: 1988a, *Astron. Astrophys. Suppl.* **76**, 53

Dimitrijević, M.S.: 1988b, in Physic of Formation of FeII Lines Outside LTE, Eds. R. Viotti, A. Vittone, M. Friedjung, D.Reidel, Dordrecht, p. 211.

Dimitrijević, M.S.: 1988c, *Bull. Obs. Astron. Belgrade*, **139**, 31.

Dimitrijević, M.S. and Konjević, N.: 1980, *JQSRT* **24**, 451.

Dimitrijević, M.S. and Konjević, N.: 1981a, in Spectral Line Shapes, Ed. B.Wende, W de Gruyter, Berlin, New York, p. 211.

Dimitrijević, M.S. and Konjević, N.: 1981b, *Astron. Astrophys.*, **102**, 93.

Dimitrijević, M.S. and Konjević, N.: 1981c, *JQSRT* **25**, 387.

Dimitrijević, M.S. and Konjević, N.: 1986, *Astron. Astrophys*, **163**, 297.

Dimitrijević, M.S. and Konjević, N.: 1987, *Astron. Astrophys*, **172**, 345.

Dimitrijević, M.S. and Kršljanin, V.: 1986, *Astron. Astrophys*, **165**, 269.

El–Farra, M.A. and Hughes, T.P.: 1983, *JQSRT* **30**, 335.

Grevesse, N.: 1984, *Physica Scripta* **T8**, 49.

Griem, H.R.: 1968, *Phys, Rev.* **165**, 258.

Griem, H.R.: 1974, Spectral Line Broadening by Plasmas, Academic Press, New York

Griem, H.R., Baranger, M., Kolb, A.C. and Oertel, G.K.: 1962, *Phys. Rev.* **125**, 177.

Hey, J.D. and Bryan, R.J : 1977, *JQSRT* **17**, 221

Jalufka, N.W., Oertel, G.K. and Ofelt, G.S.: 1966, *Phys. Rev. Lett*, **16**, 1073.

Jones, W.W., Benett, S.M. and Griem, H.R.: 1971, Tech. Rep. No. 71–128, Univ. Maryland

Klein, L.: 1973, *JQSRT* **13**, 567.

Konjević, N. and Wiese, W.L.: 1976, *J. Phys. Chem. Ref., Data* 5, 259.

Konjević, N., Dimitrijević, M.S. and Wiese, W.L.: 1984, *J. Phys. Chem. Ref. Data* **13**, 649.

Konjević, N., Labat, J., Ćirković, Lj. and Purić, J.: 1970, *Z. Phys*, **235**, 35.

Kršljanin, V.: 1989a, Ion Lines Stark Shifts in Spectra of Hot Stars, Publ. Obs. Astron. Belgrade No. 37.

Kršljanin, V.: 1989b, in Solar and Stellar Granulation, Eds. R. Rutten, G. Severino, Kluwer, Dordrecht, p. 91

Kršljanin, V. and Dimitrijević, M.S.: 1989, *Z. Physik D.* (submitted)

Labat, J., Djeniže, S., Ćirković, Lj. and Purić, J.: 1974, *J. Phys.* **B7**, 1174.

Lanz, T., Dimitrijević, M.S. and Artru, M.C.: 1988, *Astron. Astrophys*, **192**, 249.

Morris, J.C. and Morris, R.V.: 1970, Aerospace Research Laboratories Report No. ARL 70–0038

Murakawa, K., Yamamoto, M. and Hashimoto, S.: 1966, in Proceedings of VII ICPIG, Vol. II, Građevinska knjiga, Belgrade, p. 594.

Nick, K.–P. and Helbig, V.: 1986, *Phisica Scripta* **33**, 55.

Oertel, G.K. and Shomo, L.P.: 1968, *Astrophys. J. Suppl.* **16**, 175.

Pittman, T.L and Konjević, N.: 1986 *JQSRT* **35**, 247.

Popenoe, C.H. and Shumaker Jr., J.B.: 1965, *J. Res. Nat. Bur. Stand., Sect.* **A69**, 495.

Powel, W.R.: 1966, disertation, Johns Hopkins University

Roberts, D.E.: 1966, *Phys. Lett.* **22**, 417.

Roberts, D.E.: 1968, *J.Phys.* **B1**, 53.

Seaton, M.J.: 1987, *J. Phys*, **B20**, 6431.

Shore, B.W. and Menzel, D.H.: 1965, *Astrophys. J. Suppl.* **12**, 187.

Vaesen, P.H.M., van Engelen, J.M. L. and Bleize, J.J.: *JQSRT* 33, 51.

Vince, I.: 1986, disertation, Univ. Belgrade

Vince, I. and Dimitrijević, M.S.: 1989, in Solar and Stellar Granulation, Eds. R. Rutten and G. Severino, Kluwer, Dordrecht, p. 93

Vince, I., Dimitrijević .M.S. and Kršljanin, V.: 1985a, in Spectral Line Shapes III, Ed. F. Rostas, W. de Gruyter, Berlin, New York, p. 649.

Vince, I., Dimitrijević, M.S. and Kršljanin, V.: 1985b, in Progress in Stellar Spectral Line Formation Theory, Eds. J. E. Beckman, L. Crivellari, D. Reidel, Dordrecht, p. 373.

Vitel, Y. and Skowronek, M.: 1987, *J. Phys.* **B20**, 6477.

Bull. Obs. Astron. Belgrade N° 140 (1989), 15–29.

UDC 523.83
Original scientific paper

STATISTICAL STUDY OF KINEMATICS OF TRIPLE STARS FROM THE PROGRAM OF THE LENINGRAD STATE UNIVERSITY ASTRONOMICAL OBSERVATORY

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SUMMARY: The relative positions and proper motions of components of the 113 triple stars of the Leningrad State University Astronomical Observatory program at the epoch 1950.0 were determined with the least–squares method on the basis of the Ch. Worley's WDS catalogue data. The results are obtained for 92 close (AB) pairs and 82 wide (AC) pairs. Some statistical investigation of results is carried out. For the pairs AC the statistically meaningful tendency to prevalence of tangential motion components of proper motion with respect to radial ones is revealed. The positive correlation between the module of tangential motion and angular separation between components is also observed for these pairs.

1. INTRODUCTION

Examination of physical connection among components of multiple stars, revealing their dynamical states and subsequent study of a dynamical evolution are the principal purposes of investigation of the objects (Anosova, J.P., 1984, 1985, 1986a, 1986b), (Anosova, J.P., Orlov, V.V., 1985). Precise astrometrical and astrophysical observations are needed in order to obtain some reliable results. The obtaining of a complex of such observations by means of ground instruments encounters with a number of difficulties. Utilization of the space instruments (Sobeck, Ch.,/ 1987), (Dommanget, J., 1987), (Hall, T.N., 1982) will probably lead to a considerable progress of such investigations.

At the same time, a great number of astrometrical observations of relative positions of components of double and multiple stars (see the catalogues (Aitken, R.G.,1932), (Jeffers, H.M., Bos van den, W.H., Greeby, M. F., 1963), (Worley, C., 1985)) has been carried out during the past 150 years. Complete utilization of all the information contained in these catalogues may make up a lack of more precise astrometrical observations. The overwhelming majority of these observations has been brought together by Professor Ch. Worley in the catalogue that is available in a machine–readable version in the United States Naval Observaroty in Washington (briefly WDS). The Index–catalogue for WDS (Worley, C., 1985) appeared in 1985. However, the data collected in WDS are strongly heterogeneous, because the observations had been carried out with different instruments and different precision. For correct taking into account all the available astrometrical observations, the statistical treatment of these data is needed.

With a view to obtain more precise astrometrical data for the triple stars of the program of Leningrad State University Astronomical Observatory (AO of LSU) the statistical treatment of the ADS catalogue data (Aitken, R.G., 1932) has been carried out in (Anosova, J.P., Nikifiriv, I.I., Bronnikova, N.M., Kalikhevich, F.F., Yatsenko, A.I., Evdokimov, A.E., Orlov, V.V., 1986), (Anosova, J.P., Orlov, V.V., Lukashova, M.V., 1986), (Anosova, J.P. Bronnikova, N.M., Kalikhevich, F.F., Yatsenko, A.I., Orlov, V.V., 1987).

The ADS Catalogue contains the astrometrical observations of the components' relative positions which had been carried out during the period 1820–1925. In the new WDS Catalogue the data of such astrometrical observations carried out from 1820 to 1985 are contained. The precision of observational information obtained during last decades apprecibly improves in the average.

In the present paper, some statiscital investigations of the data from the WDS Catalogue for the 113 triple stars of our program (Anosova, J.P., Popović, G.P., 1989) have been caried out. The data were kindly placed at our disposal by Prof. Ch. Worley. The purpose of this paper is to make more precise the relative positions: angular separations ρ and position angles θ, the relative proper motions $\dot{\rho}$, $\dot{\theta}$ between the components at some given epoch and to estimate the uncertainties σ_ρ, σ_θ, $\sigma_{\dot{\rho}}$, $\sigma_{\dot{\theta}}$, of these quantities. Some statistical investigations of these results has also been carried out.

2. METHOD

For each pair AB, AC, BC, AB–C, A–BC under study in the WDS Catalogue there is a number of observations of relative positions of components (T, ρ, θ). The position angles given in the Catalogue at the epoches T of observations have been reduced to the choosen epoch T_o = 1950.0 by introducing the correction for precesion and proper motion of the primary component. The precise coordinates and proper motions of this component were taken from the AGK3 or SAO Catalogues. The weight that was equal to the indicated in the WDS number of performed measures, was assigned to each of the WDS observations (T, ρ, θ).

The functions $\rho(T)$ and $\theta(T)$ were approximated by the segments of their Taylor series keeping only the linear and quadratic terms. The quadratic approximation is as follows:

$$\rho(T) = \rho(T_o) + \dot{\rho}(T_o)(T-T_o) + \frac{1}{2}\ddot{\rho}(T_o)(T-T_o)^2$$
$$\theta(T) = \theta(T_o) + \dot{\theta}(T_o)(T-T_o) + \frac{1}{2}\ddot{\theta}(T_o)(T-T_o)^2 \qquad (1)$$

In the linear case we suppose $\ddot{\rho}(T_o) = \ddot{\theta}(T_o) = 0$.

The values $\rho(T_o)$, $\theta(T_o)$, $\dot{\rho}(T_o)$, $\dot{\theta}(T_o)$, $\ddot{\rho}(T_o)$, $\ddot{\theta}(T_o)$ were computed by the least–square method. The use of any polynomial of a higher degree is unsuitable because of sighificant uncertainties in the observational data. On the one hand, by increasing the degree of the fitting polynomial to the number of observations one might obtain a formally exact approximation of observations. However, the real motion could differ from the fitting one (particulary in the case of extrapolation) Thus, using the polyromials of higher degrees, we understimate the errors σ_ρ, σ_θ and others. On the other hand, in the case of a small arc, a straight line and a parabola may give sufficiently reliable fitting the real motion. The errors of approximation may be properly less than the ones of observations. Therefore we confined ourselves to the linear and quadratic fittings. The latter fitting leads to the more precise results in the case of marked curvilinear motions.

The blunders were eliminated from the treatment. Any observation was considered as a blunder, if the module of the error of the corresponding conditional equation was more than two times than rms error (confidence probability is P = 0.95 if the distribution of observational data errors is Gaussian).

Differentiating (1) with respect to T, one determines the relative proper motions of the components:

$$\dot{\rho}(T) = \dot{\rho}(T_o) + \ddot{\rho}(T_o)(T - T_o)$$
$$\dot{\theta}(T) = \dot{\theta}(T_o) + \ddot{\theta}(T_o)(T - T_o) \qquad (2)$$

For the efficiency of the suggested method 3 observations as a minimum are needed when using the linear approximation and 4 ones – when using the quadratic fitting.

3. THE RESULTS OF THE STATISTICAL TREATMENT

The results of application of the method mentioned above to the data from the WDS Catalogue are presented in Table 1.

In this first column there are the numbers of the stars according to our program, the numbers of the ADS Catalogue (Aitken, R.G., 1932) or of the IDS Catalogue (Jeffers, H.M., Bos van den, W.H., Greeby, M.F., 1963), (if this star is absent in the ADS Catalogue)–symbol I is before the number. The symbols a, b, c, d after the numbers of systems on our program mean the confident physical (a), probable physical (b), probable optical (c), and confident optical (d) systems correspondingly. The classification of these systems has been carried out in (Anosova, J.P., Popović, G.M., 1989) on the basis of statistical criterion (Anosova, J.P., 1987).

In the next column the pair of components, to which the following information belongs, is indicated. The sympol • shows taht for this pair the quadratic approximation of ρ and θ was used. The symbol + means that the quadratic approximation was applied for θ only. The following four columns contain the values $\rho \pm \sigma_\rho$, $\theta \pm \sigma_\theta$, $\dot{\rho} \pm \dot{\sigma}_\rho$, $\dot{\theta} \pm \dot{\sigma}_\theta$ at the epoch T = 1950.0. In the last column there are the maximum difference ΔT between the epoches of observations and the number n of observations. For the star included in ADS, the observations which had been carried out after the appearance of ADS, from WDS was used. For the triple stars ADS 3093 (σ Eri) and ADS 6175 (α Gem) in connection with a large number of observations in WDS and with marked curvilinear orbit of close pair, the observations during Tϵ [1920, 1970] and Tϵ [1940, 1960] periods respectively spondingly have only been used.

Table 1 contains only those systems for which there are more than two observations. It allows to estimate the uncertainties of relevant quantities.

In the Table 2 the values of ρ, θ, $\dot{\rho}$ and $\dot{\theta}$ for the pairs with only two observations are listed. These values have been obtained by linear interpolation or extrapolation. The quantity ΔT in Table 2 has the same sense as in Table 1. In these Tables there are no systems which have only one observation: such as ADS1565, 3198 and IDS 559, 1064, 1836, 2035, 3697. The systems with known elements of orbit of a close pair form another part of the systems which are absent in these two Tables: ADS 1630, 5423, 6650, 7203, 8355, 9626, 9909, 11046, 11950, 14601, α Cen. The availability of able 1

Nº ADS		$\rho \pm \sigma_\rho$	$\theta \pm \sigma_\theta$	$\dot\rho \pm \sigma_{\dot\rho}$ x10^{-3}	$\dot\theta \pm \sigma_{\dot\theta}$ x10^{-3}	ΔT n
b 818	AB*	24.516 ± 0.003	329.00 ± 0.06	69.3 ± 0.1	180.2 ± 2.1	142 27
2a 893	AB	5.177 ± 0.222	313.99 ± 1.03	7.2 ± 6.0	13 ± 28	58 7
	AC	9.156 ± 0.264	57.48 ± 0.65	9.3 ± 7.0	36 ± 17	58 7
3a 1193	AB	40.817 ± 0.080	313.36 ± 0.43	–16.9 ± 2.6	18.7 ± 13.8	73 6
4a 1228	AB	40.803 ± 0.152	318.88 ± 0.20	90.2 ± 2.5	–9.0 ± 3.3	85 12
5b 1459	AB	34.698 ± 0.091	35.62 ± 0.25	–2.2 ± 1.8	22.1 ± 5.0	104 9
8a 1727	AB	14.688 ± 0.167	237.88 ± 0.29	1.5 ± 3.4	–3.2 ± 5.8	85 5
9a 2242	AB*	0.350 ± 0.014	220.12 ± 1.57	–12.2 ± 0.7	2642 ± 64	105 45
	AB–C*	28.574 ± 0.094	223.74 ± 0.17	11.8 ± 3.7	56.6 ± 6.7	130 17
10b 2681	AB	26.217 ± 0.065	56.32 ± 0.24	–2.1 ± 1.4	16.0 ± 5.0	142 15
	AC	36.218 ± 0.125	300.12 ± 0.17	–25.2 ± 2.4	–10.5 ± 3.3	142 9
11b 2717	AB	31.858 ± 0.100	84.13 ± 0.10	30.1 ± 2.0	–29.8 ± 2.0	124 10
12b 2926	AB	7.273 ± 0.501	127.40 ± 0.04	–11 ± 11	–4.5 ± 0.8	141 27
	AC	58.207 ± 0.137	241.20 ± 0.18	0.0 ± 2.7	9.9 ± 3.5	142 8
13a 2995	AB	0.944 ± 0.30	59.88 ± 0.50	14.1 ± 2.1	–1908 ± 32	128 90
15b 3040	AB	15.637 ± 0.551	296.38 ± 0.55	–34 ± 19	–375 ± 19	34 4
	BC	11.332 ± 0.371	301.66 ± 1.49	12 ± 13	–15±51	33 4
16a 3093	AB+	83.106 ± 0.008	104.61 ± 0.01	13.7 ± 0.4	–17.1 ± 0.4	50 28
	BC*	6.611 ± 0.007	325.09 ± 2.26	87.3 ± 0.4	4901 ± 107	50 80
18b 3579	AB	39.230 ± 0.006	305.30 ± 0.02	3.1 ± 0.1	10.7 ± 0.4	151 22
	AC	54.421 ± 0.058	88.77 ± 0.04	–5.6 ± 1.7	11.8 ± 0.9	93 15

(Table 1 (continued)

N° ADS		$\rho \pm \sigma_\rho$	$\theta \pm \sigma_\theta$	$\dot{\rho} \pm \sigma_{\dot{\rho}}$ x10^{-3}	$\dot{\theta} \pm \sigma_{\dot{\theta}}$ x10^{-3}	ΔT n
19b 3954	AB	3.254 ± 0.018	97.31 ± 0.09	4.7 ± 0.7	−107 ± 3.7	146 29
	AC	61.924 ± 0.393	104.62 ± 0.14	28.1 ± 5.0	−6.9 ± 1.7	140 6
20b 4119	AB	7.760 ± 0.012	73.90 ± 0.07	−0.44 ± 0.22	6.0 ± 1.1	152 24
21c 4188	AB*	52.435 ± 0.030	92.75 ± 0.04	3.7 ± 1.0	1.8 ± 1.2	148 16
	AC	128.726 ± 0.431	97.63 ± 0.14	−1.0 ± 7.4	5.9 ± 2.4	91 4
22a 4189	AB	10.812 ± 0.064	158.69 ± 0.72	4.3 ± 1.0	57 ± 11	144 3
	BC	2.118 ± 0.071	173.56 ± 0.99	1.0 ± 1.2	34 ± 16	106 6
23b 4329	AB*	7.262 ± 0.353	89.32 ± 0.56	−17 ± 14	−38 ± 22	134 4
	AC	35.757 ± 0.177	149.04 ± 0.29	−3.0 ± 2.0	21.4 ± 3.2	134 3
24a 1915	AB	4.760 ± 0.034	220.56 ± 0.09	20.5 ± 0.9	−98.7 ± 3.1	146 30
25c 5177	AB	9.709 ± 0.130	252.71 ± 0.50	4.7 ± 2.2	14 ± 13	136 10
	AC	56.378 ± 0.285	337.69 ± 0.45	3.6 ± 7.9	22 ± 13	86 4
29b 5300	AB	6.670 ± 0.138	55.99 ± 0.69	−0.1 ± 1.7	32.4 ± 8.4	101 5
31a 11251	AB	20.706 ± 0.091	123.09 ± 0.15	6.9 ± 1.9	30.2 ± 3.0	151 14
32b 5948	AB	3.373 ± 0.122	207.67 ± 0.98	5.0 ± 2.3	8 ± 18	125 6
	AC	127.676 ± 0.142	311.47 ± 0.31	4.9 ± 3.3	16.6 ± 7.2	74 3
33b 6073	AB	60.577 ± 0.310	97.75 ± 0.24	−3.8 ± 5.0	7.7 ± 3.8	92 5
	BC	20.649 ± 0.205	324.11 ± 0.45	8.0 ± 3.2	50.9 ± 7.0	85 4
34a 6175	AB*	2.947 ± 0.002	189.46 ± 0.07	−77.24 ± 0.25	−1626 ± 6	20 189
	AC	72.489 ± 0.008	163.78 ± 0.02	−21.0 ± 1.4	−11.5 ± 3.5	20 18

Table 1 (continued)

N° ADS		$\rho \pm \sigma_\rho$	$\theta \pm \sigma_\theta$	$\dot\rho \pm \sigma_{\dot\rho}$ x10−3	$\dot\theta \pm \sigma_{\dot\theta}$ x10−3	ΔT n
35a 6336	AB	5.388 ± 0.038	339.02 ± 0.32	1.2 ± 0.9	3.0 ± 5.2	138 20
	AC	11.462 ± 0.058	176.78 ± 0.29	2.9 ± 0.9	26.6 ± 4.7	138 17
36b 11442	AB	58.004 ± 0.903	5.14 ± 0.09	11.9 ± 20.4	5.7 ± 2.1	60 6
38a 6700	BC	5.908 ± 0.104	208.10 ± 3.10	26.5 ± 2.4	−67 ± 73	62 3
39b 6777	AB	1.888 ± 0.072	169.69 ± 1.17	1.3 ± 2.3	4.9 ± 37.5	47 6
	AC	18.751 ± 0.880	7.92 ± 1.41	34 ± 24	31 ± 39	47 5
40a 6811	AB	5.771 ± 0.003	46.74 ± 0.03	−0.58 ± 0.06	85.2 ± 6.2	143 80
	BC	0.167 ± 0.002	199.37 ± 23.5	−0.27 ± 0.07	1.8 ± 1.3	76 28
41b 6811	AB	1.464 ± 0.005	318.66 ± 0.07	−0.48 ± 0.20	−121.0 ± 2.5	148 100
	A–BC	55.062 ± 0.504	198.98 ± 0.15	−39 ± 36	57 ± 11	32 3
42a 7114	AB	5.564 ± 0.015	12.09 ± 0.20	−62.5 ± 0.8	367 ± 14	130 37
	BC	0.504 ± 0.040	208.70 ± 3.03	−5.0 ± 2.3	283 ± 167	67 52
44a 7311	AB	230.499 ± 0.857	210.96 ± 0.09	35 ± 19	6.8 ± 2.0	140 6
	BC	9.429 ± 0.022	196.65 ± 0.43	−4.2 ± 7.2	15 ± 15	77 9
45b 11681	AB	75.966 ± 0.111	161.28 ± 0.07	−86.1 ± 2.3	−2.6 ± 1.5	48 17
	AC	83.860 ± 0.468	78.02 ± 0.43	14.5 ± 11.1	−34.5 ± 11.6	17 6
46b 11687	AB	63.042 ± 0.425	128.39 ± 0.70	7.0 ± 7.6	−14.3 ± 12.4	38 6
47b 7425	AB	10.438 ± 0.020	247.92 ± 0.10	−0.09 ± 0.44	23.4 ± 2.1	136 19
	AC	130.619 ± 0.689	215.10 ± 0.28	−1 ± 14	29.0 ± 5.8	62 5
	BC	121.824 ± 0.302	212.19 ± 0.19	1.3 ± 5.6	25.0 ± 3.6	135 7
48a 7438	AB	24.842 ± 0.044	148.76 ± 0.11	1.5 ± 0.9	15.9 ± 2.2	137 13

Table 1 (continued)

N° ADS		$\rho \pm \sigma_\rho$	$\theta \pm \sigma_\theta$	$\dot{\rho} \pm \sigma_{\dot{\rho}}$ x10−3	$\dot{\theta} \pm \sigma_{\dot{\theta}}$ x10−3	ΔT n
78b 9922	AB	36.195 ± 0.028	323.74 ± 0,034	34,7 ± 0.1	−41.1 ± 0.8	137 22
	AC	167.404 ± 1.18	137.60 ± 0.01	−5.6 ± 35	−5.0 ± 0.1	13 3
80b 10192	AB	2.552 ± 0.055	44.94 ± 1.01	1.1 ± 1.5	−24 ± 28	70 5
	AC	43.987 ± 0.025	204.64 ± 0.01	0.20 ± 0.72	−4.6 ± 0.1	56 3
81a 10216	AB	4.925 ± 0.003	316.80 ± 0.03	0.22 ± 0.05	−0.3 ± 1.2	144 18
	AC	28.911 ± 0.286	253.69 ± 1.27	52.0 ± 6.2	174 ± 28	85 5
82c 10288	AB	4.119 ± 0.050	57.10 ± 0.44	30.3 ± 2.9	139 ± 18	62 12
	AC	113.113 ± 0.210	262.36 ± 0.06	−13 ± 2.8	−16.9 ± 0.8	148 9
83b 10332	AB	14.903 ± 0.021	234.72 ± 0.17	145 ± 1	150 ± 6	153 35
	AC*	146.018 ± 0.479	174.12 ± 0.01	−16.2 ± 7.6	−10.7 ± 0.1	75 4
84a 10410	AB	2.719 ± 0.026	225.79 ± 0.49	0.09 ± 0.44	−10.1 ± 8.2	151 10
85b 10715	AB	16.338 ± 0.093	7.48 ± 0.24	1.44 ± 1.7	−20.8 ± 4.4	127 10
86b 12612	AB	55.533 ± 0.216	354.27 ± 0.18	6.3 ± 5.3	−25.6 ± 4.4	42 5
87a 10781	AB	10.576 ± 0.115	116.48 ± 0.72	7.6 ± 2.3	1 ± 14	103 6
89b 11328	AB*	2.739 ± 0.123	203.24 ± 1.30	−3.0 ± 4.3	48 ± 46	70 7
	AC	92.229 ± 12.6	126.41 ± 7.43	168 ± 316	177 ± 186	3 3
90b 12854	AB	18.850 ± 0.172	272.81 ± 0.57	5.9 ± 3.4	−38.9 ± 31.5	45 3
	AC	74.173 ± 0.530	163.16 ± 0.37	−16.2±10.6	−19.4 ± 7.4	45 3
91a 11853	AB*	22.182 ± 0.005	103.74 ± 0.01	3.4 ± 0.2	−3.9 ± 0.6	165 54
93a 12029	AB	9.527 ± 0.043	153.31 ± 0.04	−4.2 ± 0.8	−16.1 ± 1.6	131 20
94b 13050	AB	26.008 ± 0.493	140.93 ± 0.50	34.5 ± 8.5	−12.2 ± 8.5	122 7

Table 1 (continued)

N° ADS		$\rho \pm \sigma_\rho$	$\theta \pm \sigma_\theta$	$\dot\rho \pm \sigma_{\dot\rho}$ x10^{-3}	$\dot\theta \pm \sigma_{\dot\theta}$ x10^{-3}	ΔT n
	AC	36.831 ± 0.384	13.72 ± 0.75	16.1 ± 6.0	−25.5 ± 11.7	105 5
95b 13244	AB	113.082 ± 0.515	15.08 ± 0.50	−37.9 ± 11.5	−9.5 ± 11.2	42 4
96b 13464	AB	5.542 ± 0.012	82.35 ± 0.05	0.75 ± 0.40	−2.3 ± 7.4	64 11
	AC	35.793 ± 0.008	61.29 ± 0.02	−47.4 ± 0.3	13.7 ± 0.6	64 12
	BC	30.652 ± 0.008	57.56 ± 0.03	−45.2 ± 0.3	9.4 ± 0.9	56 11
97b 13524	AB	7.362 ± 0.028	121.63 ± 0.06	−1.6 ± 0.8	−37.4 ± 6.7	137 22
99b 14102	AB	1.980 ± 0.021	260.13 ± 0.40	−1.8 ± 0.6	−81 ± 10	148 13
	AC	43.245 ± 0.139	52.39 ± 0.30	−61.4 ± 44.3	−15 ± 9.4	58 5
100a 14184	AB	8.519 ± 0.054	86.58 ± 0.17	2 ± 10	−6.1 ± 3.5	124 16
	AC	167.324 ± 0.152	329.15 ± 10.5	5.5 ± 3.2	−372 ± 220	23 4
102a 13464	BC	23.646 ± 0.041	225.63 ± 0.22	12.2 ± 2.4	−858 ± 13	70 15
103b 14345	AB	102.169 ± 0.245	13.84 ± 0.04	32.3 ± 8.4	17.1 ± ,1.3	21 3
	BC	2.273 ± 0.020	69.03 ± 4.53	−6.8 ± 0.6	−246 ± 133	10 3
104b 14601	AB	80.112 ± 0.431	237.96 ± 0.77	23.7 ± 9.2	−21.4 ± 16.5	24 3
	BC	6.462 ± 0.228	96.70 ± 0.41	22.4 ± 5.1	8.7 ± 9.1	89 7
106b 14786	AB	84.054 ± 0.308	52.00 ± 0.29	−9.4 ± 3.7	4.3 ± 3.5	100 5
	BC	6.058 ± 0.428	338.87 ± 0.76	3.1 ± 5.3	−16.8 ± 9.5	103 5
109b 15978	AB–C	33.372 ± 0.341	296.93 ± 0.55	1 ± 11	2 ± 18	53 3
110a 16252	AB	3.613 ± 0.020	201.95 ± 0.25	1.4 ± 0.8	−4.3 ± 6.5	122 11
	AC	20.674 ± 0.032	219.16 ± 0.12	0.60 ± 0.80	−6.0 ± 3.0	122 11

Table 1 (continued)

N^o ADS		$\rho \pm \sigma_\rho$	$\theta \pm \sigma_\theta$	$\dot\rho \pm \sigma_{\dot\rho}$ x10^{-3}	$\dot\theta \pm \sigma_{\dot\theta}$ x10^{-3}
111c 16304	AB	4.392 ± 0.081	175.22 ± 0.59	−0.25 ± 2.5	31 ± 18
	AC	26.114 ± 0.128	225.34 ± 0.25	22.1 ± 3.9	−4.8 ± 7.6
113b 17131	AB	8.916 ± 0.028	312.74 ± 0.19	−3.1 ± 0.5	−7.8 ± 3.3
	AC	42.104 ± 0.094	250.93 ± 0.20	−114 ± 3	193 ± 6

Table 2

N^o	ADS		ρ	θ	$\dot\rho$	$\dot\theta$	ΔT
3	1193	BC	1.636	293.99	1.8	271.1	22
5	1459	AC	114.790	254.92	0.0	15.7	28
13	2995	AC	230.148	212.46	−88.7	79.6	18
18	3579	BC	91.046	159.40	40.9	1070	19
20	4119	AB	117.228	185.78	−40.2	22.6	29
24	1915	AC	196.740	320.60	239.5	4.2	96
26	11042	AB	27.369	278.05	30.5	21.3	14
		AC	42.604	106.47	−17.7	28.3	14
28	11069	AB	63.093	145.35	−226.0	−183.7	16
		AC	152.837	167.33	−317.8	−36.7	16
29	5300	AC	191.924	182.20	−67.6	25.8	29
31	11251	AC	153.423	300.65	−635.2	−675.9	77
38	6700	AB	20.315	246.75	11.8	402.5	49
50	11885	AC	175.934	305.76	−265.8	48.4	9
68	9327	AC	82.162	118.35	90.0	31.5	11
81	10216	BC	26.243	268.96	−45.0	310.0	10
85	10715	AC	165.670	161.31	40.0	−608.0	29
86	12612	AC	141.712	147.90	59.2	−0.5	20
87	10781	AC	106.613	197.80	30.1	−5.5	20
95	13244	AC	78.087	338.03	−31.0	−13.2	25
97	13524	AC	167.871	337.26	−40.5	−4.2	17
98	13661	AB	4.646	72.36	−1.8	−69.0	11
101	14186	AB	4.861	179.31	9.4	−176.0	10
108	15868	AB	5.102	7.16	3.8	34.0	42
112	16955	AB	8.822	294.78	−139.0	−431.0	50
		AC	32.530	42.43	−8.8	−3.1	50

Table 3

ΔT	ν_{AB}	ν_{AC}
0– 10	0.0	0.016
10– 20	0.038	0.097
20– 50	0.103	0.210
50–100	0.218	0.419
100–150	0.487	0.194
>150	0.154	0.065
	N = 78	N = 62

Table 4

n	ν_{AB}	ν_{AC}
0– 5	0.179	0.548
5– 10	0.192	0.205
10– 30	0.397	0.151
30– 50	0.077	0.0
50– 75	0.0	0.014
75–100	0.026	0.0
>100	0.128	0.082

Table 5

ρ	ν_{AB}	ν_{AC}	r = 100 pc	r = 50 pc
0– 10	0.602	0.044	1.1 10^{-2}	2.3 10^{-4}
10– 20	0.115	0.071	4.4 10^{-2}	1.1 10^{-3}
20– 30	0.088	0.062	0.10	2.5 10^{-3}
30– 50	0.088	0.142	0.29	6.9 10^{-3}
50– 75	0.053	0.168	0.62	1.6 10^{-2}
75–100	0.035	0.115	1.11	2.8 10^{-2}
100–150	0.009	0.150	2.50	6.2 10^{-2}
150–200	0.009	0.150	4.44	0.11
200–250	0.0	0.053	6.94	0.17
250–300	0.0	0.0	10.00	0.25
300–500	0.0	0.009	27.78	0.69
>500	0.0	0.026	–	–

N = 113

the orbit presupposes a large number of observations and a significant curvature of the observed arc. It makes our method ineffective. The ADS 10058 was removed from the treatment, because it is a confident optical system (class d).

Tables 3–5 contain the results of the statistical analysis of the obtained data $\{\rho, \theta, \dot\rho, \dot\theta\}_{1950}$. The first two Tables show the distribution of close and wide pairs (AB and AC) on the maximum difference between the observation epoches ΔT and the number n of observations. Tables 3 and 4 evidence the great deficiency of astrometrical observations of very distant components C in the triple stars under study.

Table 6

N° ADS		$\rho \pm \sigma_\rho$	$\theta \pm \sigma_\theta$	$\dot\rho \pm \sigma_{\dot\rho}$ x10^{-3}	$\dot\theta \pm \sigma_{\dot\theta}$ x 10^{-3}	n	ΔT
12 2926	AB	7.175 ± 0.127	126.82 ± 0.45	−2.4 ± 2.3	−7.4 ± 8.2	6	94
		7.273 ± 0.501	127.40 ± 0.04	−11 ± 11	−4.5 ± 0.8	27	141
		7.367 ± 0.036	127.26 ± 0.09	1.0 ± 0.7	−3.8 ± 1.5	55	141
	AC	58.313 ± 0.114	241.42 ± 0.20	1.7 ± 1.9	12.6 ± 3.2	4	93
		58.207 ± 0.137	241.20 ± 0.18	0.0 ± 2.7	9.9 ± 3.5	8	142
		58.198 ± 0.128	241.33 ± 0.12	−0.2 ± 2.4	11.9 ± 1.9	19	142
33 6073	AB	60.577 ± 0.310	97.75 ± 0.24	−3.8 ± 5.0	7.7 ± 3.8	5	92
		60.577 ± 0.310	97.75 ± 0.24	−3.8 ± 5.0	7.7 ± 3.8	5	92
		60.598 ± 0.247	97.65 ± 0.15	−3.0 ± 3.7	6.0 ± 2.2	8	92
	BC	20.650 ± 0.205	324.11 ± 0.45	8.0 ± 3.2	50.9 ± 7.0	4	85
		20.650 ± 0.205	324.11 ± 0.45	8.0 ± 3.2	50.9 ± 7.0	4	85
		20.654 ± 0.171	324.14 ± 0.58	8.2 ± 2.5	53.0 ± 8.6	7	85
48 7438	AB	24.747 ± 0.084	148.79 ± 0.28	−0.0 ± 1.3	16.5 ± 4.3	5	93
		24.842 ± 0.044	148.76 ± 0.11	1.5 ± 0.9	15.9 ± 2.2	13	137
		24.845 ± 0.038	148.81 ± 0.11	1.4 ± 0.7	17.4 ± 2.0	20	137
	AC	117.311 ± 0.447	323.56 ± 0.06	−10.2 ± 6.6	−10.3 ± 1.0	4	100
		117.235 ± 0.135	323.48 ± 0.04	−10.3 ± 2.8	−11.4 ± 0.7	10	143
		117.235 ± 0.123	323.54 ± 0.07	−10.5 ± 2.5	−11.7 ± 1.3	12	144
76 9865	AB	56.189 ± 0.054	58.65 ± 1.62	0.1 ± 0.9	−1.0 ± 2.8	4	88
		56.176 ± 0.043	59.19 ± 1.35	−1.0 ± 8.0	7.0 ± 24.0	5	108
		56.198 ± 0.129	60.61 ± 0.25	−0.7 ± 2.1	8.2 ± 4.0	11	108
	AC	59.927 ± 0.275	63.27 ± 1.87	0.4 ± 4.9	65.1 ± 33.0	3	48
		59.791 ± 0.187	61.33 ± 1.91	−1.9 ± 3.4	32.3 ± 35.0	4	74
		59.938 ± 0.286	59.10 ± 0.38	0.6 ± 4.6	16.9 ± 6.2	7	74
	BC	4.291 ± 0.285	207.25 ± 0.49	2.8 ± 4.8	−19.5 ± 8.2	4	90
		4.115 ± 0.119	206.77 ± 0.27	0.3 ± 2.3	−26.7 ± 5.1	10	133
		4.177 ± 0.126	206.66 ± 0.48	2.4 ± 2.1	−24.5 ± 2.1	15	104
106 14786	AB	84.195 ± 0.476	51.84 ± 0.44	−8.0 ± 5.3	2.8 ± 4.9	4	80
		84.054 ± 0.308	52.00 ± 0.29	−9.4 ± 3.7	4.3 ± 3.5	5	100
		83.843 ± 0.206	52.05 ± 0.15	−10.0 ± 2.4	4.1 ± 1.6	10	100
	BC	6.742 ± 0.992	337.18 ± 1.14	9.7 ± 10.4	−33.1 ± 11.9	3	70
		6.058 ± 0.428	338.87 ± 0.76	3.1 ± 5.3	−16.8 ± 9.5	5	103
		6.182 ± 0.206	338.65 ± 1.10	6.6 ± 3.7	−18.0 ± 3.7	12	103
110 16252	AB	3.777 ± 0.114	203.12 ± 1.04	3.8 ± 2.1	14.4 ± 18.8	4	69
		3.613 ± 0.020	201.95 ± 0.25	1.4 ± 0.8	−4.3 ± 6.5	11	122
		3.616 ± 0.019	202.03 ± 0.26	1.5 ± 0.4	−28.0 ± 6.5	16	122
	AC	20.641 ± 0.114	219.60 ± 0.46	−0.0 ± 2.0	1.5 ± 8.1	4	69
		20.674 ± 0.032	219.16 ± 0.12	0.6 ± 0.8	−6.0 ± 3.0	11	122
		20.683 ± 0.033	219.13 ± 0.19	0.6 ± 0.7	−12.7 ± 3.9	13	122

The distributions of the pairs AB and AC on the angular separation between the components are displayed in the first two columns of Table 5. The mathematical expectations of the number of occasional triple stars, whose components are not situated at the distances larger than 100 pc and 50 pc respectively, in dependence on angular separation between the most distant (in the plane of sky) components are contained in the next two columns. One can see that among the systems under consideration with large relative separations between the components, the optical systems may be present, too.

Let us compare the results of statistical investigation of the ADS data, the compiled ADS and WDS data (see above), and the WDS data. Such comparison has been carried out for 6 triple systems. The results are summarized in Table 6. Three lines containing the results of the treatment of the ADS, ADS + WDS, and WDS data correspond to each pair. In Table 7 there are the average uncertainties (and their rms errors) of the values ρ, θ, $\dot{\rho}$, $\dot{\theta}$ for close pairs (three upper lines) and for wide pairs (three lower lines). One can see from Tables 6 and 7 the following: 1) The results are in agreement within the limits of the rms errors (there are a few exceptions: the values $\dot{\theta}$ for the pairs AB and AC in ADS 9865 and 16252, the cause of this is a small number of observations in ADS); 2) the treatment of the WDS data ensures a better precision on the average.

Table 7

	σ_ρ	σ_θ	$\sigma_{\dot\rho}$ x10^{-3}	$\sigma_{\dot\theta}$ x10^{-3}
ADS	0.302 ± 0.141	0.64 ± 0.15	4.0 ± 1.3	9.7 ± 2.1
ADS+WDS	0.220 ± 0.088	0.31 ± 0.11	3.9 ± 1.6	5.2 ± 1.3
WDS	0.099 ± 0.032	0.44 ± 0.16	1.7 ± 5.4	4.1 ± 1.2
ADS	0.253 ± 0.075	0.50 ± 0.23	3.6 ± 0.9	4.0 ± 1.0
ADS+WDS	0.161 ± 0.050	0.37 ± 0.20	3.8 ± 1.0	6.4 ± 3.5
WDS	0.144 ± 0.030	0.15 ± 0.03	2.3 ± 0.4	2.5 ± 0.5

In Table 8 there are the averages X (with their rms deviations σ_X and variations δ_X) of the errors of angular separation ρ, position angle θ and relative proper motions (radial $\dot\rho$ and tangential $\rho\dot\theta$) in the close pairs AB and in the wide pairs AC (between the primary component of a close pair and the distant star). In Table there are both the absolute errors and the relative ones and also the average number h of observations. From

Table 8. The average uncertainties

	close pairs AB(N = 73)			wide paris AC(N = 45)		
error	$\bar{X}$	σ_X	δ_X	$\bar{X}$	σ_X	δ_X
σ''_ρ	0.103	0.017	0.2	0.315	0.046	0.2
θ°_θ	1.40	0.62	0.5	0.55	0.23	0.4
$\sigma_{\dot\rho}$/y.	0.0030	0.0005	0.2	0.0080	0.0014	0.2
$\sigma_{\rho\dot\theta}$''/y.	0.0027	0.0008	0.3	0.024	0.014	0.6
σ_ρ/ρ	0.0167	0.0027	0.2	0.0048	0.0010	0.2
$\sigma_{\dot\rho}/\lvert\dot\rho\rvert$	1.76	0.41	0.2	1.55	0.67	0.4
$\sigma_{\rho\dot\theta}/\lvert\rho\dot\theta\rvert$	1.14	0.30	0.3	0.69	0.30	0.4
n	21.5	3.3	0.2	8.5	1.9	0.2

Table 8 one can see the following: 1) The average error of determination of angular separation is about 0.''2 and of position angle is about 1°; in the close pairs the angular separation is determined in factor 3 as good as in the wide pairs (it is due to a smaller number of observations for the pairs AC), on the contrary the position angle is by factor 3 worse (due to a small value of ρ_{AB}). 2) The relative proper motions $\dot\rho$ and $\rho\dot\theta$ in close pairs are determined with the same precision on the average. Their average errors are about 0.''003/year that corresponds to the standard modern astrometrical observations with a difference of epoches of about 20 years. For the wide pairs the radial proper motion is determined in factor 3 more certain ($\sigma_{\dot\rho} \approx$ 0.''008/year) than the tangential one ($\sigma_{\rho\dot\theta} \approx$ 0.''024/year). The average erors σ_ρ and $\sigma_{\rho\dot\theta}$ are significantly larger than the ones for the close pairs. It is due to a smaller number n of available observations of wide pairs as compared with close ones 3). The errors of the relative proper motions on average are comparable or even slightly larger (in the

Table 9. Internal kinematics of close pairs AB

Sample	All pairs				Physical pairs			
Parameter	All	$>\sigma$	$>2\sigma$	hier.	All	$>\sigma$	$>2\sigma$	hier.
$\bar{\dot\rho} \pm \sigma_{\dot\rho}$	0.005 ± 3	0.007 ± 5	0.014 ± 8	0.002 ± 5	0.003 ± 4	0.003 ± 7	0.006 ± 10	0.003 ± 12
$\overline{\lvert\dot\rho\rvert} \pm \sigma_{\lvert\dot\rho\rvert}$	0.011 ± 3	0.017 ± 4	0.025 ± 7	0.012 ± 4	0.012 ± 4	0.018 ± 6	0.023 ± 8	0.023 ± 9
$\overline{\lvert\rho\dot\theta\rvert} \pm \sigma_{\lvert\rho\dot\theta\rvert}$	0.018 ± 8	0.027 ± 14	0.043 ± 23	0.034 ± 22	0.028 ± 18	0.048 ± 31	0.064 ± 42	0.27 ± 13
$\bar\lambda \pm \sigma_\lambda$	3.46 ±0.96	3.04 ± 1.31	1.49 ± 0.43	4.44 ± 2.10	4.74 ± 1.98	4.36 ± 2.80	1.67 ± 0.58	0.18 ± 0.06
$\bar\mu \pm \sigma_\mu$	0.65 ± 0.31	0.65 ± 0.27	0.64 ± 0.27	0.65 ± 0.30	0.70 ± 0.30	0.67 ± 0.29	0.63 ± 0.29	0.17 ± 0.16
N	73	41	24	26	32	18	13	11

case of $\dot{\rho}$) than the motions themselves. Therefore on the basis of the WDS data for a complete sample of triple stars under study one cannot make any reliable statistical conclusion about their inner kinematics.

In connection with this conclusion obtained for the complete sample of the triple stars under consideration (see Table 8), the study has also been performed for a few subsamples of close AB and wide AC pairs inside the triple stars: a) all pairs; b) the binaries, in which the modulis of relative proper motions are greater than their rms errors: $|\dot{\rho}| > \sigma_{\dot{\rho}}$ and $|\rho\dot{\theta}| > \sigma_{\rho\dot{\theta}}$; c) the pairs, in which $|\dot{\rho}| > 2\sigma_{\dot{\rho}}$ and $|\rho\dot{\theta}| > 2\sigma_{\rho\theta}$.

The triple systems with moderate ($2 < \rho_{AC}/\rho_{AB} < 10$) and strong hierarchy ($\rho_{AC}/\rho_{AB} > 10$) are studied separately. Such a separation has been performed both within the complete sample and within a subsample of confident physical triple systems, revealed by applying the criterion, (Anosova, J.P. 1987).

Table 10. Internal kinematics of wide pairs AC

Sample / Parameter	All pairs: All	All pairs: $>\sigma$	All pairs: $>2\sigma$	All pairs: hier.	Physical pairs: All	Physical pairs: $>\sigma$	Physical pairs: $>2\sigma$	Physical pairs: hier.
$\dot{\rho} \pm \sigma_{\dot{\rho}}$	−0.009 ± 5	−0.013 ± 7	−0.016 ± 10	−0.009 ± 7	−0.001 ± 8	−0.002 ± 9	−0.006 ± 10	−0.009 ± 10
$\overline{\vert\dot{\rho}\vert} \pm \sigma_{\vert\dot{\rho}\vert}$	0.025 ± 4	0.030 ± 5	0.035 ± 7	0.028 ± 5	0.023 ± 5	0.023 ± 6	0.024 ± 7	0.027 ± 7
$\overline{\vert\rho\dot{\theta}\vert} \pm \sigma_{\vert\rho\dot{\theta}\vert}$	0.068 ± 25	0.089 ± 35	0.073 ± 19	0.087 ± 42	0.099 ± 63	0.119 ± 76	0.046 ± 18	0.134 ± 97
$\dot{\lambda} \pm \sigma_{\dot{\lambda}}$	1.67 ± 0.42	1.02 ± 0.24	0.98 ± 0.29	1.57 ± 0.45	1.46 ± 0.61	0.62 ± 0.14	0.62 ± 0.14	2.01 ± 0.91
$\dot{\mu} \pm \sigma_{\dot{\mu}}$	0.50 ± 0.32	0.51 ± 0.26	0.50 ± 0.25	0.53 ± 0.34	0.50 ± 0.29	0.45 ± 024	0.46 ± 0.21	0.56 ± 0.34
N	45	32	21	26	17	14	12	11

Table 11. Medians and quartils as the kinematic parameters

Sample / Parameter		close pairs AB: All	close pairs AB: Strong hier.	close pairs AB: mod. hier.	wide pairs AC: All	wide pairs AC: strong hier.	wide pairs AC: mod. hier.
$\dot{\rho}$	1/4	−0.002	−0.004	−0.002	−0.027	−0.035	−0.022
	1/2	0.001	−0.000	0.001	−0.002	−0.001	−0.004
	3/4	0.005	0.002	0.007	0.007	0.019	0.003
$\vert\dot{\rho}\vert$	1/4	0.001	0.001	0.001	0.004	0.007	0.003
	1/2	0.003	0.004	0.003	0.021	0.026	0.010
	3/4	0.008	0.006	0.009	0.033	0.035	0.026
$\vert\rho\dot{\theta}\vert$	1/4	0.001	0.001	0.001	0.009	0.009	0.007
	1/2	0,003	0.003	0.004	0.023	0.030	0.013
	3/4	0.010	0.010	0.010	0.036	0.045	0.025
λ	1/4	0.44	0.59	0.41	0.22	0.17	0.25
	1/2	1.10	0.98	1.27	0.54	0.62	0.47
	3/4	2.25	1.91	2.44	1.17	1.47	0.65
μ	1/4	0.41	0.51	0.38	0.22	0.16	0.24
	1/2	0.74	0.70	0.79	0.48	0.52	0.42
	3/4	0.91	0.89	0.93	0.76	0.83	0.54
		73	26	47	45	26	19

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BEHAVIOUR OF SECOND LEVELS IN THE FIELD OF HORIZONTAL TEMPERATURE GRADIENTS

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SUMMARY: On the basis of level examinations, done in a laboratory and during star observations, a nonnegligible temperature influence on the measuring results is found. For practical purposes, such as reductions of observational materials, expressions (13) and (14) which should be taken into account in coordinate derivations of observed celestial bodies and, in our case, in the derivation of the geographic latitude are proposed.

1. INTRODUCTION

Numerous accurate measurements in various parts of science and technology require knowledge of inclinations of measuring instruments and of their variations in the course of measurements with an accuracy as high as possible. At present such measurements are mostly made with very sensible tube levels (angular value corresponding to the distance between two neighbour division lines about 1"). During the sixties new apparatus fulfilling the functions of levels, whose work is based on the pendulum principle, were included in precise inclination measurements (electronic levels).

The pendulum apparatus, though they have found a wide application in the technical levelling domain, on account of their lower accuracy they have not eliminated the classical tube levels because the latter ones are irreplaceable in defining a direction, or a plane in space. For astrogeodetical purposes it is necessary to know the astronomical coordinates and the direction azimuth with an accuracy of the other of 0".1. In astrometry the requirements are much more rigorous. In absolute determinations of star coordinates it is necessary to achieve the highest possible accuracy, hence the defining of the plumb–line or knowledge of the inclination of the rotational axis of the instrument are of a paramount importance. In order to satisfy such requirements one should know the properties of the levels used at the measuring instruments very well. The accuracy of performed measurements is directly related to the accuracy of level measurements. The notion „accuracy of level measurements" comprises a number of factors defining this accuracy. The determination and examination of these factors are subjects to special investigations, most frequently appearing under the name–level examination.

The final aim of a level examination is to determine all systematic errors which arise or can arise in level measurements, in order to exclude their influence from the results of measurements. Some properties of tube levels such as the duration of damping of the bubble's oscillations appear as limiting factors to the possibility of measuring the inclination with this precise measuring organ of the instrument for objects which are at rest or can be at rest during a necessary time interval. The length of the bubble directly affects the basic constant of the level and this is the angular value corresponding to the distance between two neighbour division lines. The latter one is also directly affected by temperature variations. The present paper is aimed at analysing the influence of temperature gradients on tube levels and at attemping to establish the laws of their acting. First more serious analyses of such kind were done in the fifties.

2. LEVEL CHARACTERISTICS AND EXISTING THEORIES ON THE BUBBLE'S MOTION

The basic parameter of a tube is the angular value corresponding to the distance between two neighbour division lines (τ). This quantity is most frequently expressed in seconds of arc and it is given by

$$\tau = \frac{p}{R}\,\rho''$$

where p is the distance between two neighbour division lines; R is the radius of the curvature of the level tube and ρ'' is equal to 206 265.

The value of p is for the levels of recent production dates equal to 2 mm, but in the practical work one can meet also levels of older production dates for which this quantity is equal to 2.256 mm, i.e. it is equal to the length of a Parisian line. At recent times in catalogues of level producers one can often find the number of seconds (for example 1"/2 mm).

The second important parameter of a level is its sensibleness (η). It is defined as the ratio of the linear displacement of the bubble to the corresponding change in the inclination of the level's axis where **dl** is the displacement of the bubble, **di** the corresponding change in the inclination and **c** is a coefficient of proportionality depending on the units of measuring.

Since it is $dl = r \cdot di$, it follows $\eta = c \cdot R$, i.e.

$$\eta = \frac{c \cdot \rho \cdot l}{\tau''}$$

In other words the sensibleness of the level is directly proportional to the radius of the level tube curvature and inversely proportional to τ.

In the specialist literautre the sensibleness of the level has been also defined as the sensibleness of the bubble that it could reach for the same value of **r**, the highest position sooner or later (damping duration of its oscillations). The sensibleness depends on the bubble's length, quality of grinding, kind of filling the level etc.

The existing specialist literature treats in details the dependence of the adptation of the skating surface, quality of the liquid, influence of the form and size of the bubble, the action of the forces appearing within the level and beyond it and affecting the bubble's motion etc. As a final step in the literature are given conclusions concerning the most favourable choice of all these factors aimed at achieving an optimal usability of a level (Drodofsky, 1956; Alpar, 1967; Sardy, 1967; Tovchigrechko, 1965).

The solutions of the differential equations of the bubble motion represented as oscillations have given enough elements to level producers to produce qualitative levels and they have answered the questions such as the most favourable accuracy as function of the radius of the skating surface, the size (tube volume) with respect to the size of the bubble provided that the damping duration is as short as possible. The dimensions of the tube walls are calculated provided that the deformations of the skating surface due to the change of the liquid pressure caused by the temperature are minimal. All of this has a paramount importance for level producers. However, to an astronomer being merely a user of levels in such a way that he (she) defines the direction of the plumb–line, or another direction on the instrument of importancee to him (her) with them, this is of no importance since he (she) has no way to change any property of a level except the length of the bubble. The length of the bubble is, as both theory and praxis show, a quantity which affects the basic parameter of a level and also the damping duration. By examining a level it is not difficult to find the dimensions of the bubble being optimal in the case of that level.

The influence of the temperature is a second external parameter upon which an astronomer–practician can make no influence, but which affects the parameters of a level significantly (Wanach, 1926; Barnes, 1966). Within the pavilion and in the surroundings of a level physical processes disturbing the uniform distribution mentioned above occur incessantly. Levels are always subjects to fine thermal: radiations coming from the observer and frequently to more rough ones arising from currents of the warm, or cold, air. These thermal sources always produce temperature differences within the level liquid and the latter factor causes pressure variations within the tube and oscillations of the bubble. The thermal processes are reflected in the bubble's position and the dilatation variations in the envelope and piers of the level. All of this affects directly astronomical measurements and requires careful examinations and analyses.

3. EXAMINATION OF THE THERMIC SOURCE ON GEOGRAPHIC LATITUDE DETERMINATION

From what has been said above it is evident that for a level a very important condition exists: appearance of a significant temperature difference at individual parts of the tube should be avoided. According Drodofsky in the case of an one–second level whose tube length is 150 mm a temperature difference at the tube terminals greater than 0.009°C causes a measurable effect in the position of the bubble. Sardy has measured average temperature differences of 0.25°C on external parts of levels in the field conditions. These examinations done by him have demonstrated that a temperature difference between the terminals of 1°C causes a change of 2" in the geographic latitude determined by use of Talcot's method. The datum given by Drodofsky is valid for the hydrostatic influences only, whereas the effect demonstrated by Sardy is a sum of influences of hydrostatic and mechanical characters. The system of holders even in the case of a uniform temperature distribution can cause a change in the tube curvature. If the temperature is not uniformly distributed this influence becomes much more complex and prominent. The hydrostatic effects can be large, whereas the mechanical ones are practically different for different levels. Therefore, a careful study of the level behaviour in the temperature field is needed. Usually this behaviour is not taken into account since it is assumed that level tubes are well isolated from external influences. Unfortunately, this statement is not true.

In the case of field measurements, partly because of the influence of a wind which preserves its sense, partly because of the influence of an object which radiates the temperature, at the level terminals a measurable temperature difference arises. This difference is reflected through the temperature errors of the level which produce a systematic influence on the geografic latitude value derived from the measurements. In the case of more accurate measurements this influence is not negligible and hence one should examine it in order to establish its amount.

The geographic latitude is determined by use of Talcot's method by applying the formula

$$\varphi = \frac{1}{2}(\delta_N + \delta_s) + \frac{1}{2}(m_w - m_E)\cdot R + \frac{1}{2}(c_w - c_E)\cdot p + \frac{1}{2}(\rho_s - \rho_N) \qquad (1)$$

in which the following designations are used S – south, N – north, W – west, E – east, c – position of the middle of the bubble, p" – level constant, declination of a star δ_N, δ_S, m_E, m_W – reading of the eye–piece micrometer, R – value of its revolution.

Between the transits of the first and second stars in a star pair there is a time interval of 4–20 minutes.

From the readings of positions of the level's bubble one obtains the true values only then, if there are no systematic errors. Of systematic errors we shall study the temperature ones which affect the regular work of the level. The other ones will be neglected; they will not be taken into account.

The temperature dependent level errors are divided into two groups: thermomechanical and thermohydrostatic ones. Thermomechanical errors are those errors caused by changes in the dimensiosn of bodies due to the temperature influences. Thermohydrostatic errors are difined as influences on the equilibrium position of the bubble due to the temperature changes within the level liquid.

In order to estimate the order of magnitude of the total influence of errors I made a number measurements of the geographic latitude with a universal instrument WILD T–4 which was situated in the field of an articifial heat source.

Before analysing the obtained results we establish the influence of the temperature differnce at the terminals of Talcot's levels on the derived value of the geographic latitude. One should mention that in all series of measurements the alhidade axis of the universal instrument was set to a vertical position and that between the observations of two stars within a star pair there were no influences of measurements except the change in the inclination of the instrument due to the thermal influence.

A few series of the geographic latitude deremination were done by myself without using an artificial source of heat in order to establish the quality of the instrument and its constants. The constants had been communicated by the collaborators of the Military Geographic Institute (the instrument is its property) and the constants should have been verified once more in order to remove any hidden error of them. After measuring four series consisting of 10 stars pairs each, I obtained for the geographic latitude of Belgrade (taking into account the motion of the Pole) the following value

$$\varphi = 44^{0}48'13''.125 \pm 0''.013$$

On the basis of a comparison with the mean geographic latitude of the Belgrade Observatory derived from a vast number ($\approx$ 10 000) of measurements (Djurković et al., 1947).

$$\varphi = 44^{0}48'13''.170 \pm 0''.01$$

one can conclude that the instrument and its constants are of a good quality so that one can attribute the systematic deviations found in the analysis of the measurements performed in he field of a heat source to the temperature influence alone.

The temperatures at the northern and southern level terminals are denoted as t_n atn t_s, respectively and the middle of the bubble as c'. Let us see what will happen if $t_n > t_s$. The difference $t_n - t_s$ corresponding to the clump west will be denoted as t_w. As a first approximation one can assume that the thermomechanical influence of the temperature is refleced through the level holders which will be more intensively enlarged in the north than in the south and the level axis will be rotated clockwise. The bubble will be shifted, as a consequence, to the north from the point c'.

It is known that due to the thermohydrostatic influence of the temperature the bubble is shifted towards the warmer end (in our case to the north).

These two influences have the same sense and on account of this the bubble is shifted from the position c'_w to the position c_w.

We assume, as a first approximation, that the shift of the bubble Δc is proportional to the temperature difference

$$\Delta = \mathcal{H} \cdot \Delta t \qquad (2)$$

and we obtain

$$c_w = c'_w + \mathcal{H} \cdot \Delta t \qquad (3)$$

After observing the first star in a pair, the alhidade is rotated to the eastern position. If the condition $t_n = t_s$ is satisfied, and if the assumption given above that the alhidade axis is in the vertical direction is also satisfied so that no change of the telescope's position caused by other factors exists, the bubble should show

$$c'_o = c'_w \tag{4}$$

However, if a temperature difference between the level terminals is present, then one has

$$\Delta t_e = t_n - t_s \tag{5}$$

and since between two transits of a star the time intervla is between 4 and 20 minutes, a possibility arises that the bubble terminals take this temperature difference after the rotation. Because of this the bubble is shifted northwards from the position c'_e to c_e

$$c_e = c'_e - \mathcal{K} \cdot \Delta t \tag{6}$$

We start with the expression

$$\Delta\varphi = \frac{1}{2}(c_w - c_e) \cdot p'' \tag{7}$$

and we substitute the values c_e and c_w to obtain

$$\Delta\varphi = \frac{1}{2}(c'_w + \mathcal{K} \cdot \Delta t_w - c'_e + \mathcal{K} \cdot \Delta t_e) \cdot p''$$

and taking into account the equality $c'_e = c'_w$ we obtain

$$\Delta\varphi = \mathcal{K} \cdot p \frac{\Delta t_w + \Delta t_e}{2} \tag{8}$$

Since in the course of measurements two levels are used, the last expression may be rewritten as

$$\Delta\varphi = \mathcal{K} \cdot \frac{\Delta t_w + \Delta t_e}{2} \cdot \frac{p_e + p_w}{2} \tag{9}$$

where p_e is the constant of the level with smaller scale numeration and p_w is the constant of that with larger scale numeration. The temperature coefficient denoted as $E = \frac{p_e + p_w}{2}$ after substituting into (9) yields

$$\Delta\varphi = \frac{1}{2}(\Delta t_w + \Delta t_e) \; E \tag{10}$$

As seen from (10) the temperature errors of the level act as systematic errors and their influence preserves its sign as long as the sing of the temperature difference is unchanged

$$t = t_n - t_s \tag{11}$$

With regard to all what has been said above it is seen that one has to take into account the temperature influence in the calculation of the geographic latitude in the following way

$$\varphi = (\varphi) - \frac{1}{2}(\Delta t_w + \Delta t_e) \cdot E \tag{12}$$

The temperature coefficient is derived from (12) and the values of φ and E are calculated from direct measurements by applying the smoothing method (Sardy, 1967).

These Syrdy's ideas appear as an immediate source of a serious difficulty when they are directly applied in such a way that one should measure the temperature difference at the level terminals. In addition, a different temperature affects evidently the position of the vision line by amounts one cannot registrate separately .The complexity of measuring minor temperature differences and of the choice of points at which the temperature difference was measured, the impossibility of separation between the hydrostatic and thermomechanical effects arising within a level under the temperature influence on the one side and the fact proved by measurements that a certain proportionality between the duration of heating and the motion of the bubble exists, on the other side, give a possibility to propose such a relation

$$\Delta\varphi = E \cdot \Delta T \tag{13}$$

where T is the time interval during which the level is exposed to a thermal source; E is the proportionality coefficient; $\Delta\varphi$ is the systematic deviation in the geographic latitude due to the thermal source influence.

When the latitude is measured by use of Talcot's method, the time intervals T are known as the right ascension defferences between two pairs and $\Delta\varphi$ one can obtain from the difference between the latitude obtained from the measurements performend under the „normal" conditions and the latitude measured in the presence of the thermal soruce.

In the reductions of the measurements carried out by using Talcot's method in the field of a thermal source the inclination influence is computed in three ways: a) the classical one; b) only the second level reading for the first star and the first level reading for the second star are used; c) only the first reading for the first star and the second reading for the second star are used.

The three ways are justified because: in the case b) the influence of the thermal source must be logically minimal and vice versa in the case c). The last assumption is quite evident from the comparisons of individual latitude values determined in the three ways (Table 1).

There were 10 such series from both sides (southern and northern) with both warm and cold air from the thermal source (an electric heater of 2000 W power situated at a distance of 2 m from the instrument).

Table 1.

	φ_a	φ_b	φ_c
	10."964	9."459	12."468
	11."120	10."900	11."187
	9."759	9."346	10."172
	10."419	9."873	10."966
	11."474	10."368	12."580
	7."850	7."790	7."910
	9."639	9."446	9."872
	11."200	10."401	11."998
	10."680	9."877	11."384
	10."884	10."843	10."923
	11."962	10."897	11."026
	10."004	9."998	10."012
	12."161	12."152	12."169
	11."941	11."918	11."985
	11."482	11."467	11."498
mean values	10."569	10."182	10."943

The results presented in Table 2 are obtained by use of the least–square method from (13) using the three conditions mention ed above a), b), c).

If the basic assumption concerning the proportionality of E with time were absolutely correct, then all the systems would yield the same solution. However, since this is not the case and the analysis of the laboratory examinations points out existence of a certain thermal inertia, a question of if it should be also incorporated into (13) arises by itself. Simultaneously with the observations laboratory examinations of the levels were also carried out under various thermal conditions which will be a subject of another contribution.

This quantity is naturally included in E as a sum, hence it is possible by using (13) to form a following equation

$$\Delta\varphi = E(\Delta T + \gamma) \qquad (14)$$

and the correction equations then become:

$$\Delta\varphi - E(\Delta T + \gamma) = \nu_i$$

By applying ghe well–known procedure based on the least–square method one obtains the normal equations whose solution is

$$E = \frac{[\Delta\varphi]}{n\gamma + [T]}$$

$$\gamma = \frac{[\Delta\varphi]\ [\Delta T\ \ \Delta T] - [\Delta\varphi\ \ \Delta T]\ [\Delta T]}{n\,[\Delta T\ \ \Delta\varphi] - [\Delta T]\ [\Delta\varphi]}$$

The values presented in Table 3 are obtained by using these expressions. The differing values of the thermal inertia are probably due to the way of formation of the correction equations.

It may be not quite correct to determine the coefficients T from the right ascension differences within a pair, because both the level and the instrument are in the field of the thermal source during the whole series. Nevertheless, its value derived from the equations formed from the normal reductions is approximately equal to that resulting from the laboratory measuremens. By comparing the solutions of (13) and (14) one reaches the conclusion that the mean value determined from (14) is closer to the real one than that obtained from (13). This fact indicates the correctness of the assumption concerning the corresponding influence of the thermal inertia. In Table 4 the values of the geographic latitude calculated by using (13) and (14) and by applying the conditions a), b) and c) are presented together with their comparisons to the mean

Table 2.

E_a	ϵ_a	E_b	ϵ_b	E_c	ϵ_c	φ_a	φ_b	φ_c
0.105	± 0.011	0.111	± 0.016	0.100	± 0.009	12."984	12."950	12."874

Table 3.

E_a	γ_a	ϵ_a	E_b	γ_b	ϵ_b	E_c	γ_c	ϵ_c
6.905	0.085	± 0.084	12.351	0.078	± 0.068	2.883	0.091	± 0.075

Table 4.

φ_a	ϵ_a	φ_a'	ϵ_a	φ_b	ϵ_b	φ_b'	ϵ_b	φ_c	ϵ_c	S_c'	ϵ_c'
12."984	± 0."141	13."009	± 0."116	12."916	± 0."209	13."002	± 0."123	12."739	± 0."386	12."997	± 0."128

value for the geographic latitude of $\varphi = 44^o48' 13''125$ (the position of the instrument with which the observations were performed.

CONCLUSION

On the basis of the complied observational material one can reach a reliable conclusion that in calculations of the geographic latitude temperature gradients should be certainly taken into account and their influence should be determined. The following formulae are proposed

$$\varphi_i = \varphi_o + \Delta\varphi = \varphi_o + E \cdot \Delta T$$
$$\varphi_i = \varphi_o + \Delta\varphi' = \varphi_o + (E + \Delta E) \cdot \Delta T$$

where φ_o is the mean geographic latitude of the site where the instrument is situated. The linear temperature increase indicates a dependence between the motion of the bubble and the temperature difference depending on the room temperature. This is nothing else than a relative enhancement of the thermal source which produces the temperature difference existing at the level terminals.

A significant displacement of the bubble even at small temperature differences at the level terminals, indicates a serious danger for measurements as a systematic influence, if they are performed in the presence of a thermal source, even if its intensity is very small (proximity of a heated wall, warm or cold wind from one direction, etc.). This ultimately requires that an observer must carefully choose the site of measurements (to avoid any near objects with possible radiation) take into account the direction intensity and the difference between the air temperature and the temperature of the instrument.

Any protection of levels by using various thermoisolating materials has given, according to my laboratory examinations, no reliable results. However, it is a quite different situation if a total isolation from currents and radiations by inserting distant envelopes with glass windows for level reading can be provided.

The analysis of the tendence shifting the bubble in the thermal field on time points out that in shorter time intervals (less than 20 minutes) one can assume that the shift is proportional to the time. This property may be used in some measurements (for example measuring the geographic latitude by application of Talcot's method) for the purpose of calculating the proportionality coefficients and through the latter one also the systematic deviations of the measured values.

In such calculations a special care should be devoted to the time coefficients for which is desirable to be corrected for the amounts of the thermal inertia. A good knowledge of this quantity is possible only if careful laboratory examinations of it comprising a sufficeint number of measurements have been carried out.

ACKNOWLEDGEMENT

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REFERENCES

Alpar, Dđ.: 1967,*Geodezia es Kartografia*, Budapest, **19**, 2, p 81.

Drodofsky, S: 1956, *Deutsche Geodesche Kommision* (Reihe C. Heft Nr. 17).

Barnes, G.L.: 1966, *Bull. Geodesique*, 81.

Djurković, P., Ševarlić, B., Brkić, Z.: 1951, *Publ. Astron. Obs. Beograd*, **4**.

Orlov, A.J.: 1961, *Izbranije Trudy*, Tom II.

Sardy, A.: 1967, *Epitoipari es kol. Muzaki egyetem Tudomanyos kozlemenyel*, Budapest, VII, 2.

Tovchigrechko, S.S.: 1965, *Izd. Komitet standard. Priborov SSSR*, Moskva.

Wanach, B.: 1926 *Zeit fur Inst.* XLVI, Jahrang, funftes Heft.

Bull. Obs. Astron. Belgrade N° 140 (1989), 37–42. UDC 520.254 : 520.2.028
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FLEXURE OF THE BELGRADE LARGE VERTICAL CIRCLE IN THE PERIOD 1976–1980

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SUMMARY: In the present paper an analysis of the variations in the flexure of the Large Vertical Circle of Belgrade Observatory between 1976 and 1980 is given.

The examinations show a very prominent temperature dependence a significant variation during an observation night, and a dependence on observers and on quality of measurements; no dependence on meteorological parameters such as the pressure and humidity, as well as on weather conditions under which the measurements were made (cloudiness, wind, etc.) was found. Seasonal variations, being most prominent during the autumn season, are found.

The most important systematic influences are collimator displacement and the tube refraction.

The accuracy of the flexure determination is $\epsilon_b = \pm 0''.22$.

1. INTRODUCTION

During the period 1976–1980 together with the compilation of the Absolute Declination Catalogue of 308 Bright Northern Stars (declination zone +65° – +90°) on the Large Vertical Circle (LVC) of Belgrade Astronomical Observatory, the fluxure determination with collimators (d = 80 mm, f = 1000 mm) situated horizontally east and west of the instrument was carried out. The preliminary results of these determinations (including measurements carried out by October 1979) were published by Mijatov and Bozhichkovich (1982).

In the present paper the results of the deterination including the whole period are given and an analysis of the flexure dependence on observers, weather conditions under which the measurements were made, quality of the measurements, variations during an observation night, as well as on seasonal variations, is carried out.

2. OBSERVATIONAL DATA

In the period from March 1976 till the end of 1980 a total of 263 flexure determinations were realised. They were done almost every observation night when observations for the Catalogue were performed, and during a few nights only the flexure was measured. Before the beginning of every determination the internal temperature and the humidity were measured, whereas the pressure was measured at the beginning and the end of the observation night. The atmospheric conditions (clearness, wind etc.) were noted, too.

In Table 1 the number of flexure determinations regarding to observers and the year of determination is given.

In the columns with two observers the first one was setting the collimators and also was setting the telescope to the collimators and the second one was reading the

Table 1

Year	OBSERVERS MM, DB	DB	MM, BK	MM,MD	MM	DT, BK	BK	Total
1976	–	–	10	9	5	3	2	29
1977	84	–		–	–	–	–	84
1978	25	31		–	–	–	–	56
1979	38	28		–	2	–	–	68
1980	16	10		–	–	–	–	26
1976–1980	163	69	10	9	7	3	2	263

OBSERVERS: MM – M.MIJATOV, DB – DJ. BOŽIČKOVIĆ
BK – B. KUBIČELA, MD – M.DAČIĆ, DT – DJ. TELEKI

circle and the levels. The duration of a series was about 20 minutes when two observers were working and about 30 minutes when there was only one observer.

Unlike the other years in 1976 the flexure was determined by many observers with a small number of determinations. This circumstance, as it was found later on has significantly reduced accuracy.

In Table 2 the number of flexure determinations distributed by the seasons is presented.

The major part of determinations, as seen from Table 2, was performed during springs or summers.

In Fig. 1 the flexure values b_i measured during the observation period are presented.

Table 2

Year	MONTHS I–III	IV–VI	VII–IX	X–XII	Total
1976	–	16	13	–	29
1977	22	34	26	2	84
1978	3	6	36	11	56
1979	13	24	18	13	68
1980	4	7	–	15	26
1976–1980	42	87	93	41	263

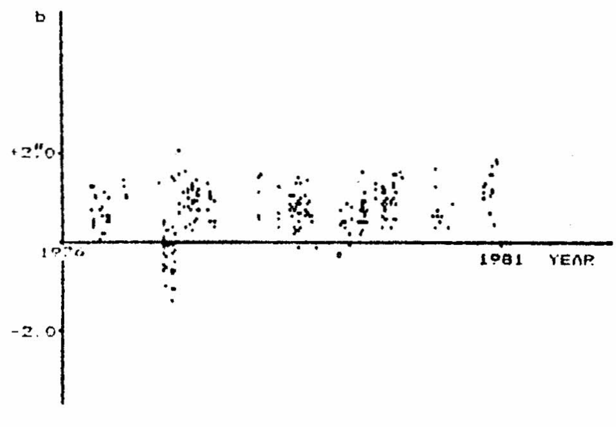

Fig. 1.

The values b are within the limits $-1''.3$ and $+2''.1$, but they are mostly positive. The values b corresponding to the first falf of 1977 are mostly negative, thus the flexure in that year was anomalous compared to the other years.

The temperature range was between $-7.8^{o}C$ and $+24.5^{o}C$.

3. DETERMINATION ACCURACY

The random error of a single flexure determination ϵ_b is obtained from the difference of two successive determinations b_{EW} and b_{WE} during a single series of measurements.

In Table 3 the mean systematic differences $\overline{\Delta b} = \overline{b_{EW}} - \overline{b_{WE}}$ and ϵ_b are presented. The latter one is calculated according to the relation

$$\epsilon_b = \pm\, 0.625 \frac{\sum_{i=1}^{n} \mathrm{abs}\,(\Delta\, b_i')}{n}\,, \qquad (1)$$

where $\Delta b'_i$ – are the values $(b_{EW} - b_{WE})_i$ released from the mean systematic difference $\overline{\Delta b}$ from Table 3 and n – is the number of differences.

Table 3

Year	$\overline{\Delta b}$	ϵ_b	n
1976	$+0''.06 \pm 0''.15$	$\pm 0''.37$	29
1977	$+0.14 \pm 0.06$	± 0.24	84
1978	$+0.09 \pm 0.05$	± 0.20	56
1979	$+0.12 \pm 0.04$	± 0.17	68
1980	$+0.09 \pm 0.06$	± 0.14	26
1976–1980	$+0.11 \pm 0.03$	± 0.22	263

As seen from Table 3 the measurements performed in 1976 are well below the necessary accuracy and this is a consquence, as has been already said, of a large number of observers with a small number of determinations. In the other years the accuracy is at the accuracy level obtained by applying this method on meridian isntruments of similar characteristics. Increasing of the accuracy from year to the year may be attributed to the increasing experience of observers. The accuracy for the whole period is $\epsilon_b = \pm\ 0''.22$ and if the year 1976 is excluded the accuracy is $\epsilon_b = \pm\ 0''.19$. The existence of the systematic difference Δb demonstrates primary that a displacement of the collimators was present (Mijatov, 1971–1972).

4. ANALYSIS OF THE DATA

Soon after the first considerations of the observational material it was clear that a prominent dependence of the flexure on the temperautre exists. This dependence is presented in Fig. 2 and as seen it is approximately linear. After smoothing this fact became more strongly confirmed.

In order to determine this influence we haved used the linear relation

$$b_i = b_o + \alpha(T_i - T_o) \qquad (2)$$

where is $T_0 = (\Sigma T_i)/n$. The values of the unknown values b_0 and α are derived by using the least–square method where $T_0 = +12.9^{\circ}C$. From 263 conditional equations of the form (2) we obtain the following values of the unknown quantities: $b_0 = +0.69 \pm 0.03$ and $\alpha = +0.04 \pm 0.01$. The obtained correlation coefficient $r = 0.42$ indicates that the presentation of the obtained data by a linear relation is quite satisfactory. Such a temperature influence on the fluxure ($0''.04/1^{\circ}C$) has been also obtained for other meridian instruments of similar characteristics. This fact is an indication of its reality

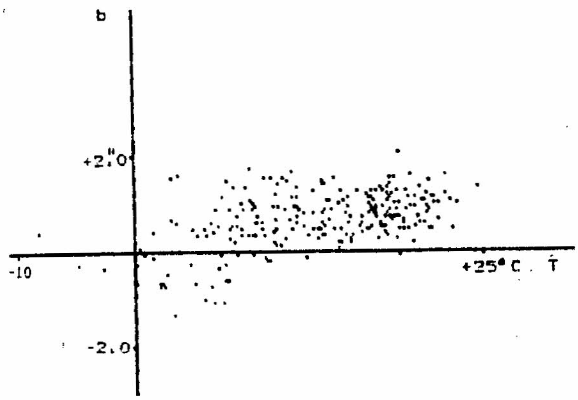

Fig. 2.

A dependence on other meteorological parameters such as the pressure and the humidity is not noticed.

The residuals $\nu_i = b_i - b_0 - \alpha(T_i - T_0)$, as well as the values $\Delta b_i = (b_{EW} - b_{WE})_i$ and b are subjected to various examinations: the determination of differences among the observers, the determinations of variations due to different atmospheric conditions and different measurement gradings, as well as the determination of variations occuring during an observation night. It is possible to carry out these examinations since we have established that the different systematic differences derived from the existing observational material do not practically affect the determination of other ones.

The difference among the observers is determined only for the observers MM, DB and DB (Table 1), because they performed the major part of the measurements (about 90%). This difference is determined from the measurements performed between 1978 and 1980 only when the two observers were engaged.

Table 4

OBSERVERS	$\bar{\nu}$	$\overline{\Delta b}$	ϵ_b	n
MM, DB	$-0''.27 \pm 0''.06$	$+0''.08 \pm 0''.04$	$\pm 0''.18$	79
DB	-0.01 ± 0.04	$+0.14 \pm 0.04$	± 0.18	69

In Table 4 the values $\bar{\nu}$, $\overline{\Delta b}$, ϵ_b and n for the observers are presented.

The systematic difference between the observers MM, DB and DB of $\Delta = -0''.26 + 0''.07$ may be considered as a real one because it is obtained within the accuracy limits and also when it is determined for each year separately. The collimator displacement (values Δb) had a larger influence on the flexure determination by the observer DB. This is understandable bearing in mind that the duration of the determination was longer. The determination accuracy b is the same in both cases.

Variations in the flexure can also arise due to the actions of various atmospheric parameters during the measurements. The variations arising in the conditions: clear, partially cloudy, calm and wind are here considered. In Table 5 the values $\bar{\nu}$, $\overline{\Delta b}$, ϵ_b and n corresponding to different combinations of these conditions are presented.

Table 5

CONDITIONS	$\bar{\nu}$	$\overline{\Delta b}$	ϵ_b	n
CLEAR, CALM	$+0''.02 \pm 0''.04$	$+0''.12 \pm 0''.04$	$\pm 0''.22$	135
CLEAR, WIND	$+0.02 \pm 0.07$	$+0.14 \pm 0.07$	± 0.23	59
PARTIALLY CLOUDY CALM	$+0.01 \pm 0.07$	$+0.05 \pm 0.05$	± 0.19	54
PARTIALLY CLOUDY WIND	-0.21 ± 0.18	$+0.29 \pm 0.14$	± 0.21	12

As seen from Table 5 a change in ν occurs only when measurements are performed in a partially cloudy and windy weather. This change cannog be considered as quite real, because it is determined from a small number of measurements, though it is in principle possible bearing in mind the influence of the wind on the instrument and collimators which is confirmed by the increased value of Δb. One may claim: since the wind does not cause changes when the weather is clear, nevertheless there are no changes depending on the mentioned atmospheric conditions.

The values of $\bar{\nu}$, $\overline{\Delta b}$, ϵ_b and n as depending on the measurement gradings (bad, satisfactory, good and very good) are given in Table 6 These gradings are derived on the basis of the behaviour of the instrument and collimators in the course of every series.

Table 6

MEASURING GRADING	$\bar{\nu}$	$\overline{\Delta b}$	ϵ_b	n
BAD	$+0''.14 \pm 0''.06$	$+0''.32 \pm 0''.09$	$\pm 0''.36$	66
SATISFACTORY	$+0.05 \pm 0.05$	$+0.09 \pm 0.04$	± 0.19	97
GOOD	-0.12 ± 0.06	-0.02 ± 0.04	± 0.15	62
VERY GOOD	-0.18 ± 0.08	$+0.04 \pm 0.03$	± 0.10	38

The flexure variation for different gradings from bad to very good ones has a continuous trend of decreasing the values $\bar{\nu}$ and the total variation is greater than $0''.3$. On the reality of the obtained systematic differences one can, at present, say nothing reliable. A final statement will be possible only after their application to stellar observational data. However, one should here specially-emphasize that if these systematic differences are real and the observational data are corrected by their application for one or a group of gradings, one will be able to answer the question of what kind of selection should be applied to the flexure values in the future. If the determinations are bad, the values $\overline{\Delta b}$ and ϵ_b are significant, whereas in the case of the other gradings these values are smaller than the corresponding values for the whole period.

In their preliminary results Mijatov and Bozhichkovich (1982) found a significant change in the flexure during an observation night which can attain even 0.4. In order to examine this effect more thoroughly we order the values ν_i also according to the time interval t_m between the end of the twilight (moment of the sunset plus 0.5 hours) and the moment of determination of the flexure. The end of the twilight is assumed as the beginning of the time calculation t because this is the moment when the stabilization of the ambient conditions begins after the end of the insolation period and in the further course of a night the stability of the ambient conditions is growing. The observational material makes possible to follow the flexure change during a night within time intervals longer than seven hours. In Fig. 3 the dependence ν_i from t_m is presented.

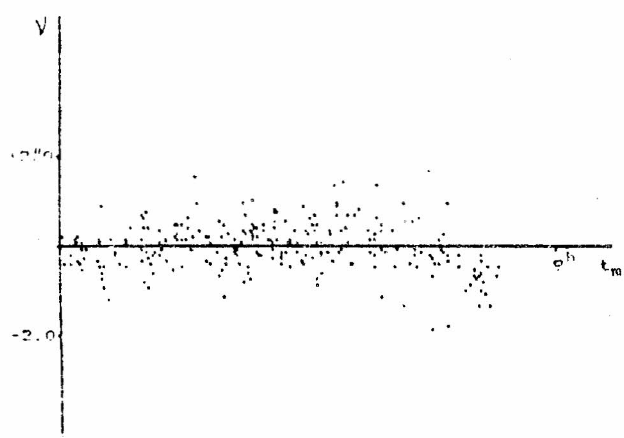

Fig. 3.

As seen this dependence has approximately a parabolic character being more confirmed by smoothing and thus we decide to determine the change of ν_i from t_m from a quadratic equation

$$\nu_i = a_o + a_1\, t_m + a_2\, t_m^2 \, . \tag{3}$$

By applying the least–square method one obtains the values of the unknown coefficients from 263 conditional equations: $a_o = -0.26 \pm 0.09$, $a_1 = +0.22 \pm 0.05$ and $a_2 = -0.03 \pm 0.01$. On the basis of the value of the correlation coefficient $r = 0.33$ one can say that the presentation of the dependency by a quadratic relation is quite satisfactory.

The curve representing the variation of ν_i from t_m is presented in Fig. 4.

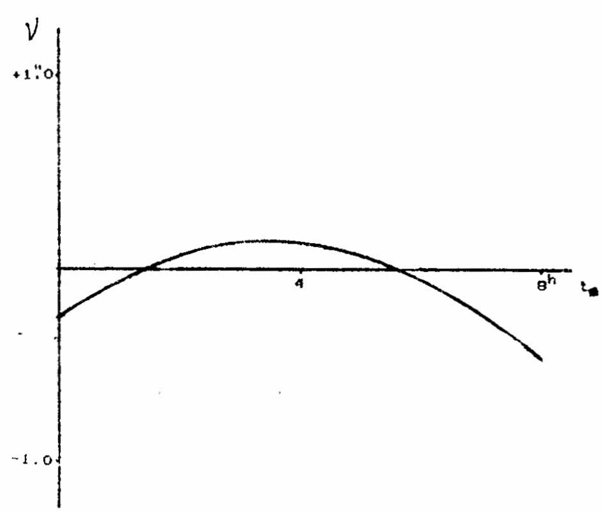

Fig. 4.

The maximal flexure change during a night according to Fig. 4. at the intervals t_m at which the measurements were performed is equal to about 0.5.

The values $\overline{\Delta b}$, ϵ_b and n corresponding to different time intervals t are given in Table 7.

Table 7

t_m	$\overline{\Delta b}$	ϵ_b	n
0–1	$+0''.33 \pm 0''.11$	$\pm 0''.32$	26
1–2	$+0.15 \pm 0.10$	± 0.22	35
2–3	$+0.16 \pm 0.08$	± 0.24	32
3–4	$+0.02 \pm 0.07$	± 0.22	48
4–5	$+0.01 \pm 0.08$	± 0.22	43
5–6	$+0.06 \pm 0.07$	± 0.19	31
6–7	$+0.17 \pm 0.10$	± 0.27	23
7–8	$+0.11 \pm 0.06$	± 0.17	25

The maximal values of b correspond to the first hour of determinations and the minimal ones correspond to the interval $3^h - 6^h$. One should point out that after 6^h the values of $\overline{\Delta b}$ are enlarged, i.e. the action of the factors strengthening the instability of the collimators begins. The values of b are also maximal within the first hour of determinations and within other intervals they are at the accuracy level for the whole period. Since there is a significant systematic influence of the collimator displacement on the flexure determination during the first hour as well as a small accuracy, one should avoid measuring at the beginning of an evening.

Since determinations evaluated with had gradings possess significant deviations from the mean value for the whole system ($\bar{\nu}$ = 0) and the measurements were performed with a low accuracy and with a significant systematic difference Δb, a question of to what degree their elimination from the whole observational material contributes to their improvement arises.

The temeprature effect derived from 197 conditional equations of form (2) after exclusion of measurements with bad gradings for T = 13.3°C yields the following values of the unknown quantities: b_o = +0.75 ± 0.04 and α = +0.03 ± 0.01. As seen the sample without bad determinations has a temperature influence smaller by about 25%.

Bearing this in mind we decided to carry out all the examinations done with the residue also with a sample without bad measurements. The results obtained for the change of the flexure on the basis of the whole observational material are also confiremed on this sample. Only the values of Δb and ϵ_b, as could be expected, are somewhat smaller for the sample than in the case of the whole observational material.

We suppose that the obtained systematic differences between the two groups of observers as well as, those arising from the determination gradings, are consequences of the systematic measuring errors in the following way: in the first case above all because of the difficulties in mutual setting of the collimators; in the second one because of different actioons of – above all – the collimator shifting and instrumental errors. The variations during a night, as will be seen, may be to some degree attributed to the tube refraction action.

In their paper Høg and Miller (1986) demonstrated that the flexure determinations for the 6–inch meridian circle of the U.S. Naval Observatory were not free from a systematic influence due to the tube refraction. This influence can be according to them represented by the following expression.

$$b_i = c_o + c_1 \, \mathrm{abs}(\dot{T}_i), \qquad (4)$$

where c_o is the mechanical flexure, c_1 abs $(\dot{T}_i)$ is the influence looked for and $\dot{T}_i$ is the change of the temperature with time for a certain value of b_i. Instead of b_i we use in (4) the values of ν_i obtained earlier, but in that case for the mechanical flexure one obtains a value less by the amount of the mean flexure b_o from (2).

The values of $\dot{T}$ are determined from the temperature change in the course of time at different values of t_m. In order to obtain the values of $\dot{T}$ we use the temperatures measured during observation nights when the flexure was determined. The dependence of $\dot{T}$ on t_m is presented in Fig. 5. The values of $\dot{T}$ are very prominent for the first three hours of t_m to become only slightly changed afterwards.

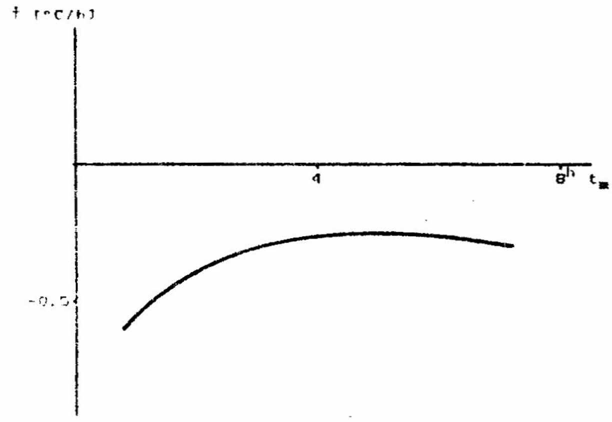

Fig. 5.

By applying the least–square method we obtain the values of the unknown quantities from 263 conditional equations of the form (4): c_o = +0.17 ± 0.11 and c_1 = –0.48 ± 0.29; this means that the mechanical flexure b = 0.86 ± 0.11 and the refraction influence is equal to –0.48 abs ($\dot{T}$). Since $\dot{T}$ is varied within the limits – 0.60 °C/h and –0.25°C/h, the maximum refraction infulence can attain about 0."3 and its variation about 0."2.

The flexure variations during an observation nihgt in the course of first five hours of t_m (Fig. 3) agree sufficiently well with the flexure variations due to the tube refraction and therefore the may be, to a somewhat degree, explained by existence of this influence. However, the promient variation appearing afterwards, especially after six hours of t, cannot be explained by this influence only, since there are probably additional significant systematic influences in this part of the observation nihgt – first of all – the collimator shifting having been already established by an enlarged value of b.

The annual seasonal variations derived from the whole period (Fig. 6) are determined from the values of ν corrected for the difference between the two observer teams, systematic differences due to the determination gradings and to the variations during the observation night.

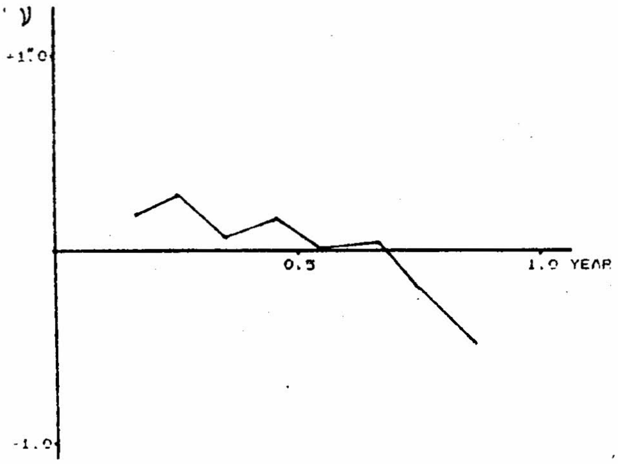

Fig. 6.

As seen, the seasonal variations in the first half of a year except January, when there were no measurements, are about +0."2 with slight fluctuations; from July to the middle of September there are almost no fluctuations, and than beginning with the midseptember a singnificant variation appears attaining −0."5. Therefore, the most significant variations occur during the autumn season and the largest variations at a season change are those occuring between autumn and winter.

5. CONCLUSION

The examinations of the LVC flexure show that determinations of this quantity realised with collimators situated horizontally are not free from random and systematic errors being especially prominent in measurements performed in the beginning of an evening. The influences due to the collimator shifting and tube refraction are specially expressed. Therefore, in future flexure determinations one should avoid measuring in first evening hours when the temperature field is still unstable and subject to rapid variations. Among significant systematic errors of determination is also the difference between the observer teams. In order to remove this influence it is necessary to carry out observations with a reversing prism in the future. In the present measurements it was not the case. The dependence of the flexure on the determination grading requires, as has been already said, additional examinations. The flexure variations during a night found here are explained, to a larger degree, by tube refraction action, but to give a complete explanation of this important phenomenon it is necessary to continue the examinations in this direction.

We hope that the application of the obrained systematic differences will improve the system of measured flexure values and in this way achieve a better accuracy of determinations of absolute declinations of celestial bodies with this instrument.

ACKNOWLEDGEMENT

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REFERENCES

Høg E., Miller R.J.: 1986, *Astron. J.*, **92**, 495.
Mijatov M.: 1971–1972, *Bull. Obs. Astron. Belgrade*, **125**, 19.
Mijatov M., Bozhichkovich Dj.: 1982, *Bull. Obs. Astron. Belgrade*, **132**, 3.

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Original scientific paper

RELATIVE PROPER MOTIONS OF COMPONENTS OF 16 TRIPLE STAR SYSTEMS

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SUMMARY: By comparing the proper motions determined from meridian measurements with the relative proper motions obtained from rectilinear trajectories it is concluded that out of 16 examined triple systems 11 systems have at least one optical component.

1. INTRODUCTION

Compiling a catalogue of triple star systems with physically connected components is the first task in analysing dynamical states of these systems. The statistical criterion of component connexion (Anosova, 1987), unavoidable in a compilation of such a catalogue, requires a complete, or almost complete, set of observational data on each component. Gathering such a set of data on multiple systems is not a simple task. Therefore, use of an accessible procedure may be also justified in a preliminary analysis of the component membership to a triple system.

The procedure used in the present paper is based on a complete series of relative measurements (θ, ρ) for the components of a pair examined and on the knowledge of the proper motion determined from meridian observations. In this way there is no waste of time in gathering the data for systems being most likely of no interest and the study is devoted to real and interesting cases.

2. THE PROCEDURE OF PRELIMINARY DETERMINATION OF COMPONENT NONMEMBERSHIP TO A STAR SYSTEM

The act of establishing of relative rectilinear uniform motion for two components within a system has been considered as a confirmation of their physical independence. In most cases this is correct. However, a short segment of the trajectory of physically connected components within a system may be approximated by a relative rectilinear uniform motion.

As a more rigorous nonmembership criterion for a component in a system it is here proposed assuming a „fixed" component and the transit of another component (or a pair) in a uniform motion along a rectilinear trajectory with respect to the fixed component. In other words it is expected the relative proper motion of a component and the proper motion obtained for this component from meridian measurements to be parallel. The opposite case is an indication that both components possess significant proper motions which can be due to their proximity in space. It is finally proposed as a nonmembership criterion existence of a distant „fixed" component and a close component whose proper motion is reliably registrated.

By adding to the series of relative triple–system measurements new observations measurement series comprising an observational period of almost 200 years are obtained. This fact gives a high weight to the derived relative proper motions.

It is necessary to decide to what limit the parallelness of the two proper motions can be established.

The errors of determinations of relative proper motions depend on the accuracy of the observational material and on the length of the observed trajectory part. As a well defined one we can consider a trajectory which will not deviate from its direction by more than a few degrees after further corrections and at the same time the error of the ratio of the propr motions – as defined below – does not exceed 0.20. These criterria are in accordance with the limits of proper–motion errors given usually in catalogues.

We assume that the two proper motions (relative and meridian one) are „in accordance" if the following conditions are fulfiled:

$$\sigma_\mu = \frac{|\Delta\mu|}{\mu_{(rel)}} = \frac{\mu_{(rel)} - \mu_{(mer)}}{\mu_{(rel)}} \leqslant 0.20$$

$$\Delta\phi = |\phi\,(rel) - \phi\,(mer) \leqslant 10^{\circ}. \qquad (1)$$

ϕ is the proper–motion position angle.

Table 1. Comparison of relative proper motion to proper motion derived from meridian observations

ADS	μ (rel.)	μ (mer.)	Source	$\Delta\mu$	$\Delta\phi$	σ_μ	d
2681 AC	A: 0″.032 in 137.3 (1950)	A: 0″.034 in 130°.2	IDS	−0″.002	7°.1	5.9	5″.1
6364 AB	A: 0.019 in 194.0 (1950)	A: 0.040 in 171.3	ADS (Yale)	−0.021	22.7	110.5	2.9
		A: 0.015 in 246.4	BDS	0.004	−52.4	26.7	
		A: 0.035 in 200.0	IDS	−0.016	− 6.0	84.2	
8100 AB	A: 0.421 in 285.8 (1950)	A: 0.406 in 285.4	ADS (Yale)	0.015	0.4	3.5	66.0
		A: 0.442 in 287.9	BDS (Porter)	−0.021	− 2.1	5.0	
		A: 0.425 in 285.4	BDS (Kustner)	−0.004	0.4	1.0	
		A: 0.406 in 283.2	IDS	0.015	2.6	3.5	
8440 AC *	A: 0.323 in 106.9 (1950)	A: 0.345 in 117.9	ADS (Cin 0 18)	−0.022	−11.0	6.8	50.6
		A: 0.348 in 120.4	BDS (Porter)	−0.025	−13.5	7.7	
		A: 0.327 in 121.3	BDS (Rad)	−0.004	−14.4	1.2	
		A: 0.379 in 122.0	IDS	−0.056	−15.1	17.3	
8601 AC	A: 0.222 in 117.2 (1950)	AB: 0.183 in 120.4	ADS (Com)	0.039	− 3.2	17.6	27.7
		AB: 0.197 in 121.1	IDS	0.025	− 3.9	11.3	
9136 AC	A: 0.169 in 262.5 (1950)	AB: 0.195 in 255.1	BDS	−0.026	7.4	15.4	13.3
		AB: 0.166 in 253.5	IDS	0.003	9.0	1.8	
9969 AC	A: 0.469 in 157.8 (1900)	AB: 0.464 in 156.9	ADS (Cin 0 19)	0.005	0.9	1.1	62.8
		AB: 0.448 in 159.4	BDS (Auwers)	0.021	− 1.6	4.5	
		AB: 0.459 in 159.6	BDS (Bossert)	0.010	− 1.8	2.1	
		AB: 0.433 in 160.5	BDS (Porter)	0.036	− 2.7	7.7	
		AB: 0.475 in 156.9	IDS	0.006	0.9	1.3	
10394 AB	B: 0.023 in 243.4 (1950)	B: 0.044 in 231.4	IDS	0.021	12.0	91.3	3.7
11632 AC **	A: 2.306 in 325.2 (1950)	AB: 2.307 in 325.3	ADS (Cin 0 18)	−0.001	− 0.1	0.0	50.8
		AB: 2.303 in 325.4	BDS (Stumpe)	0.003	− 0.2	0.1	
		AB: 2.286 in 324.5	BDS (Porter)	0.020	0.7	0.9	
		AB: 2.289 in 325.4	BDS (Kustner)	0.017	− 0.2	0.7	
		AB: 2.299	BDS (Krueger)	0.007	− 0.4	0.3	

Table 1 (continued)

ADS	μ (rel.)	μ (mer.)	Source	Δμ	Δφ	σ_μ	d
		in 325.6					
		AB: 2.286 in 325.4	IDS	0.020	− 0.2	0.9	
11811 AC	A: 0.058 in 341.2 (1950)	AB: 0.043 in 326.3	IDS	·0.015	14.9	25.9	6.2
11902 AB	A: 0.110 in 177.1 (1950)	A: 0.120 in 180.0	ADS (Cin 0 19)	−0.010	− 2.9	9.1	17.6
		A: 0.115 in 190.2	BDS (Auwers)	−0.005	−13.1	4.5	
		A: 0.111 in 187.6	BDS (Bossert)	−0.001	−10.5	0.9	
		A: 0.117 in 180.0	BDS (Paris)	−0.007	− 2.9	6.4	
		A: 0.132 in 165.5	IDS	−0.022	11.6	20.0	
11971 AC •••	A: 0.138 in 212.0 (1950)	A: 0.144 in 190.8	ADS (Cin 0 19)	−0.006	21.2	4.3	21.7
		A: 0.117 in 180.0	BDS (A.G. Nico)	0.021	32.0	15.2	
		A: 0.134 in 200.4	IDS	0.004	11.6	2.9	
		BC: 0.014 in 102.5	ADS (Comstock)				
		BC: 0.014 in 102.1	IDS				
12913 AC	A: 0.438 in 177.2 (1950)	AB: 0.433 in 178.0	ADS (Burnham)	0.005	− 0.8	1.1	44.1
		AB: 0.435 in 181.7	BDS (Auwers)	0.003	− 4.5	0.7	
		AB: 0.449 in 177.9	IDS	−0.011	− 0.7	2.5	
13886 AC	A: 0.340 in 101.0 (1950)	AB: 0.352 in 105.5	ADS (Cin 0 19)	0.012	− 4.5	3.5	29.0
		AB: 0.384 in 109.3	BDS (A.G. Ber.)	−0.044	− 8.3	12.9	
		AB: 0.351 in 102.0	IDS	−0.011	− 1.0	3.2	
14773 AB–C ••••	AB: 0.276 in 169.9 (1950)	AB: 0.321 in 172.6	ADS (Cin 0 19)	−0.045	− 2.7	16.3	25.5
		AB: 0.287 in 176.5	BDS (Stumpe)	−0.011	− 6.6	4.0	
		AB: 0.289 in 176.5	BDS (Auwers)	−0.013	− 6.6	4.7	
		AB: 0.379 in 166.2	BDS (Paris)	−0.103	3.7	37.3	
		AB: 0.320 in 169.9	IDS	−0.044	0.0	15.9	
15896 AC •••••	A: 0.316 in 90.4 (1950)	A: 0.336 in 93.2	ADS (Boss)	−0.020	− 2.8	6.3	49.2
		A: 0.317 in 93.4	BDS (Auwers)	−0.001	− 3.0	0.3	
		A: 0.318 in 90.2	IDS	−0.002	0.2	0.6	

Foot–note:

*BDS: The measurements of AC by Σ and β, 1831–1905, give for the p.m. of A, 0."321 in 107°4.

** The last measurement: 1926.65.

*** BDS: The measurements give 0."14 and a larger position angle (> 180°).
GP : There is a small systematic difference in $\Delta\theta$, which is impossible to avoid. $\Delta\rho$ satisfies the trajectory well.

**** BDS: μ_{AB} = 0."303 in 172°4 is derived from measures of the distant Herchel companion. The last measurement: 1925.72. The ephemeris for 1988.72: θ = 68°1, ρ = 65."5 (AB–C).

***** BDS: μ_A :(From measures of C) 0."324 in 90°9.

3. OBSERVATIONAL MATERIAL TREATMENT AND RESULTS

The series of triple–star–system measurements (Popović. Zulević, 1989) contains 16 systems for which determinations of rectilinear uniform motions are possible. The observations were performed during 1987 and 1988 and for a number previously done measurements they are important references since for many systems the observations ceased after the trajectories had been found as not elliptical. The measurements are reduced to a common epoch and the preliminary trajectory elements are corrected when necessary by applying differential corrections (Schlesinger, Alter, 1912). The relative proper motion of one component with respect to the other one derived here is compared to all existing proper motions of this component published in the three basic catalogues of double stars: BDS, ADS and IDS. The epoch of the latter data is not always the same as that to which the observational material is reduced. However, possible corrections which could result because of this are negligible in our case and therefore they are not taken into account.

The results of the analysis are presented in Table 1. The contents of the table columns are the following:

Column 1: ADS number and multiple of examined system pair;
Column 2: Relative proper motion of one component with respect to the other one – $\vec{\mu}$(rel.);
Column 3: Proper motions obtained from meridian measurements – their intensity and position angle – μ(mer.), ϕ(mer.);
Column 4: Source of data from column 3;
Column 5: Intensity differences $\Delta\mu = \mu(\text{rel.}) - \mu(\text{mer.})$
Column 6: Direction differences $\Delta\phi = \phi_\mu(\text{rel.}) - \phi_\mu(\text{mer.})$
Column 7: Relative error defined by (1) in %;
Column 8: Trajectory length from which the relative proper motion is derived in arc seconds: d

4. CONCLUSION

The following 11 systems from Table 1 satisfy criterion (1):

ADS 2681 AC	ADS 11902 AB
8100 AB	12913 AC
8601 AC	13886 AC
9136 AC	14773 AB–C
9969 AC	15896 AC
11632 AC	

and consequently they should be considered as optical ones. In the case of the other 5 systems:

ADS 6364 AB
8440 AC
10394 AB
11811 AC
11971 AB

the relative uniform motion of the examined pair components appears as their resulting motion and both components possess significant proper motions. Despite of this one can conclude that the proper motion one component is clearly more significant than that of the other one. This is in favour of the conclusion that also for these systems a physical connection between the examined components probably does not exist. One should also apply the criterion of Anosova (1988) to these systems if such an application is possible in view of the observational data.

REFERENCES

Anosova, J.P.: 1987, *Astrofizika*, 27, 535.

Aitken, R.: 1932, *New General Catalogue of Double Stars*, Carnegie Institution of Washington, Publ. No 417, Vol. I, II.

Burnham, S. W.: 1906, *A General Catalogue of Double Stars*, Carnegie Institution of Washington, Publ. No 5, P. I, II.

Jeffers, H.M, Bos van den W.H., Greeby, F.M.: 1963, *Index Catalogue of Visual Double Stars*, 1961,0, Publ. Lick Obs. XXI, P. I, II.

Popović, G.M., Zulević, D.J.: 1989, *Bull. Obs.Astron. Belgrade*, 140,

Schlesinger, F., Alter, D.: 1912, *Publ. Allegheny Obs.*, 2, 13.

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Preliminary report

THE INTERNAL STRUCTURE OF THE URANIAN SATELLITES: A PRELIMINARY NOTE

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SUMMARY: Preliminary results of a theoretical determination of the basic parameters of the internal structure of the five Uranian satellites are presented.

Four satellites of Urans were found by Sir William Herschel in 1781; the fifth was discovered by Kuiper in 1949. However, reliable values of their masses and radii were determined only recently, after the encounter of Voyager 2 with the Uranian system. By combining results of the Radio Science Team with the star–satellite imaging data and with 8 years of ground–based observations, it became possible to determine the radii and densities of the satellites with relative errors, n some cases, as low as 4% (Anderson et al., 1987). The best pre–Voyager results (Dermott and Nicholson, 1986) had relative errors going up to 45%. Such a situation has until recently severely hampered (Prentice, 1986; Anderson et al., 1987) any theoretical considerations of the internal structure and chemical composition of these bodies.

The purpose of this note is to present some preliminary results of a theoretical determination of the basic parameters of the internal structure of the five uranian satellites. The calculations were performed within a particular semiclassical theory of dense matter (Savić and Kašanin, 1962/65). Physically speaking, the main idea of this theory is that high pressure can cause excitation and ionisation of atoms and molecules; this process can be exactly treated quantum–mechanically. Various examples of astrophysical applications of this theory have already been published (such as Savić, 1981; Savić and Teleki, 1986, Čelebonović, 1988b and references given therein). A comparison of the predictions of this theory with high pressure experiments in diamond–anvil cells has recently given promissing results (Savić and Urošević, 1987; note that eq. (i) must be divided by 2).

The input data for the calculation (i.e., the masses and radii of the satellites) were taken from (Anderson et al., 1987). Starting from these data, and using the approach proposed by Savić and Kašanin, the following parameters of the satellites were derived:

Table 1

satellite	A(amu)	V (cm^3)	p* (kbar)	a(10^{-3}au)	ρ($g\ cm^{-3}$)
Titania	32 ± 2	19 ± 2	101 ± 3	2.9303	1.685 ± 0.008
Oberon	32 ± 1	20 ± 1	97 ± 4	3.9178	1.635 ± 0.060
Umbriel	44 ± 6	28 ± 8	60 ± 10	1.7860	1.58 ± 0.23
Ariel	43 ± 6	28 ± 8	62 ± 10	1.2820	1.55 ± 0.22
Miranda	38 ± 10	30 ± 16	55 ± 15	0.872	1.25 ± 0.33

The satellites are arranged in order of diminishing radii. A and V denote, respectively, the mean atomic mass and the molar volume under standard conditions of the material that a satellite is made of; the central pressure is denoted by p* and a is the semiaxis major of the satellite's planetocentric orbit (Allen, 1973).

Several qualitative conclusions can be drawn from the data presented in Table I.

One can, for example, compare the values of A derived in this note, with those obtained earlier for various other bodies in the planetary system (Čelebonović, 1988b and references given therein). It turns out that, by their values of A, the satellites of Uranus are situated between the Earth and Mars. However, their observed densities are 2–5 times lower than for the two planets, which can be interpreted as a result of the presence of a large proportion of ices (H_2O, NH_3, CH_4, . . .) in these satellites.

Another interesting result is the existence of gradients of A and ρ. Assuming that all the five satellites formed in the vicinity of Uranus, their present values of A and ρ reflect the distribution of ices and heavier chemical compounds in the uranian system at the time of formation. Details of these distribution functions are heavily model–dependent.

For example, in the so–called modern laplacian theory (Prentice, 1986 and references given therein, the satellites condensed from a system of orbiting gas rings that were shed by a gavitationally contracting parent envelope. This envelope disposes of its excess spin by sheding mass at the equator in discrete amounts and at discrete orbital radii. The temperature of the gas rings at the moment of detachement from the parent cloud varies with the sheding radius, and this could be the physical basis for explining the compositional gradient of the Uranian satellite system.

In the cosmogonical model proposed by Alfen and Arrhenius (Alfven, 1986; Alfven and Arrhenius, 1985 and numerous preceeding publications), the formation of planets and/or satellites is explained by invoking the so-called critical velocity, achieved by material falling towards a central body. This seems to account for the band structure of the planetary and most satellite systems. If the primordial Uranian proto-satellite cloud consisted of a mixture of ices and rocks, the critical velocity phenomenom could have easily led to the formation of two compositionally different groups of satellites. A detailed study of this process is in preparation.

REFERENCES

Alfven, H. and Arrhenius, G.: 1985, preprint TRITA–EPP–85–04.

Alfven, H.: 1986, *IEEE Trans. on Plasma Sci.*, **PS14**, 629.

Allen, C.W.: 1973, Astrophysical Quantities, Univ. of London, The Athlone Press.

Anderson, J.D., Campbell, J.K., Jacobson, R.A. et al.: 1987, *J. Geophys. Res.*, **92A**, 14877.

Čelebonović, V.: 1988b, *Earth, Moon and Planets*, **42**, 297.

Dermott, S.F. and Nicholson, P.D.: 1986, *Nature*, **319**, 115.

Prentice, A.J.R.: 1986, *Phys. Lett.*, **114A**, 211.

Savić, P. and Kašanin, R.: 1962/65, *The Behaviour of Materials Under High Pressure I–IV*, Ed. Serbina Academy of Sciences and Arts, Beograd.

Savić, P.: 1981, *Adv. Space* Res., **1**, 131.

Savić, P. and Teleki, G.: 1986, *Earth, Moon and Planets*, **36**, 139.

Savić, P. and Urošević, V.: 1987, *Chem. Phys. Lett.*, **135**, 393.

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Preliminary report

OBSERVATIONS OF THE SUN AND PLANETS WITH THE BELGRADE LARGE MERIDIAN CIRCLE

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SUMMARY: Results are presented of the Sun, Mercury, Venus and Mars observations made with Large Meridian Circle of the Belgrade Observatory in the period March 1987–Sept. 1988.

It is fifteen years now since systematic observations of the Sun, Mercury and Venus (and since January 1981, those of Mars) with the Large Meridian Circle of the Belgrade Observatory are going on.

The Observations are relative ones, the reference stars are taken from the FK4. The data treatment involved the circle division corrections, flexure, collimation and refraction calculated according to the Pulkovo Tables. No account is taken of the „day–night" corrections and the personal errors. One edge of the planets was observed if these were phased, otherwise both edges have been observed.

Before 1985 for the purpose of solar observatons a Sukharev filter was used and afterwards another one from high–quality glass.

Both edges–the front and the rear one in the right ascension – the lower and the upper one in the declination – were observed. Mercury was mostly observed by central bisection of its image. In those cases when the seeing was satisfactory, the part of the planet illuminated by the sunshine was observed. Venus was observed in the same way as the Sun, or only one edge. In both cases of Observing one edge only, the diameter correction was applied.

The ephemeris of the Sun, Mercury, Venus and Mars were calculated after 1987. We obtain ephemeris from Institute of Theoretical Astronomy, Leningrad.

The number of observations of the Sun and planets in the period 1987–1988 is presented in Table 1.

The temperature inside pavilion has been read off before and after the observation at two places, to the north and to the south of the instrument. Mean temperature has been used at reduction. Data treatment has been performed on a TEXAS 59.

The error of a single observation has been determined according to the formula

$$\epsilon_{(o-c)} = \pm\sqrt{\frac{\Sigma \nu_i^2}{n-1}}$$

where

ν_i – is the deviation (O–C) of the mean value for a particular period;

n – is the number of observations;

Table 1. Data on Observations

Object observ.	1987 N	1987 n	1987 K	1988 N	1988 n	1988 K
SUN	108	23	5	85	20	4
MERCURY	17	3	6	20	5	4
VENUS	92	20	5	75	18	4
MARS	7	2	4	11	2	6

N– the number of reference stars transits;
n – the number of observing tours;
K = N/n – the average number of reference stars transits per observing tours;

Mean yearly differences $(O-C)_{\alpha,\delta}$ for the Sun and planets; $\epsilon_{(o-c)}$–mean errors of single observations and n – the number of observations are sumarized in Table 2.

Table 2. (O–C) differences and their errors for the observed objects

Objects	years	$(O-C)_\alpha$	ϵ_α	$(O-C)_\delta$	ϵ_δ
SUN	1987	0.ˢ001	±0.ˢ027	–0.″04	±0.″29
	1988	0.012	±0.034	0.07	±0.40
MERCURY	1987	–0.031	±0.003	0.17	±0.34
	1988	–0.021	±0.057	0.00	±0.63
VENUS	1987	0.009	±0.032	–0.02	±0.34
	1988	0.020	±0.058	0.13	±0.56
MARS	1987	0.039	±0.008	0.02	±0.71
	1988	0.028	±0.047	–0.35	±0.02

Table 3. Data on the Sun Observations

Date of observ.	ob-serv.	B_a	t^oC	n	α	$(O-C)_\alpha$	δ	$(O-C)_\delta$	E_p	clamp posit.
1987									1900+	
26.03.	MD.ZS.	741.4	14.4	3	$00^h19^m15^s.192$	$0^s.014$	02°04' 55".52	0".19	87.23	E
03.04.	MD.ZS.	740.6	11.8	2	00 48 23.531	0.014	05 11 29.90	−0.16	87.25	E
08.04.	SS.MD.	741.8	18.1	6	01 06 39.885	−0.011	07 05 16.29	0.02	87.27	E
23.04.	SS.MD.	750.0	10.5	5	02 02 11.069	−0.047	12 25 38.25	−0.17	87.31	E
24.04.	SS.MD.	750.0	13.9	6	02 05 56.396	0.020	12 45 34.80	0.08	87.31	E
29.04	SS.ZS.	754.3	13.2	4	02 24 50.443	0.022	14 22 02.77	−0.01	87.33	E
13.05.	SS.MD	735.8	21.5	6	03 18 56.122	−0.006	18 18 27.00	0.52	87.36	E
02.07.	SS.MD.	742.1	28.0	6	06 43 40.688	0.001	23 03 45.61	−0.06	87.50	E
13.07.	MD.ZS.	742.7	27.0	4	07 28 47.280	−0.012	21 52 27.66	0.35	87.53	E
14.07.	SS.ZS.	743.9	27.2	4	07 32 50.803	0.066	21 43 40.77	−0.22	87.53	W
28.07.	SS.MD.	741.8	22.1	5	08 28 45.605	0.013	19 03 23.45	−0.33	87.57	W
16.09.	MD.	749.0	25.1	6	11 34 24.077	0.013	02 45 56.80	−0.10	87.71	W
01.10.	SS.MD.	748.8	13.6	4	12 28 20.256	0.012	−03 03 47.96	0.08	87.75	W
07.10.	SS.MD.	742.6	19.5	5	12 50 07.949	−0.014	−05 22 39.51	−0.15	87.77	W
09.10.	SS.MD.	745.0	18.1	3	12 57 26.819	−0.002	−06 08 27.60	−0.20	87.77	W
15.10	SS.MD.	744.6	17.2	3	13 19 34.954	−0.032	−08 23 47.04	−0.02	87.79	W
16.10.	SS.MD.	743.6	19.5	5	13 23 18.193	0.021	−08 45 58.20	0.22	87.79	W
20.10.	MD.	747.5	15.8	6	13 38 17.159	−0.031	−10 13 25.38	0.33	87.80	W
22.10.	MD.	744.3	17.7	4	13 45 50.471	0.008	−10 56 16.87	−0.39	87.81	W
27.10.	MD.	753.2	10.6	5	14 04 55.778	0.009	−12 40 27.15	0.37	87.82	W
28.10.	MD.	754.2	9.9	4	14 08 46.980	0.035	−13 00 43.27	−0.76	87.82	W
29.10.	MD.	752.8	8.7	4	14 12 38.915	−0.008	−13 20 47.08	−0.27	87.83	W
30.10.	SS.MD.	752.6	7.5	5	14 16 31.592	−0.059	−13 40 38.18	−0.16	87.83	W
1988										
20.01.	SS.MD.	744.2	6.1	5	20 07 01.958	−0.008	−20 14 30.17	0.31	88.05	W
16.03.	SS.MD.	736.2	14.0	4	23 45 33.900	0.017	−01 33 54.90	0.31	88.21	E
30.03.	SS.MD.	740.4	11.3	6	00 36 34.257	0.009	03 56 24.44	−0.10	88.24	E
12.04.	SS.MD.	744.8	15.5	4	01 24 07.365	−0.011	08 50 38.04	0.31	88.28	E
21.04.	SS.MD.	743.2	17.8	6	01 57 32.115	−0.007	12 00 37.55	0.13	88.30	W
01.07.	SS.MD.	747.6	25.1	5	06 42 39.778	−0.010	23 04 47.08	−0.18	88.50	W
12.07.	SS.MD.	743.6	24.9	3	07 27 48.158	0.043	21 54 32.21	0.18	88.53	W
14.07.	SS.MD.	740.6	27.4	3	07 35 55.333	0.040	21 36 45.72	0.56	88.53	W
01.08.	MD.	748.2	25.3	3	08 47 18.963	−0.045	17 54 19.56	−0.62	88.58	W
02.08.	SS.MD.	743.8	26.8	6	08 51 11.254	0.046	17 38 57.38	0.17	88.59	W
03.08.	SS.MD.	740.2	27.0	3	08 55 02.957	−0.026	17 23 17.88	−0.16	88.59	W
04.08.	SS.MD.	741.6	25.0	5	08 58 54.078	−0.002	17 07 21.34	0.03	88.59	W
08.08.	MD.	743.3	25.1	4	09 14 12.791	−0.001	16 00 50.83	0.68	88.60	W
09.08.	SS.MD.	741.2	22.4	6	09 18 01.033	0.023	15 43 33.68	−0.19	88.61	W
10.08.	SS.MD	741.7	26.8	5	09 21 48.704	−0.008	15 26 01.37	−0.03	88.61	W
15.08.	MD.	743.2	31.0	3	09 40 38.629	0.089	13 54 43.64	0.87	88.62	W
16.08.	SS.MD.	741.4	30.1	4	09 44 22.970	0.072	13 35 47.16	0.29	88.62	W
18.08.	SS.MD.	744.9	25.2	4	09 51 50.073	0.034	12 57 15.87	−0.43	88.63	W
19.08.	SS.MD.	743.8	22.2	3	09 55 32.857	0.010	12 37 41.74	−0.62	88.63	W
05.09.	MD.	747.0	25.0	3	10 57 36.507	−0.022	06 38 56.93	−0.21	88.68	W

Table 4. Data on the Mercury Observations

Date of observ.	ob-serv.	B_a	t^oC	n	α	$(O-C)_\alpha$	δ	$(O-C)_\delta$	E_p	clamp posit.
1987									1900+	
03.04.	MD.ZS.	740.6	11.8	5	$23^h13^m46^s.013$	$-0^s.028$	−07°20' 15".72	0".21	87.25	E
08.04.	SS.MD.	741.8	18.1	6	23 39 22.483	−0.034	−04 55 12.85	0.49	87.27	E
13.05.	SS.MD.	735.8	21.5	6	03 47 51.196	−0.031	20 59 03.52	−0.18	87.36	E
1988										
16.03.	SS.MD.	736.2	14.0	4	22 10 32.075	−0.033	−13 01 55.75	−0.61	88.21	E
12.04.	SS.MD.	744.8	15.5	4	00 54 00.842	−0.063	03 58 27.88	−0.09	88.28	E
14.07.	SS.MD.	740.6	27.4	3	06 12 50.525	−0.020	22 04 23.80	0.96	88.53	W
09.08.	SS.MD.	741.2	22.4	6	09 46 42.410	−0.065	15 13 14.30	0.21	88.61	W
15.08.	MD.	743.2	31.0	3	10 29 36.530	0.075	10 56 10.19	−0.47	88.62	W

Table 5. Data on the Venus Observations

Data of observ.	ob-serv.	B_a	t^o, C	n	α	$(O-C)_\alpha$	δ	$(O-C)_\delta$	E_p	clamp. posit.
1987									1900+	
.03.	MD.ZS.	741.4	14.4	3	$21^h58^m21^s.740$	$-0^s.028$	$-12^o53'\ 23''.58$	$0''.36$	87.23	E
3.04.	MD.ZS.	740.6	11.8	5	22 35 23.738	−0.001	−09 50 13.82	0.59.	87.25	E
.04.	SS.MD.	741.8	18.1	6	22 58 11.508	0.052	−07 46 13.14	−0.11	87.27	E
23.04.	SS.MD.	750.0	10.5	5	00 05 30.167	−0.004	−01 05 03.53	0.54	87.31	E
24.04.	SS.MD.	750.0	13.9	6	00 09 57.631	−0.044	−00 37 21.87	−0.46	87.31	E
9.04.	SS.ZS.	754.3	13.2	4	00 32 14.906	−0.043	01 41 42.68	0.02	87.33	E
7.07.	SS.MD.	742.1	28.0	6	05 41 48.416	0.015	23 05 48.62	0.40	87.50	E
13.07.	MD.ZS.	742.7	27.0	4	06 40 27.763	0.024	23 17 19.03	−0.70	87.53	E
4.07.	SS.ZS.	743.9	27.2	4	06 45 47.983	0.015	23 14 14.87	0.02	87.53	W
.07.	SS.MD.	741.8	22.1	5	07 59 48.547	0.018	21 20 30.01	−0.30	87.57	W
16.09.	MD.	749.0	25.1	6	12 00 44.216	−0.027	01 21 44.19	0.11	87.71	W
1.10.	SS.MD.	748.8	13.6	4	13 09 02.421	−0.023	−06 14 48.34	−0.15	87.75	W
7.10.	SS.MD.	742.6	19.5	5	13 36 45.644	0.033	−09 11 42.66	−0.36	87.77	W
9.10.	SS.MD.	745.0	18.1	3	13 46 05.588	−0.023	−10 09 10.90	−0.02	87.77	W
15.10.	SS.MD.	744.6	17.2	3	14 14 26.363	0.051	−12 55 41.17	0.33	87.79	W
16.10.	SS.MD.	743.6	19.5	5	14 19 13.226	0.010	−13 22 26.26	−0.05	87.79	W
20.10	MD.	747.5	15.8	6	14 38 31.447	0.042	−15 06 05.95	−0.03	87.80	W
22.10	MD.	744.3	17.7	4	14 48 17.357	0.066	−15 55 44.07	−0.10	87.81	W
28.10.	MD.	754.2	9.9	4	15 08 03.938	0.033	−18 14 34.12	−0.34	87.82	W
29.10.	MD.	752.8	8.7	4	15 23 05.995	0.009	−18 36 05.91	−0.09	87.83	W
1988										
20.01.	SS.MD.	744.2	6.1	5	22 33 08.416	0.042	−10 42 01.79	−0.29	88.05	W
30.03.	SS.MD.	740.4	11.1	6	03 31 08.325	0.003	22 09 07.29	0.41	88.24	E
12.04.	SS.MD.	744.8	15.5	4	04 23 42.334	−0.092	25 28 06.76	0.68	88.28	E
01.07.	SS.MD.	747.6	25.1	5	04 53 12.124	0.003	18 14 26.05	−0.64	88.50	W
12.07.	SS.MD.	743.6	24.9	3	04 57 17.394	0.055	17 45 35.19	0.64	88.53	W
14.07.	SS.MD.	740.6	27.4	3	04 59 51.611	−0.027	17 46 58.99	0.59	88.53	W
01.08.	MD.	748.2	25.3	3	05 41 35.818	0.094	18 51 10.42	0.37	88.58	W
02.08.	SS.MD.	743.9	26.8	6	05 44 42.077	0.056	18 55 32.24	0.32	88.59	W
03.08.	SS.MD.	740.2	27.0	3	05 47 52.304	−0.064	18 59 48.71	0.14	88.59	W
08.08.	MD.	743.3	25.1	4	06 04 38.378	0.035	19 19 05.84	0.74	88.60	W
09.08.	SS.MD.	741.2	22.4	6	06 08 09.693	−0.015	19 22 23.87	0.58	88.61	W
10.08.	SS.MD.	741.7	26.8	5	06 11 44.094	0.059	19 25 28.19	−0.32	88.61	W
15.08.	MD.	743.2	31.0	3	06 30 18.583	−0.053	19 36 49.66	0.26	88.62	W
16.08.	SS.MD.	741.4	30.1	4	06 34 09.267	0.064	19 38 11.58	0.65	88.62	W
18.08.	SS.MD.	744.9	25.2	4	06 41 57.672	0.090	19 39 54.49	0.46	88.63	W
19.08.	SS.MD.	743.8	22.2	4	06 45 55.217	0.084	19 40 13.99	−0.83	88.63	W
22.08.	MD.	738.6	25.5	4	06 58 00.215	0.069	19 38 56.57	−0.69	88.64	W
05.09.	MD.	747.0	25.0	3	07 57 34.806	−0.047	18 41 34.79	−0.80	88.68	W

Table 6. Data on the Mars Observations

Date of observ.	ob-serv.	B_a	t^oC	n	α	$(O-C)_\alpha$	δ	$(O-C)_\delta$	E_p	clamp posit.
1987									1900+	
08.04.	SS.MD.	741.8	18.1	6	$03^h58^m34^s.161$	$0^s.033$	$21^o23'\ 01''.61$	$0''.52$	87.27	E
23.04.	SS.MD.	750.0	10.5	5	04 41 00.544	0.044	23 09 17.86	−0.48	87.31	E
1988										
21.04.	SS.MD.	743.2	17.8	6	20 49 42.149	0.061	−19 08 55.64	−0.36	88.30	W
10.08.	SS.MD.	741.7	26.8	5	00 43 02.404	−0.005	−00 42 32.00	−0.33	88.61	W

The apparent right ascensions and declinations obtained from observations are compared to the ephemeris places and the results are presented in Table 3–6

Each of the four tables contains eleven columns. Their description is given below.

Column I – data of observation;

Column II – observers: Miodrag Dačić (MD), Sadžakov Sofija (SS), Zorica Cvetković (ZC).
Column III – atmospheric pressure in mm Hg;
Column IV – mean air temperature in the pavilion;
Column V – number of reference star transits;
Column VI – ephemeris right ascension (α);
Column VII – $(O-C)_\alpha$ in right ascension;
Column VIII – ephemeris declination (δ);
Column IX – $(O-C)_\delta$ in declination;
Column X – observation epoch;
Column XI – clamp position.

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REFERENCES

Sadžakov, S., Dačić, M., Šaletić, D.: 1976, *Publ. Dep. Astron. Beograd,* **6**, 119.
Sadžakov, S., Dačić, M, Šaletić, D.: 1981, *Publ. Obs. Astron. Sarajevo,* **1**, 69.
Sadžakov, S., Dačić, M, Šaletić, D.: 1982a, *Bull. Obs. Astron. Beograd,* **132**, 45.
Sadžakov, S., Dačić, M., Šaletić, D., Ševarlić, Br : 1982b, Proc VI ERMA DUBROVNIK „*Sun and Planetary System*", D. Reidel Publ Comp. Dodrecht, Holand, p. 445.
Sadžakov, S., Dačić, M., Šaletić, D.: 1983, *Bull. Obs. Astron. Beograd,* **133**, 45.
Sadžakov, S, Dačić M.: 1985, *Bull. Obs. Astron. Beograd,* **135**, 47.
Sadžakov, S., i Dačić, M., Stančić, Z: 1988, *Bull. Obs. Astron. Beograd,* **138**, 78.

Bull. Obs. Astron. Belgrade Nº 140 (1989), 53–68.

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Preliminary report

PRECISE MINOR PLANET POSITIONS OBTAINED AT ESO – LA SILLA IN FEBRUARY 1985

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SUMMARY: During the first mission in 1985, 258 accurate positions of minor planets were obtained from observations in February by GPO telescope of ESO, La Silla, Chile. The measurements were carried out on a measuring machine OPTRONICS at ESO, Garching and with Ascorecord Zeiss of the Observatoire Royal de Belgique.

Three new minor planets were discovered.

1. INTRODUCTION

The present paper contains the results of the photographic observations of nine minor planets: 123 Brunhild, 232 Russia, 1283 Komsomolia, 2158–1933 OS, 2354 Lavrov, 2943 – 1933 QU, 1985 CO_1, 1985 CP_1 and 1985 CQ_1. Last three ones are new discovered minor planets. For three stars (7006, 7007 and 7008) the precise positions are calculated.

2. OBSERVATIONS

Minor planets observations were performed with GPO (Grand Prism Objectif, f = 400 cm, D = 40 cm), using Kodak spectroscopic plates 103a–0, taken at European Southern Observatory (ESO), La Silla, Chile.

All the plates were measured on the Optronics measuring machine, Garching and on the Ascorecord Zeiss, Uccle.

3. RESULTS

The results of observations collected during this mission are presented in two Tables.

Table I contains, respectively: the ordinal number of each position, the object designation, ordinal number of the plate, date in UT, the topocentric coordinates α and δ for the equinox 1950.0 and the residuals.

For the new asteroids only the calculated positions are presented.

In the Table II we give also the ordinal number of each position, the star identification – SAO number, the last digit of α and δ of the star (proper motions are included), the residuals on the reference stars, computed for each of three exposures and the dependences.

ACKNOWLEDGEMENTS

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Table 1. Positions

NO	OBJECT		PLATE	DATE UT 1985 MON.	DAY	ALPHA 1950 H	M	S	DELTA 1950 °	'	''	RESIDUALS	M	'
1	123	BRUNHILD	8004	2	9.081250	9	40	26.484	+11	08	50.53	+	.1	- 1
2	123	BRUNHILD	8004	2	9.086805	9	40	26.134	+11	08	51.33	+	.1	- 1
3	123	BRUNHILD	8004	2	9.092361	9	40	25.778	+11	08	51.91	+	.1	- 1
4	232	RUSSIA	8004	2	9.081250	9	34	10.305	+12	11	35.76	+	.0	- 1
5	232	RUSSIA	8004	2	9.086805	9	34	10.019	+12	11	38.29	+	.0	- 1
6	232	RUSSIA	8004	2	9.092361	9	34	9.710	+12	11	40.53	+	.0	- 1
7	232	RUSSIA	8008	2	10.064236	9	33	17.907	+12	19	17.00	+	.0	0
8	232	RUSSIA	8008	2	10.070833	9	33	17.551	+12	19	20.28	+	.0	0
9	232	RUSSIA	8008	2	10.077430	9	33	17.157	+12	19	23.30	+	.0	0
10	232	RUSSIA	8015	2	11.059028	9	32	24.558	+12	27	05.62	+	.0	0
11	232	RUSSIA	8015	2	11.064583	9	32	24.250	+12	27	08.16	+	.0	0
12	232	RUSSIA	8015	2	11.070138	9	32	23.941	+12	27	10.69	+	.0	0
13	232	RUSSIA	8031	2	13.033333	9	30	38.158	+12	42	40.79	-	.0	0
14	232	RUSSIA	8031	2	13.038888	9	30	37.847	+12	42	42.61	-	.0	0
15	232	RUSSIA	8031	2	13.044444	9	30	37.538	+12	42	45.38	-	.0	0
16	232	RUSSIA	8052	2	15.029861	9	28	50.595	+12	58	30.82	-	.1	0
17	232	RUSSIA	8052	2	15.035417	9	28	50.299	+12	58	33.60	-	.1	0
18	232	RUSSIA	8052	2	15.040972	9	28	50.000	+12	58	36.14	-	.1	0
19	232	RUSSIA	8069	2	16.051389	9	27	55.758	+13	06	37.34	-	.1	0
20	232	RUSSIA	8069	2	16.056944	9	27	55.452	+13	06	40.05	-	.1	0
21	232	RUSSIA	8069	2	16.062500	9	27	55.135	+13	06	42.56	-	.1	0
22	232	RUSSIA	8087	2	17.056597	9	27	2.076	+13	14	35.22	-	.1	0
23	232	RUSSIA	8087	2	17.061458	9	27	1.802	+13	14	37.62	-	.1	0
24	232	RUSSIA	8087	2	17.066319	9	27	1.525	+13	14	40.09	-	.1	0
25	232	RUSSIA	8105	2	18.053125	9	26	9.109	+13	22	28.09	-	.1	0
26	232	RUSSIA	8105	2	18.057986	9	26	8.878	+13	22	30.33	-	.1	0
27	232	RUSSIA	8105	2	18.062847	9	26	8.535	+13	22	32.90	-	.1	0
28	232	RUSSIA	8123	2	19.051736	9	25	16.621	+13	30	18.57	-	.1	0
29	232	RUSSIA	8123	2	19.056597	9	25	16.345	+13	30	21.24	-	.1	0
30	232	RUSSIA	8123	2	19.061458	9	25	16.088	+13	30	23.36	-	.1	0
31	232	RUSSIA	8141	2	20.049653	9	24	24.691	+13	38	08.58	-	.1	0
32	232	RUSSIA	8141	2	20.054166	9	24	24.436	+13	38	10.69	-	.1	0
33	232	RUSSIA	8141	2	20.058333	9	24	24.232	+13	38	12.12	-	.1	0
34	1283	KOMSOMOLIA	8004	2	9.081250	9	34	51.326	+10	43	31.49	+	.0	0
35	1283	KOMSOMOLIA	8004	2	9.086805	9	34	51.057	+10	43	33.34	+	.0	0
36	1283	KOMSOMOLIA	8004	2	9.092361	9	34	50.802	+10	43	35.32	+	.0	0
37	2158	1933 OS	8015	2	11.059028	9	32	17.805	+12	56	09.45	+	.0	0
36	2158	1933 OS	8015	2	11.064583	9	32	17.566	+12	56	10.88	+	.0	0
39	2158	1933 OS	8015	2	11.070138	9	32	17.320	+12	56	12.12	+	.0	0
40	2158	1933 OS	8031	2	13.033333	9	30	44.325	+13	04	14.24	-	.0	0
41	2158	1933 OS	8031	2	13.038888	9	30	44.049	+13	04	14.78	-	.0	0
42	2158	1933 OS	8031	2	13.044444	9	30	43.749	+13	04	15.65	-	.0	0
43	2158	1933 OS	8052	2	15.029861	9	29	10.094	+13	12	23.35	-	.0	0
44	2158	1933 OS	8052	2	15.035417	9	29	9.878	+13	12	24.45	-	.0	0
45	2158	1933 OS	8052	2	15.040972	9	29	9.631	+13	12	26.00	-	.0	0
46	2158	1933 OS	8069	2	16.051389	9	28	22.075	+13	16	33.37	-	.1	0
47	2158	1933 OS	8069	2	16.056944	9	28	21.828	+13	16	34.40	-	.1	0
48	2158	1933 OS	8069	2	16.062500	9	28	21.532	+13	16	35.45	-	.1	0
49	2158	1933 OS	8087	2	17.056597	9	27	35.038	+13	20	37.58	-	.1	0
50	2158	1933 OS	8087	2	17.061458	9	27	34.779	+13	20	38.82	-	.1	0

Table 1 (continued)

NO	OBJECT		PLATE	DATE UT 1985 MON.	DAY	ALPHA 1950 H	M	S	DELTA 1950 °	'	''	RESIDUALS M	''
51	2158	1933 OS	8087	2	17.066319	9	27	34.531	+13	20	40.00	- .1	0
52	2158	1933 OS	8105	2	18.053125	9	26	48.527	+13	24	39.82	- .1	0
53	2158	1933 OS	8105	2	18.057986	9	26	48.295	+13	24	40.90	- .1	0
54	2158	1933 OS	8105	2	18.062847	9	26	48.028	+13	24	42.00	- .1	0
55	2158	1933 OS	8123	2	19.051736	9	26	2.273	+13	28	38.36	- .1	0
56	2158	1933 OS	8123	2	19.056597	9	26	2.000	+13	28	40.00	- .1	0
57	2158	1933 OS	8123	2	19.061458	9	26	1.808	+13	28	41.48	- .1	0
58	2354	LAVROV	8004	2	9.081250	9	33	5.081	+11	35	05.46	+ .0	0
59	2354	LAVROV	8004	2	9.086805	9	33	4.802	+11	35	07.35	+ .0	0
60	2354	LAVROV	8004	2	9.092361	9	33	4.517	+11	35	09.57	+ .0	0
61	2354	LAVROV	8008	2	10.064236	9	32	13.654	+11	40	08.89	+ .0	0
62	2354	LAVROV	8008	2	10.070833	9	32	13.330	+11	40	11.12	+ .0	0
63	2354	LAVROV	8008	2	10.077430	9	32	13.007	+11	40	12.50	+ .0	0
64	2354	LAVROV	8015	2	11.059028	9	31	21.662	+11	45	16.15	+ .0	0
65	2354	LAVROV	8015	2	11.064583	9	31	21.334	+11	45	17.92	+ .0	0
66	2354	LAVROV	8015	2	11.070138	9	31	21.027	+11	45	19.17	+ .0	0
67	2354	LAVROV	8031	2	13.033333	9	29	38.449	+11	55	27.41	- .0	0
68	2354	LAVROV	8031	2	13.038888	9	29	38.180	+11	55	29.18	+ .0	0
69	2354	LAVROV	8031	2	13.044444	9	29	37.901	+11	55	30.80	+ .0	0
70	2354	LAVROV	8052	2	15.029861	9	27	54.834	+12	05	44.59	- .0	0
71	2354	LAVROV	8052	2	15.035417	9	27	54.521	+12	05	46.35	- .0	0
72	2354	LAVROV	8052	2	15.040972	9	27	54.243	+12	05	48.28	- .0	0
73	2354	LAVROV	8069	2	16.051389	9	27	2.366	+12	11	01.75	- .1	+ 1
74	2354	LAVROV	8069	2	16.056944	9	27	2.100	+12	11	03.08	- .1	+ 1
75	2354	LAVROV	8069	2	16.062500	9	27	1.829	+12	11	04.28	- .1	+ 1
76	2354	LAVROV	8087	2	17.056597	9	26	10.670	+12	16	09.58	- .1	+ 1
77	2354	LAVROV	8087	2	17.061458	9	26	10.410	+12	16	11.77	- .1	+ 1
78	2354	LAVROV	8087	2	17.066319	9	26	10.207	+12	16	13.40	- .1	+ 1
79	2354	LAVROV	8105	2	18.053125	9	25	20.069	+12	21	15.35	- .1	+ 1
80	2354	LAVROV	8105	2	18.057986	9	25	19.801	+12	21	16.59	- .1	+ 1
81	2354	LAVROV	8105	2	18.062847	9	25	19.513	+12	21	18.53	- .1	+ 1
82	2354	LAVROV	8123	2	19.051736	9	24	29.805	+12	26	20.41	- .1	+ 1
83	2354	LAVROV	8123	2	19.056597	9	24	29.569	+12	26	21.78	- .1	+ 1
84	2354	LAVROV	8123	2	19.061458	9	24	29.319	+12	26	23.26	- .1	+ 1
85	2354	LAVROV	8141	2	20.049653	9	23	40.049	+12	31	22.16	- .1	+ 1
86	2354	LAVROV	8141	2	20.054166	9	23	39.792	+12	31	23.38	- .1	+ 1
87	2354	LAVROV	8141	2	20.058333	9	23	39.615	+12	31	24.50	- .1	+ 1
88	2354	LAVROV	8160	2	21.054861	9	22	50.549	+12	36	24.23	- .1	0
89	2354	LAVROV	8160	2	21.060416	9	22	50.211	+12	36	26.00	- .1	0
90	2354	LAVROV	8160	2	21.065972	9	22	49.940	+12	36	27.54	- .1	0
91	2354	LAVROV	8176	2	22.055555	9	22	1.804	+12	41	23.00	- .1	0
92	2354	LAVROV	8176	2	22.061111	9	22	1.509	+12	41	24.66	- .1	0
93	2354	LAVROV	8176	2	22.067014	9	22	1.180	+12	41	26.45	- .1	0
94	2354	LAVROV	8196	2	24.031250	9	20	27.712	+12	51	04.03	- .0	0
95	2354	LAVROV	8196	2	24.035417	9	20	27.531	+12	51	05.24	- .0	0
96	2354	LAVROV	8196	2	24.039583	9	20	27.344	+12	51	06.59	- .0	0
97	2354	LAVROV	8219	2	25.035417	9	19	40.954	+12	55	55.20	- .1	0
98	2354	LAVROV	8219	2	25.040972	9	19	40.752	+12	55	57.07	- .1	0
99	2354	LAVROV	8219	2	25.046527	9	19	40.483	+12	55	58.71	- .1	0
100	2354	LAVROV	8235	2	26.020486	9	18	56.056	+13	00	36.60	- .1	+ 1

Table 1 (continued)

NO	OBJECT		PLATE	DATE UT 1985 MON.	DAY	ALPHA 1950 H	M	S	DELTA 1950 °	'	"	RESIDUALS M	'
101	2354	LAVROV	8235	2	26.026042	9	18	55.843	+13	00	38.49	- .1	+ 1
102	2354	LAVROV	8235	2	26.030902	9	18	55.535	+13	00	39.35	- .1	+ 1
103	2354	LAVROV	8253	2	27.026389	9	18	11.1[illegible]	+13	05	20.00	- .2	+ 1
104	2354	LAVROV	8253	2	27.031944	9	18	10.804	+13	05	22.11	- .2	+ 1
105	2354	LAVROV	8271	2	28.022222	9	17	27.332	+13	09	57.84	- .2	+ 1
106	2354	LAVROV	8271	2	28.027778	9	17	27.124	+13	09	58.35	- .2	+ 1
107	2943	1933 QU	8004	2	9.081250	9	39	37.225	+10	44	41.38	+ .1	0
108	2943	1933 QU	8004	2	9.086805	9	39	36.844	+10	44	41.78	+ .1	0
109	2943	1933 QU	8004	2	9.092361	9	39	36.456	+10	44	42.08	+ .1	0
110		1985C01	8004	2	9.081250	9	34	34.171	+11	22	30.00		
111		1985C01	8004	2	9.086805	9	34	33.850	+11	22	31.92		
112		1985C01	8004	2	9.092361	9	34	33.531	+11	22	34.62		
113		1985C01	8008	2	10.064236	9	33	38.968	+11	28	56.00		
114		1985C01	8008	2	10.070833	9	33	38.606	+11	28	58.50		
115		1985C01	8008	2	10.077430	9	33	38.240	+11	29	01.42		
116		1985C01	8015	2	11.059028	9	32	42.943	+11	35	28.91		
117		1985C01	8015	2	11.064583	9	32	42.628	+11	35	31.28		
118		1985C01	8015	2	11.070138	9	32	42.314	+11	35	33.81		
119		1985C01	8031	2	13.033333	9	30	51.943	+11	48	31.60		
120		1985C01	8031	2	13.038888	9	30	51.636	+11	48	33.91		
121		1985C01	8031	2	13.044444	9	30	51.305	+11	48	36.19		
122		1985C01	8052	2	15.029861	9	29	0.451	+12	01	45.16		
123		1985C01	8052	2	15.035417	9	29	0.174	+12	01	47.41		
124		1985C01	8052	2	15.040972	9	28	59.845	+12	01	49.57		
125		1985C01	8069	2	16.051389	9	28	4.345	+12	08	32.35		
126		1985C01	8069	2	16.056944	9	28	4.029	+12	08	34.40		
127		1985C01	8069	2	16.062500	9	28	3.723	+12	08	36.34		
128		1985C01	8087	2	17.056597	9	27	8.772	+12	15	07.75		
129		1985C01	8087	2	17.061458	9	27	8.485	+12	15	09.58		
130		1985C01	8087	2	17.066319	9	27	8.199	+12	15	11.66		
131		1985C01	8105	2	18.053125	9	26	14.652	+12	21	40.58		
132		1985C01	8105	2	18.057986	9	26	14.366	+12	21	42.78		
133		1985C01	8105	2	18.062847	9	26	14.106	+12	21	44.79		
134		1985C01	8123	2	19.051736	9	25	21.040	+12	28	11.00		
135		1985C01	8123	2	19.056597	9	25	20.780	+12	28	12.69		
136		1985C01	8123	2	19.061458	9	25	20.489	+12	28	14.43		
137		1985C01	8141	2	20.049653	9	24	28.189	+12	34	38.10		
138		1985C01	8141	2	20.054166	9	24	27.984	+12	34	40.09		
139		1985C01	8141	2	20.058333	9	24	27.757	+12	34	42.00		
140		1985C01	8160	2	21.054861	9	23	35.852	+12	41	05.76		
141		1985C01	8160	2	21.060416	9	23	35.579	+12	41	07.47		
142		1985C01	8160	2	21.065972	9	23	35.287	+12	41	09.70		
143		1985C01	8176	2	22.055555	9	22	44.540	+12	47	27.77		
144		1985C01	8176	2	22.061111	9	22	44.246	+12	47	29.76		
145		1985C01	8176	2	22.067014	9	22	43.942	+12	47	32.00		
146		1985C01	8196	2	24.031250	9	21	6.244	+12	59	48.85		
147		1985C01	8196	2	24.035417	9	21	6.044	+12	59	50.22		
148		1985C01	8196	2	24.039583	9	21	5.831	+12	59	51.78		
149		1985C01	8219	2	25.035417	9	20	17.939	+13	05	59.43		
150		1985C01	8219	2	25.040972	9	20	17.672	+13	06	01.18		

Table 1 (continued)

NO	OBJECT	PLATE	DATE UT 1985 MON.	DAY	ALPHA 1950 H	M	S	DELTA 1950 °	'	''	RESIDUALS M	"
151	1985CO1	8219	2	25.046527	9	20	17.402	+13	06	03.50		
152	1985CO1	8235	2	26.020486	9	19	31.661	+13	11	56.66		
153	1985CO1	8235	2	26.026042	9	19	31.417	+13	11	58.75		
154	1985CO1	8235	2	26.030902	9	19	31.196	+13	12	00.46		
155	1985CO1	8253	2	27.026389	9	18	45.790	+13	17	56.17		
156	1985CO1	8253	2	27.031944	9	18	45.540	+13	17	58.38		
157	1985CO1	8271	2	28.022222	9	18	1.672	+13	23	45.25		
158	1985CO1	8271	2	28.027778	9	18	1.421	+13	23	47.21		
159	1985CP1	8008	2	10.064236	9	27	55.971	+12	22	54.00		
160	1985CP1	8008	2	10.070833	9	27	55.646	+12	22	56.51		
161	1985CP1	8008	2	10.077430	9	27	55.321	+12	22	59.00		
162	1985CP1	8015	2	11.059028	9	27	4.452	+12	29	05.00		
163	1985CP1	8015	2	11.064583	9	27	4.162	+12	29	07.43		
164	1985CP1	8015	2	11.070138	9	27	3.895	+12	29	09.28		
165	1985CP1	8031	2	13.033333	9	25	22.327	+12	41	27.17		
166	1985CP1	8031	2	13.038388	9	25	22.047	+12	41	29.00		
167	1985CP1	8031	2	13.044444	9	25	21.759	+12	41	30.70		
168	1985CP1	8052	2	15.029861	9	23	39.695	+12	53	56.17		
169	1985CP1	8052	2	15.035417	9	23	39.403	+12	53	58.24		
170	1985CP1	8052	2	15.040972	9	23	39.116	+12	54	00.33		
171	1985CP1	8069	2	16.051389	9	22	47.465	+13	00	19.62		
172	1985CP1	8069	2	16.056944	9	22	47.201	+13	00	21.41		
173	1985CP1	8069	2	16.062500	9	22	46.933	+13	00	23.54		
174	1985CP1	8087	2	17.056597	9	21	56.416	+13	06	35.75		
175	1985CP1	8087	2	17.061458	9	21	56.197	+13	06	37.72		
176	1985CP1	8087	2	17.066319	9	21	55.944	+13	06	39.61		
177	1985CP1	8105	2	18.053125	9	21	6.257	+13	12	46.31		
178	1985CP1	8105	2	18.057986	9	21	6.013	+13	12	48.16		
179	1985CP1	8105	2	18.062847	9	21	5.781	+13	12	50.17		
180	1985CP1	8123	2	19.051736	9	20	16.399	+13	18	58.29		
181	1985CP1	8123	2	19.056597	9	20	16.150	+13	18	59.55		
182	1985CP1	8123	2	19.061458	9	20	15.925	+13	19	01.00		
183	1985CP1	8141	2	20.049653	9	19	27.213	+13	25	05.82		
184	1985CP1	8141	2	20.054166	9	19	26.984	+13	25	07.33		
185	1985CP1	8141	2	20.058333	9	19	26.777	+13	25	08.60		
186	1985CP1	8160	2	21.054861	9	18	38.219	+13	31	13.04		
187	1985CP1	8160	2	21.060416	9	18	37.929	+13	31	14.72		
188	1985CP1	8160	2	21.065972	9	18	37.660	+13	31	16.45		
189	1985CP1	8176	2	22.055555	9	17	50.137	+13	37	15.37		
190	1985CP1	8176	2	22.061111	9	17	49.862	+13	37	17.40		
191	1985CP1	8176	2	22.067014	9	17	49.572	+13	37	19.50		
192	1985CP1	8196	2	24.031250	9	16	17.575	+13	49	02.70		
193	1985CP1	8196	2	24.035417	9	16	17.395	+13	49	04.04		
194	1985CP1	8196	2	24.039583	9	16	17.213	+13	49	05.37		
195	1985CP1	8219	2	25.035417	9	15	31.688	+13	54	56.70		
196	1985CP1	8219	2	25.040972	9	15	31.429	+13	54	59.05		
197	1985CP1	8219	2	25.046527	9	15	31.190	+13	55	00.85		
198	1985CQ1	8008	2	10.064236	9	28	51.774	+11	01	58.49		
199	1985CQ1	8008	2	10.070833	9	28	51.334	+11	02	00.47		
200	1985CQ1	8008	2	10.077430	9	28	50.900	+11	02	02.43		

Table 1 (continued)

NO	OBJECT	PLATE	DATE UT 1985 MON.	DAY	ALPHA 1950 H	M	S	DELTA 1950 °	′	″	RESIDUALS M	″
201	1985CQ1	8015	2	11.059028	9	27	46.683	+11	06	58.70		
202	1985CQ1	8015	2	11.064583	9	27	46.336	+11	07	00.32		
203	1985CQ1	8015	2	11.070138	9	27	45.959	+11	07	02.00		
204	1985CQ1	8031	2	13.033333	9	25	38.366	+11	16	56.00		
205	1985CQ1	8031	2	13.038888	9	25	38.000	+11	16	57.60		
206	1985CQ1	8031	2	13.044444	9	25	37.613	+11	16	59.28		
207	1985CQ1	8052	2	15.029861	9	23	30.134	+11	27	00.19		
208	1985CQ1	8052	2	15.035417	9	23	29.773	+11	27	01.66		
209	1985CQ1	8052	2	15.040972	9	23	29.403	+11	27	03.37		
210	1985CQ1	8069	2	16.051389	9	22	25.198	+11	32	08.03		
211	1985CQ1	8069	2	16.056944	9	22	24.833	+11	32	09.24		
212	1985CQ1	8069	2	16.062500	9	22	24.464	+11	32	11.15		
213	1985CQ1	8087	2	17.056597	9	21	22.078	+11	37	09.48		
214	1985CQ1	8087	2	17.061458	9	21	21.768	+11	37	10.94		
215	1985CQ1	8087	2	17.066319	9	21	21.460	+11	37	12.29		
216	1985CQ1	8105	2	18.053125	9	20	20.188	+11	42	06.31		
217	1985CQ1	8105	2	18.057986	9	20	19.895	+11	42	07.60		
218	1985CQ1	8105	2	18.062847	9	20	19.605	+11	42	08.85		
219	1985CQ1	8123	2	19.051736	9	19	18.978	+11	47	02.13		
220	1985CQ1	8123	2	19.056597	9	19	18.665	+11	47	03.61		
221	1985CQ1	8123	2	19.061458	9	19	18.353	+11	47	05.06		
222	1985CQ1	8141	2	20.049653	9	18	18.813	+11	51	55.08		
223	1985CQ1	8141	2	20.054166	9	18	18.543	+11	51	56.36		
224	1985CQ1	8141	2	20.058333	9	18	18.288	+11	51	57.63		
225	1985CQ1	8160	2	21.054861	9	17	19.057	+11	56	46.34		
226	1985CQ1	8160	2	21.060416	9	17	18.721	+11	56	48.01		
227	1985CQ1	8160	2	21.065972	9	17	18.373	+11	56	49.61		
228	1985CQ1	8176	2	22.055555	9	16	20.594	+12	01	34.66		
229	1985CQ1	8176	2	22.061111	9	16	20.281	+12	01	36.30		
230	1985CQ1	8176	2	22.067014	9	16	19.948	+12	01	37.75		
231	1985CQ1	8196	2	24.031250	9	14	28.650	+12	10	51.45		
232	1985CQ1	8196	2	24.035417	9	14	28.416	+12	10	52.65		
233	1985CQ1	8196	2	24.039583	9	14	28.186	+12	10	53.80		
234	1985CQ1	8219	2	25.035417	9	13	33.599	+12	15	30.69		
235	1985CQ1	8219	2	25.040972	9	13	33.292	+12	15	32.25		
236	1985CQ1	8219	2	25.046527	9	13	32.986	+12	15	33.80		
237	1985CQ1	8235	2	26.020486	9	12	40.791	+12	19	57.83		
238	1985CQ1	8235	2	26.026042	9	12	40.476	+12	19	59.40		
239	1985CQ1	8235	2	26.030902	9	12	40.201	+12	20	00.71		
240	1985CQ1	8253	2	27.026389	9	11	48.169	+12	24	27.36		
241	1985CQ1	8253	2	27.031944	9	11	47.900	+12	24	28.80		
242	1985CQ1	8271	2	28.022222	9	10	57.297	+12	29	19.84		
243	1985CQ1	8271	2	28.027778	9	10	57.014	+12	29	21.36		
244	7006	8123	2	19.051736	9	20	56.685	+11	40	13.03	- .0	- 0
245	7006	8123	2	19.056597	9	20	56.676	+11	40	13.00	- .0	- 0
246	7006	8123	2	19.061458	9	20	56.698	+11	40	13.00	- .0	- 0
247	7007	8105	2	18.053125	9	21	54.264	+13	19	56.66	- .0	+ 0
248	7007	8105	2	18.057986	9	21	54.281	+13	19	56.68	- .0	+ 0
249	7007	8105	2	18.062847	9	21	54.252	+13	19	56.50	- .0	+ 0
250	7007	8123	2	19.051736	9	21	54.248	+13	19	56.32	- .0	+ 0

Table 1 (continued)

			DATE UT 1985				
NO	OBJECT	PLATE	MON.	DAY	ALPHA 1950	DELTA 1950	
251	7007	8123	2	19.056597	9 21 54.214	+13 19 56.48	- .0 + 0
252	7007	8123	2	19.061458	9 21 54.236	+13 19 56.33	- .0 + 0
253	7008	8123	2	19.051736	9 24 1.218	+12 43 30.85	- .0 + 0
254	7008	8123	2	19.056597	9 24 1.229	+12 43 30.83	- .0 + 0
255	7008	8123	2	19.061458	9 24 1.192	+12 43 30.86	- .0 + 0
256	7008	8141	2	20.049653	9 24 1.206	+12 43 30.91	- .0 + 0
257	7008	8141	2	20.054166	9 24 1.213	+12 43 31.23	- .0 + 0
258	7008	8141	2	20.058333	9 24 1.215	+12 43 31.00	- .0 + 0

Table 2. Star residuals. Dependences

OBSERVATIONS			NO SAO	POSITIONS USED s	POSITIONS USED ''	STAR RESIDUALS s	''	s	''	s	''	DEPENDENCES		
1	2	3	98727	+26.512	44.65	-0.014	+0.25	-0.016	+0.26	-0.023	+0.19	+0.512142	+0.511351	+0.510567
			98718	+06.448	15.78	+0.011	+0.43	+0.018	+0.41	+0.021	+0.26	+0.376541	+0.376107	+0.375632
			98713	+29.772	10.54	+0.002	-0.60	-0.001	-0.59	+0.000	-0.39	+0.326130	+0.325796	+0.325423
			98652	+15.956	16.62	-0.012	+0.42	-0.014	+0.42	-0.018	+0.29	-0.218476	-0.217427	-0.216375
			98701	+17.700	14.19	+0.013	-0.50	+0.015	-0.50	+0.020	-0.35	+0.003657	+0.004173	+0.004753
4	5	6	98713	+29.772	10.54	[illegible]	+0.13	+0.011	+0.12	+0.010	+0.09	-0.381195	-0.382795	-0.384306
			98652	+15.956	16.62	-0.018	-0.27	-0.022	-0.24	-0.021	-0.18	-0.090974	-0.091566	-0.092175
			98663	+22.464	42.67	-0.012	-0.04	+0.001	+0.10	-0.009	+0.04	+0.220566	+0.220903	+0.221302
			98664	+40.2[illegible]	25.01	[illegible]	+0.25	+0.018	+0.03	+0.029	+0.08	+0.284906	+0.285423	+0.285964
			98710	+22.603	34.04	-0.023	-0.07	-0.024	-0.01	-0.008	-0.02	+0.866696	+0.867974	+0.869165
7	8	9	98569	+40.085	25.01	+0.025	+0.13	+0.020	+0.05	+0.028	+0.07	+0.425521	+0.426762	+0.424926
			98647	+43.530	[illegible]	-0.046	-0.25	-0.048	-0.09	-0.054	-0.11	+0.079727	+0.079484	+0.078150
			98656	+35.721	24.42	-0.015	-0.17	-0.011	-0.10	-0.007	-0.17	+0.565425	+0.565582	+0.565485
			98641	+50.961	24.75	+0.025	+0.27	+0.020	+0.41	+0.009	+0.40	+0.116258	+0.117037	+0.117769
			98631	+56.390	22.30	+0.019	-0.02	+0.015	-0.19	+0.025	-0.18	-0.109931	-0.107770	[illegible]
10	11	12	98647	+40.530	12.20	+0.015	+0.03	+0.016	+0.02	+0.001	-0.01	+0.301927	+0.303569	[illegible]
			98569	+40.095	25.01	-0.010	-0.02	-0.015	-0.02	+0.012	+0.00	+0.057197	+0.058150	+0.058899
			98656	+35.721	24.42	+0.021	-0.05	+0.018	-0.03	+0.017	+0.09	+0.233166	+0.233645	+0.234124
			98602	+17.013	41.37	-0.025	-0.01	-0.036	-0.04	-0.047	-0.05	+0.274600	+0.275747	+0.276891
			98604	+26.254	45.77	+0.014	+0.05	+0.022	+0.04	+0.030	-0.07	+0.135042	+0.135995	+0.137682
13	14	15	98632	+58.791	[illegible]	-0.009	-0.05	-0.041	-0.10	-0.047	-0.12	-0.096204	-0.096309	-0.095659
			98636	+17.165	[illegible]	+0.037	-0.34	+0.037	-0.47	+0.037	-0.27	+0.228635	[illegible]	+0.227282
			98641	+62.961	24.75	+0.011	+0.37	[illegible]	+0.43	+0.001	+0.27	+0.715222	+0.713702	+0.712311
			98624	+37.0[illegible]	[illegible]	[illegible]	-0.16	-0.015	-0.22	-0.019	-0.20	+0.455254	+0.455760	+0.456729
			98602	+21.6[illegible]	[illegible]	+0.005	+0.27	[illegible]	+0.36	+0.011	+0.27	-0.302707	-0.301107	-0.299783
16	17	18	98592	+47.759	35.79	-0.033	-0.09	[illegible]	-0.24	[illegible]	-0.14	-0.155210	-0.155114	-0.154575
			98591	+43.744	37.24	[illegible]	+0.17	+0.072	+0.43	[illegible]	+0.20	+0.036425	+0.037107	+0.037816
			98604	+37.0[illegible]	40.06	[illegible]	+0.15	+0.009	+0.36	+0.019	+0.20	+0.502118	+0.501915	+0.501646
			98615	+40.030	34.51	-0.026	-0.17	-0.020	-0.58	-0.079	-0.38	+0.409540	[illegible]	+0.409770
			98621	+56.295	23.0[illegible]	[illegible]	+0.01	[illegible]	-0.33	+0.005	+0.03	+0.207532	+0.206440	+0.205349
19	20	21	98594	+50.740	19.97	[illegible]	-0.50	[illegible]	-0.47	-0.007	-0.45	-0.006213	[illegible]	-0.005793
			98595	+09.447	13.19	+0.044	+0.74	+0.049	+0.69	+0.040	+0.65	+0.066214	[illegible]	+0.072287
			98609	+40.036	34.01	-0.014	-0.09	-0.015	-0.30	-0.011	-0.15	+0.238591	+0.231382	+0.244756
			98624	+37.080	45.[illegible]	[illegible]	+0.12	+0.018	+0.19	+0.011	+0.14	+0.765670	+0.767114	[illegible]
			98609	+40.036	34.51	[illegible]	-0.17	-0.016	-0.12	-0.013	-0.24	+0.288576	[illegible]	[illegible]
22	23	24	98580	+53.372	[illegible]	-0.057	[illegible]	[illegible]	-0.27	-0.037	-0.41	+0.045700	+0.046646	+0.047327
			98542	+47.759	35.77	[illegible]	+0.05	[illegible]	+0.09	[illegible]	+0.19	[illegible]	[illegible]	-0.063720
			98622	+22.0[illegible]	44.1[illegible]	-0.012	-0.05	-0.011	-0.35	[illegible]	-0.08	-0.167127	[illegible]	[illegible]
			[illegible]	+09.447	13.19	[illegible]	+0.07	+0.003	+0.35	[illegible]	+0.48	[illegible]	[illegible]	[illegible]
			98609	+40.036	34.51	[illegible]	-0.27	+0.030	-0.13	+0.001	-0.15	[illegible]	[illegible]	[illegible]
25	26	27	98591	+43.744	37.26	-0.041	+0.03	+0.029	+0.17	[illegible]	+0.06	+0.497229	[illegible]	[illegible]
			98607	+33.419	27.36	+0.018	-0.19	+0.019	-0.25	+0.014	[illegible]	[illegible]	[illegible]	[illegible]
			98615	+09.[illegible]	16.[illegible]	-0.017	-0.04	[illegible]	-0.10	-0.009	-0.06	+0.840350	[illegible]	+0.844911
			98609	+40.036	34.[illegible]	[illegible]	+0.01	[illegible]	+0.35	[illegible]	[illegible]	-0.167443	[illegible]	[illegible]
			98595	+09.447	13.14	[illegible]	-0.01	[illegible]	-0.17	[illegible]	[illegible]	+0.100487	[illegible]	[illegible]
28	29	30	[illegible]	+36.577	27.[illegible]	[illegible]	+0.01	[illegible]	+0.10	-0.001	[illegible]	-0.619020	-0.618975	-0.619575
			[illegible]	+57.375	[illegible]	-0.036	-0.42	[illegible]	-0.19	+0.002	-0.40	-0.110656	[illegible]	[illegible]
			98595	+09.447	13.14	[illegible]	+0.12	[illegible]	-0.04	[illegible]	+0.15	+0.464227	[illegible]	+0.465380
			98551	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	+0.19	[illegible]	+0.14	+0.527759	[illegible]	[illegible]
			98544	[illegible]	[illegible]	-0.001	-0.10	[illegible]	+0.06	+0.000	[illegible]	+0.739891	+0.740806	[illegible]

Table 2 (continued)

OBSERVATIONS			NO SAO	POSITIONS USED		STAR RESIDUALS						DEPENDENCES		
				s	"	s	"	s	"	s	"			
31	32	33	98544	+16.083	10.83	-0.001	-0.01	-0.002	+0.00	-0.000	-0.03	+0.984612	+0.985188	+0.985574
			98580	+53.376	06.16	+0.016	-0.06	+0.015	-0.11	+0.017	-0.14	+0.534369	+0.533432	+0.532708
			98550	+36.977	07.03	-0.040	+0.17	-0.037	+0.27	-0.043	+0.39	+0.129523	+0.129425	+0.129346
			98527	+29.636	27.31	-0.007	-0.01	-0.012	+0.04	-0.005	-0.07	-0.467677	-0.467536	-0.467407
			98528	+29.725	48.85	+0.031	-0.09	+0.036	-0.21	+0.031	-0.14	-0.180827	-0.180509	-0.180221
34	35	36	98682	+15.956	16.62	-0.008	+0.05	-0.005	+0.07	-0.007	-0.08	-0.255576	-0.255485	-0.255255
			98701	+17.705	14.19	+0.001	-0.10	+0.006	-0.22	+0.003	+0.06	+0.104655	+0.103297	+0.101922
			98686	+25.496	38.00	-0.022	+0.16	-0.015	+0.24	-0.018	-0.22	+0.446990	+0.446872	+0.446870
			98679	+57.829	53.52	+0.037	+0.00	+0.009	+0.24	+0.025	+0.23	+0.291169	+0.291455	+0.291651
			98671	+47.758	15.30	-0.008	-0.12	+0.005	-0.33	-0.003	+0.01	+0.412763	+0.413860	+0.414812
37	38	39	98647	+40.530	12.28	+0.010	+0.03	+0.016	+0.02	+0.021	-0.01	+0.160601	+0.162111	+0.163484
			98669	+40.085	25.01	-0.010	-0.02	-0.015	-0.02	-0.020	+0.00	-0.215744	-0.217327	-0.218927
			98656	+35.721	04.42	+0.011	-0.05	+0.014	-0.00	+0.017	+0.09	+0.358306	+0.358640	+0.358972
			98652	+17.013	41.30	-0.025	-0.01	-0.036	-0.04	-0.048	-0.05	+0.444208	+0.445058	+0.445915
			98664	+28.254	45.77	+0.014	+0.05	+0.022	+0.04	+0.030	-0.03	+0.252429	+0.251519	+0.250555
40	41	42	98632	+58.791	31.24	-0.029	-0.05	-0.042	-0.10	-0.043	-0.12	-0.284153	-0.284181	-0.284146
			98636	+17.155	49.52	+0.039	-0.39	+0.037	-0.47	+0.037	-0.38	+0.189008	+0.188483	+0.187969
			98641	+58.961	34.75	-0.011	+0.33	+0.000	+0.43	+0.001	+0.37	+0.877517	+0.876121	+0.874512
			98624	+37.080	45.88	-0.005	-0.16	-0.015	-0.22	-0.015	-0.20	+0.681024	+0.681403	+0.681955
			98622	+22.601	44.36	+0.005	+0.27	+0.020	+0.36	+0.021	+0.33	-0.463396	-0.461828	-0.460289
43	44	45	98592	+47.759	05.79	-0.033	-0.09	-0.022	-0.24	-0.025	-0.19	-0.322451	-0.321962	-0.321449
			98591	+43.744	37.24	+0.048	+0.17	+0.032	+0.43	+0.039	+0.32	+0.000890	+0.001385	+0.001951
			98624	+37.080	45.88	+0.012	+0.15	+0.009	+0.36	+0.019	+0.20	+0.661394	+0.661131	+0.660834
			98609	+40.636	34.51	-0.036	-0.23	-0.025	-0.56	-0.039	-0.36	+0.545010	+0.544935	+0.544930
			98631	+56.395	22.30	+0.009	+0.01	+0.006	+0.03	+0.005	+0.03	+0.115157	+0.114511	+0.113734
46	47	48	98594	+50.746	14.97	-0.030	-0.52	-0.034	-0.47	-0.027	-0.45	-0.269488	-0.270350	-0.271327
			98595	+09.447	10.14	+0.044	+0.76	+0.049	+0.69	+0.040	+0.65	+0.033911	+0.035303	+0.037002
			98609	+40.636	34.51	-0.014	-0.09	-0.013	-0.30	-0.011	-0.15	+0.486426	+0.487949	+0.489858
			98624	+37.080	45.88	+0.013	+0.22	+0.014	+0.19	+0.011	+0.19	+0.262852	+0.259059	+0.254649
			98609	+40.636	34.51	-0.013	-0.37	-0.016	-0.12	-0.013	-0.24	+0.486298	+0.488039	+0.489818
49	50	51	98580	+53.376	06.16	-0.037	-0.36	-0.029	-0.27	-0.037	-0.41	-0.079899	-0.078964	-0.078186
			98592	+47.759	05.79	+0.036	+0.05	+0.035	+0.09	+0.046	+0.19	-0.164927	-0.164566	-0.164160
			98622	+22.601	44.36	-0.012	-0.05	-0.011	-0.05	-0.014	-0.08	-0.133218	-0.134306	-0.135362
			98595	+09.447	10.14	+0.018	+0.57	+0.005	+0.36	+0.005	+0.48	+0.350889	+0.351056	+0.351354
			98609	+40.636	34.51	-0.005	-0.22	+0.000	-0.13	+0.001	-0.18	+1.027154	+1.026781	+1.026354
52	53	54	98591	+43.744	37.24	+0.041	+0.03	+0.029	+0.17	+0.032	+0.06	+0.244655	+0.246294	+0.247998
			98607	+33.419	27.34	+0.014	-0.19	+0.015	-0.25	+0.014	-0.29	-0.048204	-0.049923	-0.051835
			98605	+09.644	56.83	-0.013	-0.04	-0.008	-0.10	-0.009	-0.06	+0.743805	+0.745207	+0.746799
			98609	+40.636	34.51	+0.007	+0.21	-0.001	+0.35	+0.003	+0.32	+0.051358	+0.049942	+0.048210
			98595	+09.447	10.14	-0.049	-0.01	-0.035	-0.17	-0.039	-0.04	+0.008386	+0.008480	+0.008828
55	56	57	98550	+36.977	07.03	+0.003	+0.21	-0.004	+0.10	-0.001	+0.20	-0.741908	-0.741526	-0.741240
			98580	+53.376	06.16	-0.006	-0.42	+0.008	-0.19	+0.002	-0.40	-0.099681	-0.099729	-0.100059
			98595	+09.447	10.14	+0.008	+0.12	-0.003	-0.04	-0.002	+0.15	+0.552474	+0.551886	+0.551672
			98591	+43.744	37.24	-0.004	+0.19	-0.003	+0.19	+0.001	+0.14	+0.599995	+0.599626	+0.599394
			98544	+16.083	10.83	-0.001	-0.10	+0.002	-0.06	+0.000	-0.09	+0.689120	+0.689740	+0.690232
58	59	60	98682	+15.956	16.62	-0.038	+0.03	-0.023	+0.04	-0.033	-0.07	+0.158938	+0.158099	+0.157342
			98679	+57.829	53.52	+0.020	+0.01	+0.001	+0.20	+0.013	+0.15	-0.171239	-0.172318	-0.173620
			98671	+47.758	15.30	-0.004	-0.03	+0.014	-0.34	+0.003	-0.19	+0.064156	+0.063961	+0.063863
			98653	+22.404	42.57	-0.027	+0.04	-0.025	+0.22	-0.026	+0.05	+0.481015	+0.482466	+0.483893
			98669	+40.085	25.01	+0.049	-0.04	+0.033	-0.12	+0.043	+0.05	+0.467129	+0.467792	+0.468521

Table 2 (continued)

OBSERVATIONS			NO SAO	POSITIONS USED		STAR RESIDUALS						DEPENDENCES		
				s	"	s	"	s	"	s	"			
61	62	63	98632	+58.791	01.24	+0.009	+0.16	+0.023	+0.21	+0.024	+0.13	+0.152638	+0.153866	+0.155136
			98671	+47.758	15.30	-0.017	-0.06	-0.003	+0.15	-0.006	-0.07	-0.032309	-0.033289	-0.034064
			98653	+22.404	42.57	+0.023	-0.00	-0.010	-0.40	-0.006	+0.04	+0.118911	+0.118679	+0.118765
			98669	+40.085	25.01	+0.018	+0.21	+0.027	+0.16	+0.029	+0.17	+0.399713	+0.399170	+0.398345
			98647	+40.530	12.28	-0.032	-0.30	-0.037	-0.12	-0.041	-0.26	+0.361046	+0.361574	+0.361817
64	65	66	98627	+14.916	17.03	+0.008	+0.04	+0.018	+0.28	-0.009	+0.71	+0.117901	+0.118680	+0.119609
			98647	+40.530	12.28	-0.027	-0.27	-0.025	-0.49	-0.017	-0.51	+0.565261	+0.566160	+0.566875
			98632	+58.791	01.24	+0.010	+0.15	-0.002	+0.04	+0.022	-0.43	+0.272172	+0.272931	+0.273358
			98653	+22.404	42.57	-0.015	-0.14	-0.017	-0.31	-0.006	-0.43	-0.266197	-0.268181	-0.269722
			98669	+40.085	25.01	+0.024	+0.23	+0.026	+0.48	+0.010	+0.66	+0.310863	+0.310410	+0.309880
67	68	69	98632	+58.791	01.24	-0.029	-0.05	-0.042	-0.10	-0.043	-0.12	+0.341779	+0.341696	+0.341626
			98636	+17.155	49.52	+0.039	-0.39	+0.037	-0.47	+0.037	-0.38	+0.237364	+0.236849	+0.236310
			98641	+58.961	34.75	-0.011	+0.33	+0.000	+0.43	+0.001	+0.37	+0.098854	+0.097493	+0.096085
			98624	+37.080	45.88	-0.005	-0.16	-0.015	-0.22	-0.015	-0.20	+0.021250	+0.021938	+0.022599
			98622	+22.601	44.36	+0.005	+0.27	+0.020	+0.36	+0.021	+0.33	+0.300754	+0.302025	+0.303381
70	71	72	98592	+47.759	05.79	+0.007	-0.27	+0.012	-0.05	+0.005	+0.01	+0.340678	+0.341398	+0.342029
			98627	+14.916	17.03	-0.048	-0.23	-0.040	+0.22	-0.033	+0.67	+0.252991	+0.252148	+0.251400
			98612	+49.050	13.02	+0.058	-0.01	+0.055	-0.28	+0.040	-0.71	-0.042093	-0.042113	-0.042291
			98622	+22.601	44.36	+0.019	+0.32	+0.011	-0.07	+0.013	-0.35	+0.514984	+0.514095	+0.513437
			98593	+48.929	12.96	-0.036	+0.20	-0.038	+0.18	-0.025	+0.37	-0.066560	-0.065517	-0.064576
73	74	75	98592	+47.759	05.79	+0.008	+0.09	+0.009	+0.07	+0.009	+0.08	-1.575458	-1.568610	-1.561777
			98593	+48.929	12.96	-0.003	-0.04	-0.004	-0.03	-0.004	-0.03	+2.281813	+2.274555	+2.267264
			98594	+50.746	14.97	-0.015	-0.16	-0.016	-0.13	-0.017	-0.14	-1.688395	-1.682071	-1.675367
			98595	+09.447	10.14	+0.002	+0.02	+0.002	+0.02	+0.002	+0.02	+3.557498	+3.544737	+3.531657
			98592	+47.759	05.79	+0.008	+0.09	+0.009	+0.07	+0.009	+0.08	-1.575458	-1.568610	-1.561777
76	77	78	98593	+48.929	12.96	+0.004	+0.15	-0.009	+0.07	-0.008	+0.05	+0.297378	+0.297533	+0.297669
			98580	+53.376	06.16	-0.037	-0.33	-0.021	-0.24	-0.031	-0.33	+0.186755	+0.187605	+0.188285
			98592	+47.759	05.79	+0.036	+0.09	+0.044	+0.13	+0.054	+0.29	+0.199116	+0.199376	+0.199571
			98622	+22.601	44.36	-0.015	-0.15	-0.006	-0.10	-0.010	-0.14	+0.193879	+0.192483	+0.191398
			98595	+09.447	10.14	+0.012	+0.25	-0.008	+0.14	-0.004	+0.13	+0.122872	+0.123003	+0.123076
79	80	81	98580	+53.376	06.16	-0.032	-0.53	-0.030	-0.52	-0.028	-0.58	+0.343480	+0.345177	+0.347098
			98593	+48.929	12.96	-0.017	-0.07	-0.013	-0.09	-0.012	+0.07	+0.304974	+0.303934	+0.302650
			98592	+47.759	05.79	+0.051	+0.37	+0.044	+0.41	+0.038	+0.17	+0.240265	+0.240262	+0.240241
			98591	+43.744	37.24	+0.014	+0.49	+0.015	+0.45	+0.016	+0.65	+0.193068	+0.193986	+0.195055
			98607	+33.419	27.34	-0.016	-0.25	-0.015	-0.25	-0.014	-0.28	-0.081757	-0.083359	-0.085045
82	83	84	98550	+36.977	07.03	-0.006	-0.08	-0.009	-0.09	-0.011	-0.05	+0.235745	+0.236734	+0.237783
			98583	+58.802	12.50	-0.003	+0.01	+0.001	+0.01	+0.002	+0.02	+0.169235	+0.169046	+0.168837
			98592	+47.759	05.79	+0.013	-0.08	-0.010	-0.11	-0.013	-0.10	+0.191398	+0.191031	+0.190640
			98594	+50.746	14.97	-0.034	-0.19	-0.022	-0.19	-0.024	-0.09	+0.197611	+0.197442	+0.197058
			98580	+53.376	06.16	+0.031	+0.34	+0.039	+0.38	+0.046	+0.23	+0.205811	+0.205747	+0.205692
85	86	87	98544	+16.083	10.83	-0.001	-0.01	-0.002	+0.00	-0.000	-0.03	-0.116148	-0.115820	-0.115505
			98580	+53.376	06.16	+0.016	-0.06	+0.015	-0.11	+0.017	-0.14	+0.704082	+0.703222	+0.702611
			98550	+36.977	07.03	-0.040	+0.17	-0.037	+0.27	-0.043	+0.39	+0.274018	+0.273910	+0.273804
			98527	+29.636	27.31	-0.007	-0.01	-0.012	+0.04	-0.005	-0.07	+0.123690	+0.123935	+0.124104
			98528	+29.725	48.85	+0.031	-0.09	+0.036	-0.21	+0.031	-0.14	+0.014359	+0.014753	+0.014985
88	89	90	98528	+29.725	48.64	+0.030	-0.10	+0.031	-0.01	+0.040	-0.15	+0.020572	+0.021200	+0.021742
			98527	+29.636	27.31	-0.005	+0.08	-0.009	-0.10	-0.018	+0.08	+0.136324	+0.136736	+0.136982
			500008	+01.206	30.85	+0.019	-0.02	+0.019	-0.11	+0.018	-0.07	+0.633999	+0.632658	+0.631556
			98550	+36.977	07.03	-0.038	+0.01	-0.037	+0.25	-0.034	+0.12	+0.312579	+0.312249	+0.312018
			98544	+16.083	10.83	-0.003	+0.02	-0.003	-0.03	-0.006	+0.03	-0.103474	-0.102843	-0.102298

Table 2 (continued)

OBSERVATIONS			NO SAO	POSITIONS USED s	POSITIONS USED "	STAR RESIDUALS s	"	s	"	s	"	DEPENDENCES		
91	92	93	98527	+29.636	27.31	-0.016	+0.07	-0.014	+0.08	-0.000	-0.12	+0.186592	+0.186912	+0.187310
			98529	+29.725	48.84	+0.038	-0.18	+0.040	-0.16	+0.022	+0.03	+0.111198	+0.111750	+0.112331
			98544	+16.083	10.63	-0.005	+0.00	-0.005	+0.03	-0.001	-0.03	+0.000947	+0.001546	+0.002197
			100068	+01.206	30.85	+0.019	-0.10	+0.020	-0.07	+0.019	-0.09	+0.435255	+0.434064	+0.432739
			98550	+36.977	07.03	-0.035	+0.18	-0.045	+0.12	-0.040	+0.21	+0.266008	+0.265726	+0.265472
94	95	96	98550	+36.977	07.03	-0.019	-0.45	-0.019	-0.68	-0.003	-0.40	+0.403752	+0.402369	+0.401926
			98544	+16.083	10.63	+0.008	+0.43	+0.009	+0.59	-0.005	+0.38	+0.159430	+0.159298	+0.159191
			98520	+34.704	29.69	-0.019	-0.53	-0.017	-0.78	+0.000	-0.49	+0.008554	+0.009376	+0.010227
			98528	+29.725	48.84	+0.042	+0.19	+0.036	+0.46	+0.027	+0.24	+0.222905	+0.222892	+0.222695
			98522	+41.799	13.32	-0.013	+0.37	-0.011	+0.41	-0.020	+0.29	+0.205358	+0.205565	+0.205761
97	98	99	98520	+34.704	29.69	+0.026	-0.78	+0.011	-0.49	+0.020	-0.45	+0.421054	+0.421712	+0.421674
			98528	+29.725	48.84	+0.017	+0.59	+0.020	+0.36	+0.006	+0.40	+0.485147	+0.484415	+0.483253
			98527	+29.636	27.31	-0.052	+0.22	-0.038	+0.15	-0.037	+0.04	+0.382754	+0.382001	+0.380960
			98515	+13.345	17.81	+0.040	-0.65	+0.023	-0.40	+0.037	-0.34	-0.113004	-0.113047	-0.112709
			98501	+03.367	14.36	-0.031	+0.63	-0.016	+0.40	-0.027	+0.35	-0.176401	-0.175081	-0.173476
100	101	102	98502	+05.207	03.18	-0.023	+0.47	-0.031	+0.37	-0.028	+0.16	+0.056553	+0.057396	+0.058343
			98501	+03.367	14.36	+0.025	-0.26	+0.037	-0.27	+0.031	-0.08	-0.042194	-0.041354	-0.040216
			98520	+34.704	29.69	+0.004	-0.33	+0.002	-0.16	+0.004	-0.12	+0.460772	+0.460699	+0.460061
			98528	+29.725	48.84	+0.005	+0.38	+0.013	+0.15	+0.007	+0.14	+0.392419	+0.391385	+0.390168
			98522	+41.799	13.32	-0.011	-0.27	-0.021	-0.06	-0.014	-0.10	+0.132450	+0.131892	+0.131644
103	104		98502	+05.207	03.18	-0.050	-0.08	-0.056	-0.24			+0.159583	+0.159917	
			98501	+03.367	14.36	+0.016	-0.55	+0.004	-0.41			+0.077073	+0.077506	
			98520	+34.704	29.69	+0.010	-0.05	+0.010	-0.01			+0.505951	+0.504754	
			98522	+41.799	13.32	+0.004	+0.30	+0.010	+0.27			+0.232696	+0.231613	
			98485	+56.022	29.18	+0.019	+0.38	+0.030	+0.39			+0.024697	+0.026209	
105	106		98501	+03.367	14.36	+0.040	-0.31	+0.039	-0.21			+0.442134	+0.441780	
			98473	+37.794	28.74	-0.005	+0.26	-0.002	+0.16			-0.113477	-0.112366	
			98497	+54.407	18.11	+0.008	+0.24	+0.013	+0.14			+0.324566	+0.323666	
			98475	+04.148	10.70	+0.005	-0.34	+0.001	-0.20			-0.080520	-0.080097	
			98502	+05.207	03.18	-0.049	+0.15	-0.050	+0.12			+0.427297	+0.426979	
107	108	109	98727	+28.512	44.65	-0.014	+0.25	-0.018	+0.26	-0.023	+0.19	+0.566863	+0.566047	+0.565246
			98718	+06.448	15.78	+0.011	+0.43	+0.018	+0.41	+0.021	+0.26	+0.184237	+0.183767	+0.183240
			98710	+29.772	10.54	+0.002	-0.60	-0.001	-0.59	+0.000	-0.39	-0.022393	-0.022847	-0.023353
			98682	+15.956	16.62	-0.012	+0.42	-0.014	+0.42	-0.018	+0.29	-0.106804	-0.105669	-0.104500
			98701	+17.705	14.19	+0.013	-0.50	+0.015	-0.50	+0.020	-0.35	+0.378057	+0.378703	+0.379366
110	111	112	98682	+15.956	16.62	-0.038	+0.03	-0.023	+0.04	-0.033	-0.07	+0.382553	+0.381605	+0.380779
			98679	+57.829	53.52	+0.020	+0.01	+0.001	+0.20	+0.013	+0.15	+0.238862	+0.237550	+0.236104
			98671	+47.758	15.30	-0.004	-0.03	+0.014	-0.34	+0.003	-0.19	+0.126125	+0.126081	+0.125650
			98653	+22.404	42.57	-0.027	+0.04	-0.025	+0.22	-0.026	+0.05	+0.027415	+0.029069	+0.030685
			98669	+40.085	25.01	+0.049	-0.04	+0.033	-0.12	+0.043	+0.05	+0.225046	+0.225691	+0.226583
113	114	115	98632	+58.791	01.24	+0.009	+0.16	+0.023	+0.21	+0.024	+0.13	-0.155401	-0.154013	-0.152700
			98671	+47.758	15.30	-0.017	-0.06	-0.003	+0.15	-0.006	-0.07	+0.270738	+0.269675	+0.268284
			98653	+22.404	42.57	+0.023	-0.00	-0.010	-0.40	-0.006	+0.04	+0.161466	+0.161180	+0.161062
			98669	+40.085	25.01	+0.018	+0.21	+0.027	+0.16	+0.029	+0.17	+0.513673	+0.513113	+0.512638
			98647	+40.530	12.28	-0.032	-0.30	-0.037	-0.12	-0.041	-0.26	+0.209514	+0.210085	+0.210716
116	117	118	98627	+14.916	17.03	+0.008	+0.04	+0.018	+0.28	-0.009	+0.71	-0.019534	-0.019099	-0.018652
			98647	+40.530	12.28	-0.027	-0.27	-0.025	-0.49	-0.017	-0.51	+0.221943	+0.223373	+0.224828
			98632	+58.791	01.24	+0.010	+0.15	-0.002	+0.04	+0.022	-0.43	+0.052680	+0.053521	+0.054443
			98653	+22.404	42.57	-0.015	-0.14	-0.017	-0.31	-0.006	-0.43	+0.311671	+0.309360	+0.306952
			98669	+40.085	25.01	+0.024	+0.23	+0.026	+0.48	+0.010	+0.66	+0.433540	+0.433084	+0.432629

Table 2 (continued)

OBSERVATIONS			NO SAO	POSITIONS USED		STAR RESIDUALS						DEPENDENCES		
				s	"	s	"	s	"	s	"			
119	120	121	98632	+58.791	01.24	-0.021	+0.23	-0.028	+0.37	-0.020	+0.31	+0.240587	+0.240965	+0.241357
			98647	+40.530	12.28	+0.003	-0.05	+0.007	-0.12	+0.002	-0.10	+0.444472	+0.441145	+0.437943
			98636	+17.155	49.52	+0.036	-0.31	+0.031	-0.28	+0.038	-0.23	+0.145482	+0.146262	+0.147031
			98631	+56.395	22.30	-0.001	-0.04	+0.011	-0.25	-0.005	-0.21	+0.078888	+0.080711	+0.082341
			98641	+58.961	34.75	-0.017	+0.18	-0.022	+0.28	-0.016	+0.23	+0.090572	+0.090917	+0.091328
122	123	124	98631	+56.395	22.30	+0.061	-0.27	+0.052	-0.39	+0.032	-0.51	+0.384025	+0.383443	+0.382678
			98632	+58.791	01.24	-0.002	+0.27	+0.001	+0.06	+0.012	-0.37	+0.022971	+0.021339	+0.019416
			98627	+14.916	17.03	-0.072	-0.06	-0.066	+0.40	-0.058	+1.18	-0.010166	-0.010817	-0.011427
			98612	+49.050	13.02	+0.052	-0.09	+0.046	-0.31	+0.035	-0.65	-0.004116	-0.003199	-0.002020
			98622	+22.601	44.36	-0.039	+0.16	-0.034	+0.25	-0.022	+0.35	+0.607285	+0.609273	+0.611354
125	126	127	98592	+47.759	05.79	+0.008	+0.09	+0.009	+0.07	+0.009	+0.08	-3.094096	-3.085717	-3.077843
			98593	+48.929	12.96	-0.003	-0.04	-0.004	-0.03	-0.004	-0.03	+3.881205	+3.872290	+3.863770
			98594	+50.746	14.97	-0.015	-0.16	-0.016	-0.13	-0.017	-0.14	-3.244218	-3.236914	-3.229384
			98595	+09.447	10.14	+0.002	+0.02	+0.002	+0.02	+0.002	+0.02	+6.551205	+6.536058	+6.521301
			98592	+47.759	05.79	+0.008	+0.09	+0.009	+0.07	+0.009	+0.08	-3.094096	-3.085717	-3.077843
128	129	130	98593	+48.929	12.96	+0.004	+0.15	-0.009	+0.07	-0.008	+0.05	+0.136813	+0.137119	+0.137384
			98580	+53.376	06.16	-0.037	-0.33	-0.021	-0.24	-0.031	-0.33	+0.019192	+0.020148	+0.021058
			98592	+47.759	05.79	+0.036	+0.09	+0.044	+0.13	+0.054	+0.29	+0.143291	+0.143598	+0.143912
			98622	+22.601	44.36	-0.015	-0.15	-0.006	-0.10	-0.010	-0.14	+0.500560	+0.499050	+0.497597
			98595	+09.447	10.14	+0.012	+0.25	-0.008	+0.14	-0.004	+0.13	+0.200144	+0.200084	+0.200140
131	132	133	98580	+53.376	06.16	-0.032	-0.53	-0.030	-0.52	-0.028	-0.58	+0.019257	+0.021201	+0.022979
			98593	+46.929	12.96	-0.017	-0.07	-0.015	-0.09	-0.012	+0.03	+0.442518	+0.441190	+0.439966
			98592	+47.759	05.79	+0.051	+0.37	+0.044	+0.41	+0.038	+0.17	+0.231086	+0.231009	+0.230965
			98591	+43.744	37.24	+0.014	+0.49	+0.015	+0.45	+0.016	+0.65	+0.045219	+0.046335	+0.047325
			98607	+33.419	27.34	-0.016	-0.25	-0.015	-0.25	-0.014	-0.25	+0.261919	+0.260265	+0.258764
134	135	136	98592	+47.759	05.79	+0.005	-0.03	+0.011	-0.02	+0.009	-0.05	+0.491630	+0.489420	+0.487093
			98594	+50.746	14.97	-0.000	+0.20	-0.006	+0.21	-0.003	+0.20	+0.238761	+0.237512	+0.236105
			98580	+53.376	06.16	-0.005	-0.09	-0.007	-0.10	-0.007	-0.07	+0.472778	+0.476745	+0.481146
			98595	+09.447	10.14	-0.011	-0.23	-0.014	-0.25	-0.014	-0.18	-0.099393	-0.101055	-0.102999
			98591	+43.744	37.24	+0.011	+0.15	+0.017	+0.16	+0.015	+0.10	-0.103776	-0.102621	-0.101335
137	138	139	98544	+16.083	10.83	-0.001	-0.01	-0.002	+0.00	-0.000	-0.03	-0.062007	-0.061467	-0.060942
			98580	+53.376	06.16	+0.016	-0.06	+0.015	-0.11	+0.017	-0.14	+0.833854	+0.833087	+0.832271
			98550	+36.977	07.03	-0.040	+0.17	-0.037	+0.27	-0.043	+0.39	+0.276775	+0.276651	+0.276505
			98527	+29.636	27.31	-0.007	-0.01	-0.012	+0.04	-0.005	-0.07	+0.019936	+0.019996	+0.020148
			98528	+29.725	48.65	+0.031	-0.09	+0.036	-0.21	+0.031	-0.14	-0.068557	-0.068266	-0.067982
140	141	142	98528	+29.725	48.84	+0.030	-0.10	+0.031	-0.01	+0.040	-0.15	-0.074351	-0.073849	-0.073271
			98527	+29.636	27.31	-0.008	+0.08	-0.009	-0.10	-0.018	+0.08	+0.019902	+0.020195	+0.020395
			500008	+01.206	30.85	+0.019	-0.02	+0.019	-0.11	+0.018	-0.07	+0.770398	+0.769288	+0.768053
			98550	+36.977	07.03	-0.038	+0.01	-0.037	+0.25	-0.034	+0.12	+0.325166	+0.324885	+0.324604
			98544	+16.083	10.83	-0.003	+0.02	-0.003	-0.03	-0.006	+0.03	-0.041115	-0.040512	-0.039781
143	144	145	98527	+29.636	27.31	-0.016	+0.07	-0.014	+0.08	-0.000	-0.12	+0.064473	+0.064757	+0.065063
			98528	+29.725	48.84	+0.038	-0.18	+0.040	-0.16	+0.022	+0.03	+0.019768	+0.020316	+0.020831
			98544	+16.083	10.83	-0.005	+0.02	-0.005	+0.03	-0.001	-0.03	+0.087885	+0.088569	+0.089328
			500008	+01.206	30.85	+0.019	-0.10	+0.023	-0.07	+0.019	-0.09	+0.555397	+0.554189	+0.552913
			98550	+36.977	07.03	-0.035	+0.18	-0.045	+0.12	-0.040	+0.21	+0.272476	+0.272169	+0.271865
146	147	148	98550	+36.977	07.03	-0.019	-0.45	-0.019	-0.68	-0.003	-0.42	+0.484194	+0.483207	+0.482159
			98544	+16.083	10.83	+0.008	+0.43	+0.009	+0.59	-0.005	+0.38	+0.335003	+0.334874	+0.334732
			98520	+34.704	29.69	-0.018	-0.53	-0.017	-0.78	+0.000	-0.49	-0.040104	-0.039205	-0.038201
			98528	+29.725	48.84	+0.042	+0.19	+0.038	+0.46	+0.027	+0.24	+0.160317	+0.160307	+0.160288
			98522	+41.799	10.32	-0.013	+0.37	-0.011	+0.41	-0.020	+0.29	+0.060590	+0.060817	+0.061022

Table 2 (continued)

OBSERVATIONS			NO SAO	POSITIONS USED		STAR RESIDUALS						DEPENDENCES		
				s	"	s	"	s	"	s	"			
149	150	151	98520	+34.704	29.69	+0.026	-0.78	+0.011	-0.49	+0.026	-0.45	+0.591958	+0.592004	+0.592358
			98528	+29.725	48.84	+0.017	+0.58	+0.020	+0.36	+0.005	+0.40	+0.650772	+0.649776	+0.648692
			98527	+29.636	27.31	-0.052	+0.22	-0.038	+0.15	-0.037	+0.04	+0.469514	+0.468586	+0.467488
			98515	+13.845	17.81	+0.040	-0.65	+0.023	-0.42	+0.033	-0.34	-0.334473	-0.334317	-0.334090
			98501	+03.367	14.36	-0.031	+0.63	-0.016	+0.40	-0.027	+0.35	-0.377771	-0.376048	-0.374449
152	153	154	98502	+05.207	03.18	-0.023	+0.47	-0.031	+0.37	-0.028	+0.16	-0.022687	-0.021782	-0.020936
			98501	+03.367	14.36	+0.025	-0.26	+0.037	-0.27	+0.031	-0.08	-0.290466	-0.289458	-0.288571
			98520	+34.704	29.69	+0.004	-0.33	+0.002	-0.18	+0.004	-0.12	+0.857541	+0.857452	+0.857303
			98528	+29.725	48.84	+0.005	+0.38	+0.013	+0.15	+0.007	+0.14	+0.523465	+0.522257	+0.521144
			98522	+41.799	10.32	-0.011	-0.27	-0.021	-0.06	-0.014	-0.10	-0.067854	-0.068469	-0.068940
155	156		98502	+05.207	03.18	-0.050	-0.08	-0.056	-0.24			+0.142729	+0.142942	
			98501	+03.367	14.36	+0.016	-0.55	+0.004	-0.41			-0.125551	-0.125296	
			98520	+34.704	29.69	+0.010	-0.05	+0.010	-0.01			+0.995403	+0.994628	
			98522	+41.799	10.32	+0.004	+0.30	+0.012	+0.27			+0.062703	+0.061708	
			98485	+56.022	29.18	+0.019	+0.38	+0.030	+0.39			-0.075284	-0.073983	
157	158		98501	+03.367	14.36	+0.040	-0.31	+0.039	-0.21			+0.338733	+0.336080	
			98473	+37.794	28.74	-0.005	+0.26	-0.002	+0.16			-0.437911	-0.436764	
			98497	+54.407	18.11	+0.008	+0.24	+0.013	+0.14			+0.653780	+0.653233	
			98475	+04.148	10.70	+0.005	-0.34	+0.001	-0.20			+0.003583	+0.004353	
			98502	+05.207	03.18	-0.049	+0.15	-0.050	+0.12			+0.441815	+0.441118	
159	160	161	98641	+58.961	34.75	+0.005	+0.15	+0.004	+0.20	+0.002	+0.14	+0.307366	+0.307160	+0.306922
			98631	+56.395	22.30	-0.013	-0.50	-0.007	-0.69	+0.000	-0.47	+0.069316	+0.068485	+0.067737
			98592	+47.759	05.79	+0.006	+0.09	+0.008	+0.06	+0.007	+0.08	+0.210604	+0.211129	+0.211662
			98594	+50.746	14.97	-0.009	-0.24	-0.008	-0.28	-0.006	-0.23	+0.320251	+0.321133	+0.322019
			98622	+22.601	44.36	+0.012	+0.50	+0.003	+0.73	-0.004	+0.47	+0.092462	+0.092093	+0.091660
162	163	164	98592	+47.759	05.79	-0.013	-0.12	-0.014	-0.17	-0.017	-0.16	-0.031427	-0.030117	-0.028697
			98594	+50.746	14.97	+0.014	+0.20	+0.015	+0.27	+0.020	+0.27	+0.084005	+0.084749	+0.085497
			98591	+43.744	37.24	+0.054	+0.03	+0.054	+0.12	+0.049	+0.06	+0.212819	+0.212935	+0.212861
			98595	+09.447	10.14	-0.065	-0.13	-0.065	-0.26	-0.062	-0.18	+0.274478	+0.274141	+0.273727
			98622	+22.601	44.36	+0.010	+0.01	+0.010	+0.03	+0.009	+0.02	+0.460124	+0.458293	+0.456612
165	166	167	98580	+53.376	06.16	-0.026	-0.08	-0.024	-0.11	-0.026	-0.08	+0.482647	+0.486895	+0.491274
			98592	+47.759	05.79	+0.015	-0.02	+0.012	-0.03	+0.000	-0.06	+0.063644	+0.061307	+0.059058
			98594	+50.746	14.97	+0.019	+0.17	+0.020	+0.24	+0.043	+0.24	+0.114615	+0.113244	+0.111712
			98595	+09.447	10.14	-0.059	-0.21	-0.055	-0.27	-0.062	-0.21	+0.071689	+0.069845	+0.068007
			98591	+43.744	37.24	+0.051	+0.14	+0.047	+0.17	+0.044	+0.11	+0.267405	+0.268709	+0.269948
168	169	170	500007	+54.222	56.33	-0.009	-0.12	-0.010	-0.30	-0.014	-0.29	+0.315594	+0.316275	+0.316968
			98550	+36.977	07.03	+0.008	+0.11	+0.009	+0.27	+0.012	+0.26	+0.215643	+0.216172	+0.216669
			98592	+47.759	05.79	-0.003	-0.12	-0.005	-0.26	-0.011	-0.30	+0.118169	+0.117672	+0.117179
			98594	+50.746	14.97	-0.013	-0.06	-0.011	-0.17	-0.010	-0.09	+0.149731	+0.149297	+0.148877
			98591	+43.744	37.24	+0.017	+0.19	+0.017	+0.46	+0.022	+0.42	+0.200863	+0.200585	+0.200306
171	172	173	98550	+36.977	07.03	-0.005	-0.08	-0.011	-0.06	-0.006	-0.09	+0.957859	+0.959350	+0.960874
			98580	+53.376	06.16	+0.011	+0.13	+0.039	+0.03	+0.013	+0.19	-0.103123	-0.103950	-0.104478
			98594	+50.746	14.97	-0.033	-0.52	-0.053	-0.46	-0.033	-0.50	-0.365941	-0.366986	-0.368398
			98595	+09.447	10.14	+0.042	+0.70	+0.037	+0.75	+0.038	+0.59	+0.022061	+0.021777	+0.021309
			98609	+40.636	34.51	-0.014	-0.23	-0.012	-0.25	-0.013	-0.20	+0.489144	+0.489809	+0.490692
174	175	176	98580	+53.376	06.16	-0.028	-0.48	-0.010	-0.31	-0.023	-0.48	+0.070932	+0.070713	+0.070489
			98550	+36.977	07.03	-0.012	+0.16	-0.021	+0.05	-0.018	+0.09	+0.360427	+0.360713	+0.361150
			98592	+47.759	05.79	+0.039	+0.14	+0.039	+0.18	+0.045	+0.25	-0.080314	-0.080780	-0.081250
			98595	+09.447	10.14	-0.017	+0.22	-0.031	+0.06	-0.027	+0.11	+0.056723	+0.056465	+0.056091
			500007	+54.222	56.33	+0.018	-0.04	+0.023	+0.03	+0.023	+0.03	+0.592232	+0.592889	+0.593521

Table 2 (continued)

OBSERVATIONS			NO SAO	POSITIONS USED		STAR RESIDUALS						DEPENDENCES		
				S	"	S	"	S	"	S	"			
177	178	179	98544	+16.083	10.83	-0.007	-0.01	-0.004	-0.07	-0.005	+0.03	+0.566047	+0.566550	+0.567116
			98528	+29.725	48.65	+0.040	-0.08	+0.033	+0.14	+0.035	-0.23	+0.182074	+0.182435	+0.182691
			98527	+29.636	27.31	-0.024	-0.03	-0.016	-0.22	-0.019	+0.13	+0.051192	+0.051319	+0.051481
			98550	+36.977	07.03	-0.018	+0.19	-0.023	+0.22	-0.020	+0.14	+0.145625	+0.145505	+0.145367
			98580	+53.376	06.16	+0.009	-0.07	+0.010	-0.06	+0.010	-0.07	+0.055062	+0.054192	+0.053344
180	181	182	98520	+34.704	29.69	-0.010	-0.70	+0.005	-0.66	+0.007	-0.76	+0.327953	+0.329020	+0.330005
			98522	+41.799	10.32	+0.014	+0.46	-0.011	+0.50	-0.013	+0.63	+0.045543	+0.045963	+0.046332
			98527	+29.636	27.31	-0.005	+0.26	+0.009	+0.17	+0.008	+0.10	+0.024692	+0.024590	+0.024462
			98550	+36.977	07.03	-0.006	-0.66	-0.000	-0.59	+0.002	-0.64	+0.139818	+0.138702	+0.137657
			98544	+16.083	10.83	+0.008	+0.64	-0.003	+0.59	-0.005	+0.67	+0.461994	+0.461725	+0.461543
183	184	185	98544	+16.083	10.83	+0.001	+0.34	+0.006	+0.47	+0.007	+0.26	+0.401317	+0.401049	+0.400742
			98550	+36.977	07.03	-0.004	-0.47	-0.011	-0.64	-0.011	-0.37	-0.112060	-0.113148	-0.114068
			98527	+29.636	27.31	-0.010	+0.20	-0.012	+0.33	-0.006	+0.13	+0.000915	+0.000960	+0.000957
			98528	+29.725	48.85	+0.020	+0.37	+0.032	+0.43	+0.025	+0.33	+0.149097	+0.149288	+0.149479
			98520	+34.704	29.69	-0.007	-0.43	-0.015	-0.58	-0.013	-0.35	+0.560731	+0.561852	+0.562891
186	187	188	98520	+34.704	29.69	+0.025	+0.02	+0.024	+0.01	+0.022	+0.04	+0.254523	+0.254845	+0.255144
			98528	+29.725	48.84	+0.036	+0.27	+0.032	+0.19	+0.039	+0.06	+0.076511	+0.076609	+0.076654
			98550	+36.977	07.03	-0.048	-0.29	-0.044	-0.21	-0.049	-0.08	+0.005058	+0.004449	+0.003875
			98544	+16.083	10.83	+0.021	+0.15	+0.019	+0.10	+0.022	+0.04	+0.248164	+0.247531	+0.246983
			98497	+54.407	18.11	-0.034	-0.15	-0.032	-0.10	-0.033	-0.05	+0.415744	+0.416566	+0.417344
189	190	191	98489	+12.297	44.06	-0.023	+0.01	-0.016	+0.15	-0.005	+0.08	-0.096421	-0.096533	-0.096702
			98528	+29.725	48.84	+0.021	-0.01	+0.016	-0.15	+0.002	-0.09	-0.224562	-0.225559	-0.226535
			98485	+56.022	29.18	+0.006	-0.01	+0.006	-0.03	-0.005	-0.05	+0.627744	+0.628922	+0.630195
			98520	+34.704	29.69	+0.017	+0.02	+0.009	-0.02	+0.017	-0.00	+0.360001	+0.360235	+0.360465
			98544	+16.083	10.83	-0.022	+0.00	-0.014	+0.11	-0.010	+0.05	+0.333237	+0.332935	+0.332577
192	193	194	98486	+04.279	48.94	-0.036	-0.00	-0.033	-0.24	-0.035	-0.01	+0.584132	+0.584672	+0.585359
			98497	+54.407	18.11	+0.048	-0.02	+0.044	+0.28	+0.047	-0.01	+0.431270	+0.431493	+0.431531
			98485	+56.022	29.18	-0.016	+0.48	-0.011	+0.68	-0.010	+0.48	+0.017300	+0.017288	+0.017172
			98520	+34.704	29.69	-0.009	-0.15	-0.009	-0.30	-0.011	-0.15	-0.046412	-0.047505	-0.048549
			98473	+37.794	28.74	+0.014	-0.31	+0.010	-0.42	+0.009	-0.31	+0.013711	+0.014052	+0.014487
195	196	197	98473	+37.794	28.74	+0.006	-0.08	-0.004	-0.12	-0.008	-0.09	+0.042566	+0.043262	+0.043987
			98475	+04.146	10.70	+0.017	-0.12	+0.036	-0.02	+0.035	-0.08	+0.598120	+0.600250	+0.602111
			98486	+04.279	48.94	-0.039	+0.32	-0.063	+0.17	-0.058	+0.25	+0.406782	+0.407151	+0.407401
			98497	+54.407	18.11	+0.029	-0.26	+0.035	-0.21	+0.029	-0.23	+0.114290	+0.112643	+0.111132
			98485	+56.022	29.18	-0.013	+0.14	-0.003	+0.18	+0.002	+0.15	-0.161758	-0.163305	-0.164631
198	199	200	98629	+38.776	52.83	+0.012	-0.34	+0.006	-0.02	+0.014	+0.04	+0.657309	+0.655599	+0.653973
			98628	+23.324	45.24	-0.023	+0.64	-0.012	+0.04	-0.027	-0.06	+0.337891	+0.337506	+0.337000
			98612	+49.050	13.02	+0.006	-0.06	+0.002	+0.04	+0.003	+0.04	+0.337751	+0.341484	+0.345195
			98627	+14.916	17.03	-0.005	-0.18	+0.000	-0.15	+0.005	-0.09	-0.042741	-0.042647	-0.042563
			98632	+58.791	01.24	+0.009	-0.06	+0.003	+0.08	+0.004	+0.07	-0.290210	-0.291942	-0.293606
201	202	203	98612	+49.050	13.02	+0.022	+0.35	+0.050	+0.49	+0.030	+0.31	+0.488419	+0.488625	+0.489767
			98593	+48.929	12.96	-0.010	-0.16	-0.023	-0.23	-0.014	-0.14	+0.328170	+0.329601	+0.331140
			98627	+14.916	17.03	+0.011	+0.03	+0.009	+0.09	+0.008	+0.21	-0.777996	-0.779770	-0.781820
			98628	+23.324	45.23	-0.028	-0.13	-0.029	-0.28	-0.023	-0.53	+0.121068	+0.120635	+0.120180
			98629	+38.776	52.83	+0.005	-0.09	-0.007	-0.07	-0.001	+0.15	+0.840339	+0.840710	+0.840733
204	205	206	98622	+22.601	44.36	+0.002	-0.08	-0.003	-0.11	-0.005	-0.08	-0.516409	-0.516768	-0.517173
			98583	+58.802	12.50	-0.007	-0.19	-0.014	-0.25	-0.018	-0.22	+0.652984	+0.654047	+0.655115
			98593	+48.929	12.96	-0.012	+0.17	+0.001	+0.23	+0.004	+0.13	+0.237266	+0.237909	+0.238664
			98612	+49.050	13.02	+0.048	+0.22	+0.039	+0.25	+0.044	+0.39	+0.349811	+0.349531	+0.349161
			98628	+23.324	45.23	-0.029	-0.11	-0.023	-0.12	-0.026	-0.21	+0.276347	+0.275281	+0.274232

Table 2 (continued)

OBSERVATIONS			NO SAO	POSITIONS USED		STAR RESIDUALS						DEPENDENCES		
				s	"	s	"	s	"	s	"			
207	208	209	98592	+47.759	05.79	+0.014	-0.05	+0.006	+0.02	+0.008	-0.07	-0.856764	-0.857746	-0.858673
			98550	+36.977	07.03	-0.011	-0.10	-0.005	-0.14	-0.009	-0.10	+0.417655	+0.418618	+0.419645
			98612	+49.050	13.02	-0.016	-0.23	-0.007	-0.28	-0.014	-0.25	+0.145959	+0.145282	+0.144657
			98593	+48.929	12.96	-0.006	+0.46	-0.002	+0.37	+0.003	+0.52	+0.242996	+0.242918	+0.242678
			98583	+58.802	12.50	+0.019	-0.08	+0.008	+0.03	+0.011	-0.11	+1.050155	+1.050926	+1.051693
210	211	212	500006	+56.686	12.99	+0.003	+0.04	+0.004	+0.05	+0.008	-0.01	+0.685657	+0.686753	+0.687621
			98583	+58.802	12.50	-0.001	-0.24	-0.006	-0.25	-0.005	-0.06	+0.288111	+0.288040	+0.287873
			98612	+49.050	13.02	+0.007	-0.00	+0.002	+0.00	+0.017	-0.05	+0.090371	+0.089488	+0.088462
			98593	+48.929	12.96	-0.014	+0.28	-0.011	+0.28	-0.033	+0.12	+0.099980	+0.099828	+0.099748
			98592	+47.759	05.79	+0.006	-0.08	+0.005	-0.08	+0.013	-0.06	-0.164318	-0.164108	-0.163704
213	214	215	500006	+56.686	12.99	+0.009	-0.09	+0.017	-0.03	+0.015	-0.06	+0.779632	+0.780417	+0.781043
			98583	+58.802	12.50	-0.027	-0.22	-0.015	-0.25	-0.016	-0.21	+0.255927	+0.255458	+0.255024
			98593	+48.929	12.96	+0.022	+0.43	-0.005	+0.39	-0.000	+0.37	+0.034862	+0.034314	+0.033699
			98580	+53.376	06.16	+0.001	-0.35	+0.025	-0.25	+0.020	-0.28	-0.224420	-0.224695	-0.224905
			98550	+36.977	07.03	-0.006	+0.23	-0.022	+0.14	-0.018	+0.17	+0.153799	+0.154509	+0.155139
216	217	218	98528	+29.725	48.85	+0.042	-0.14	+0.037	+0.01	+0.039	-0.19	+0.081472	+0.081762	+0.082116
			98527	+29.636	27.31	-0.025	+0.02	-0.013	-0.19	-0.021	+0.21	+0.343516	+0.344001	+0.344386
			98550	+36.977	07.03	-0.024	+0.13	-0.027	+0.13	-0.024	+0.04	-0.317243	-0.317602	-0.317965
			500006	+56.686	12.99	-0.003	+0.06	-0.009	+0.13	-0.005	-0.05	+0.838151	+0.838605	+0.839102
			98583	+58.802	12.50	+0.010	-0.07	+0.013	-0.09	+0.010	-0.00	+0.054103	+0.053233	+0.052360
219	220	221	98516	+19.918	16.89	-0.007	-0.02	-0.003	+0.13	-0.007	+0.17	+0.810307	+0.810894	+0.811348
			98522	+41.799	10.32	+0.019	-0.16	+0.003	-0.21	+0.004	-0.18	+0.184256	+0.184643	+0.184951
			98527	+29.636	27.31	-0.010	+0.22	+0.003	+0.01	+0.007	-0.09	+0.155963	+0.156178	+0.156384
			98550	+36.977	07.03	-0.005	-0.03	-0.003	+0.11	-0.006	+0.15	-0.514664	-0.514967	-0.515226
			98583	+58.802	12.50	+0.003	-0.02	+0.001	-0.04	+0.001	-0.05	+0.363947	+0.363251	+0.362545
222	223	224	98550	+36.977	07.03	-0.005	-0.05	-0.003	-0.01	-0.003	+0.03	+0.132233	+0.130426	+0.128615
			98527	+29.636	27.31	+0.014	+0.15	+0.010	+0.02	+0.008	-0.09	+0.062422	+0.062755	+0.063078
			98508	+45.444	10.24	+0.003	+0.22	+0.005	+0.24	+0.002	+0.28	+0.745168	+0.744044	+0.742939
			98515	+13.845	17.81	-0.011	-0.51	-0.013	-0.51	-0.008	-0.56	+0.252395	+0.252988	+0.253592
			98522	+41.799	10.32	-0.001	+0.19	+0.002	+0.26	+0.000	+0.34	-0.192318	-0.190212	-0.188223
225	226	227	98516	+19.918	16.89	+0.009	-0.59	+0.020	-0.42	+0.007	-0.14	+0.649691	+0.649393	+0.648920
			98489	+12.297	44.06	-0.003	+0.33	-0.008	+0.26	-0.001	+0.08	+0.543760	+0.545493	+0.547292
			98520	+34.704	29.69	-0.002	-0.44	+0.004	-0.39	-0.006	-0.10	-0.398299	-0.397777	-0.397293
			98528	+29.725	48.84	+0.017	+0.54	+0.014	+0.61	+0.029	+0.11	-0.015091	-0.015872	-0.016583
			98527	+29.636	27.31	-0.021	+0.16	-0.029	-0.06	-0.029	+0.05	+0.219739	+0.218762	+0.217665
228	229	230	98489	+12.297	44.06	-0.006	+0.01	-0.006	+0.02	-0.004	-0.05	+0.630531	+0.632492	+0.634509
			98508	+45.444	10.23	+0.003	+0.01	+0.006	+0.06	+0.000	-0.01	+0.467304	+0.466811	+0.466411
			98516	+19.918	16.89	+0.013	-0.04	+0.007	-0.14	+0.011	+0.15	+0.231010	+0.230690	+0.230309
			98527	+29.636	27.31	-0.036	+0.06	-0.033	+0.07	-0.022	-0.27	-0.129912	-0.130693	-0.131542
			98528	+29.725	48.84	+0.026	-0.04	+0.026	-0.01	+0.015	+0.18	-0.198932	-0.199305	-0.199702
231	232	233	98520	+34.704	29.69	-0.006	-0.01	-0.004	-0.11	+0.013	-0.01	-0.545002	-0.545226	-0.545562
			98528	+29.725	48.84	-0.003	+0.06	-0.006	+0.19	-0.021	+0.08	-0.268766	-0.269297	-0.269718
			98515	+13.845	17.81	+0.028	-0.14	+0.030	-0.21	+0.022	-0.21	+0.580605	+0.580365	+0.580151
			98489	+12.297	44.06	-0.040	+0.16	-0.040	+0.18	-0.017	+0.25	+0.765043	+0.765314	+0.765471
			98473	+37.794	28.74	+0.021	-0.07	+0.020	-0.04	+0.003	-0.12	+0.468120	+0.468844	+0.469641
234	235	236	98515	+13.845	17.81	+0.037	-0.16	+0.023	-0.05	+0.025	-0.21	+0.192956	+0.192212	+0.191471
			98501	+03.367	14.36	-0.027	-0.30	-0.020	-0.09	-0.022	-0.27	-0.127715	-0.127982	-0.128166
			98454	+17.284	13.86	+0.001	-0.17	-0.001	-0.06	-0.001	-0.17	+0.769254	+0.769918	+0.770627
			98489	+12.297	44.06	-0.042	+0.58	-0.024	+0.23	-0.025	+0.64	+0.219147	+0.219003	+0.218761
			98473	+37.794	28.74	+0.032	+0.06	+0.021	-0.00	+0.023	+0.02	-0.053642	-0.053151	-0.052691

Table 2 (continued)

OBSERVATIONS			NO SAO	POSITIONS USED		STAR RESIDUALS						DEPENDENCES		
				s	''	s	''	s	''	s	''			
237	238	239	98454	+17.284	13.86	-0.003	-0.22	-0.018	-0.25	-0.023	-0.27	+0.842886	+0.843568	+0.844154
			98489	+12.297	44.06	-0.001	+0.45	+0.024	+0.52	+0.033	+0.52	+0.305078	+0.304017	+0.303145
			98473	+37.794	28.74	+0.007	+0.28	+0.027	+0.30	+0.033	+0.35	+0.038917	+0.040116	+0.041158
			98502	+05.207	03.18	-0.023	-0.21	-0.049	-0.15	-0.056	-0.30	-0.152044	-0.153265	-0.153462
			98501	+03.367	14.36	+0.021	-0.30	+0.016	-0.42	+0.013	-0.30	-0.033637	-0.034435	-0.034995
240	241		98454	+17.284	13.86	-0.012	-0.18	-0.009	-0.15			+0.950231	+0.950760	
			98473	+37.794	28.74	+0.019	+0.22	+0.014	+0.19			+0.248075	+0.249284	
			98502	+05.207	03.18	-0.044	-0.11	-0.035	-0.15			-0.196075	-0.196318	
			98501	+03.367	14.36	+0.024	-0.30	+0.021	-0.18			-0.138869	-0.139408	
			98489	+12.297	44.06	+0.012	+0.37	+0.008	+0.29			+0.136437	+0.135582	
242	243		98436	+10.546	18.49	-0.004	+0.16	-0.014	+0.30			+0.577958	+0.578546	
			98454	+17.284	13.86	+0.008	-0.32	+0.022	-0.46			+0.382325	+0.382208	
			98489	+12.297	44.06	-0.007	+0.29	-0.010	+0.26			+0.007076	+0.006000	
			98501	+03.367	14.36	+0.005	-0.20	+0.001	-0.07			-0.090250	-0.090657	
			98473	+37.794	28.74	-0.002	+0.06	+0.002	-0.02			+0.122889	+0.123704	
244	245	246	98516	+19.918	16.09	-0.007	-0.02	-0.003	+0.13	-0.007	+0.17	+0.656973	+0.656947	+0.656687
			98522	+41.799	10.22	+0.019	-0.16	+0.003	-0.21	+0.004	-0.18	+0.086259	+0.086311	+0.086282
			98527	+29.636	27.31	-0.010	+0.22	+0.003	+0.01	+0.007	-0.09	+0.100456	+0.100507	+0.100523
			98550	+36.977	07.03	-0.005	-0.07	-0.003	+0.11	-0.006	+0.15	-0.422137	-0.422222	-0.422185
			98563	+58.302	12.50	+0.003	-0.02	+0.001	-0.04	+0.001	-0.05	+0.578450	+0.578458	+0.578493
247	248	249	98544	+16.083	10.83	-0.007	-0.01	-0.004	-0.07	-0.005	+0.03	+0.684062	+0.684079	+0.684047
			98528	+29.725	48.85	+0.040	-0.08	+0.033	+0.14	+0.035	-0.23	+0.092277	+0.092285	+0.092272
			98527	+29.636	27.31	-0.024	-0.03	-0.016	-0.22	-0.019	+0.13	-0.082375	-0.082436	-0.082305
			98550	+36.977	07.03	-0.016	+0.19	-0.023	+0.22	-0.020	+0.14	+0.139417	+0.139422	+0.139415
			98580	+53.376	06.16	+0.009	-0.07	+0.010	-0.06	+0.010	-0.07	+0.166599	+0.166650	+0.166576
250	251	252	98550	+36.977	07.03	+0.003	+0.21	-0.004	+0.10	-0.001	+0.20	+0.210514	+0.210573	+0.210553
			98580	+53.376	06.16	-0.006	-0.42	+0.008	-0.19	+0.002	-0.40	-0.004049	-0.004049	-0.004054
			98595	+09.447	10.14	+0.008	+0.12	-0.003	-0.04	-0.002	+0.15	+0.029975	+0.029902	+0.029964
			98591	+43.744	37.24	-0.004	+0.19	-0.003	+0.19	+0.001	+0.14	+0.096321	+0.096276	+0.096299
			98544	+16.083	10.83	-0.001	-0.10	+0.002	-0.06	+0.000	-0.09	+0.667238	+0.667304	+0.667246
253	254	255	98550	+36.977	07.03	+0.003	+0.21	-0.004	+0.10	-0.001	+0.20	+0.382028	+0.382012	+0.382112
			98580	+53.376	06.16	-0.006	-0.42	+0.008	-0.19	+0.002	-0.40	+0.308904	+0.308867	+0.308896
			98595	+09.447	10.14	+0.008	+0.12	-0.003	-0.04	-0.002	+0.15	+0.172717	+0.172767	+0.172670
			98591	+43.744	37.24	-0.004	+0.19	-0.003	+0.19	+0.001	+0.14	+0.147092	+0.147111	+0.147048
			98544	+16.083	10.83	-0.001	-0.10	+0.002	-0.06	+0.000	-0.09	-0.010740	-0.010757	-0.010726
256	257	258	98544	+16.083	10.83	-0.001	-0.01	-0.002	+0.00	-0.000	-0.03	+0.084129	+0.084214	+0.084153
			98580	+53.376	06.16	+0.016	-0.06	+0.015	-0.11	+0.017	-0.14	+0.712443	+0.712440	+0.712472
			98550	+36.977	07.03	-0.040	+0.17	-0.037	+0.27	-0.043	+0.39	+0.250530	+0.250521	+0.250514
			98527	+29.636	27.31	-0.007	-0.01	-0.012	+0.04	-0.005	-0.07	-0.005119	-0.005185	-0.005139
			98528	+29.725	48.85	+0.031	-0.09	+0.036	-0.21	+0.031	-0.14	-0.041983	-0.041989	-0.041999

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Preliminary report

OBSERVATIONS À LA LUNETTE ZENITHALE (DE 110 mm) DU SERVICE DE LATITUDE DE L'OBSERVATOIRE DE BELGRADE EN 1981, 1982, 1983, 1984, 1985

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RÉSUMÉ: On présente les valeurs de latitude ansi que quelques données météorologiques prises au cours d'observations.

Les valeurs observées de φ (Tableau I) sont reduites à la manière déjâ signalée (Ševarlić,B., Teleki,G. 1959) mais sans tenir compte des erreurs progréssives et periodiques et de coefficient de température (Milovanović, V et les autres, 1970). Les réductions ont été faites dans le systéme FK4 et on a appliqué les corrections des déclinaisons présentées dans le Tableau 2 (Grujić, R. et les autres, 1975)

La valeur du tour de la vis micrométrique adoptée était: R = 40".0660 (Grujić, R., Teleki, G., 1984 et Djokić, M., 1985). La même valeur doit être utilisée aussi lors de la réduction du matériel d'observations se rapportant à l'intervalle du temps 1971.0–1981.0.

Tableau 1. – Les valeurs de latitude ansi que quelques donnés météorologiques au cours d'observations

DATE	τ	OBS.	Tz	Ti	Tv	Bo	GR.	φ_a	φ_b	φ_d
									44° 48′+	
1981										
I 17	1981.046	RG	- 3°.4C	- 2°.6C	- 3°.5C	735.3	I	-	10".343	10".343
25	.069	RG	- 2.8	- 2.4	- 2.8	745.9	I	-	10.474	
	.070	RG	- 4.1	- 3.8	- 4.0	744.7	II	10.468	-	10.471
II 1	.089	RG	4.3	1.5	2.1	751.6	II	10.253	10.267	10.260
3	.094	RG	7.1	4.0	4.8	735.5	II	10.333	10.372	10.352
22	.146	RG	3.0	2.0	2.6	739.7	II	-	10.401	10.401
26	.157	MD	- 2.6	- 1.2	- 2.2	745.6	II	10.443	10.315	10.379
III 5	.176	RG	2.0	1.6	1.8	741.6	II	-	10.379	
	.176	RG	1.8	0.8	1.0	742.0	III	10.343	-	10.361
7	.182	MD	9.6	7.2	7.3	746.6	II	-	10.408	10.408
14	.201	RG	8.2	7.7	7.7	736.8	III	10.443	10.353	10.398
21	.220	RG	9.0	7.5	7.4	738.2	III	10.449	10.396	10.422
23	.226	MD	12.4	10.2	9.9	737.9	III	10.523	10.262	10.392
28	.239	RG	8.3	9.9	8.8	740.1	III	10.311	10.254	10.282
IV 4	.258	RG	6.8	7.1	6.4	740.8	III	-	10.521	10.521
7	.267	RG	11.6	11.8	11.1	743.2	III	10.408	10.335	10.372
12	.280	RG	13.0	12.1	11.4	745.6	III	10.445	10.186	
	.281	RG	12.0	10.7	10.6	745.4	IV	10.210	-	10.280
13	.283	MD	15.7	13.7	13.5	744.8	III	-	10.355	10.355
22	.308	MD	11.2	10.8	10.4	736.8	III	-	10.315	10.315

Table 1 (continued)

DATE	τ	OBS.	Tz	Ti	Tv	Bo	GR.	φ_a	φ_b	φ_d
30	.330	RG	11.0	9.9	9.6	731.9	IV	-	10.569	10.569
V 10	.357	RG	12.8	13.4	12.8	736.1	IV	10.172	10.490	10.331
19	.382	RG	15.8	15.8	15.1	745.0	IV	10.312	10.492	10.402
30	.412	RG	18.4	19.6	18.4	742.0	IV	-	10.595	10.595
31	.414	RG	20.5	20.6	19.4	742.8	IV	10.334	10.522	10.428
VI 4	.425	RG	24.9	24.8	24.0	735.9	IV	10.268	10.552	10.410
27	.489	MD	18.0	20.0	18.9	741.3	V	-	10.171	10.171
29	.494	MD	25.4	24.9	24.4	737.2	V	10.386	10.322	10.354
VII 2	.502	RG	19.2	19.2	18.2	740.9	V	10.315	10.423	10.369
11	.527	RG	21.2	21.7	20.9	738.6	V	10.375	10.481	10.428
16	.540	RG	18.8	20.1	18.8	741.3	V	10.365	10.336	10.350
VIII 20	.636	RG	22.9	21.7	21.5	734.3	V	-	10.354	
	.637	RG	20.7	20.2	19.6	734.3	VI	10.378	-	10.366
IX 26	.738	RG	17.5	18.3	17.8	739.9	VI	10.321	-	10.321
X 6	.765	RG	20.8	19.1	19.2	742.0	VI	10.200	10.142	10.171
8	.770	RG	14.0	14.9	13.8	745.2	VI	10.286	10.336	10.311
9	.773	MD	15.4	15.5	14.9	741.7	VI	10.296	10.198	10.247
17	.795	RG	10.8	12.6	11.6	746.6	VI	10.353	10.236	10.294
25	.817	RG	4.0	6.0	4.9	742.6	VI	10.287	10.189	10.238
29	.828	RG	8.4	8.0	7.6	746.2	VI	-	10.276	10.276
XI 5	.847	RG	11.6	10.7	10.4	741.6	VI	10.286	10.271	10.278
21	.891	RG	8.9	7.4	8.2	747.5	VI	-	10.147	
	.891	RG	8.2	6.6	6.8	747.4	I	10.204	-	10.176
23	.896	MD	12.4	9.6	10.0	744.4	VI	-	10.079	
	.896	MD	10.7	8.6	8.5	743.5	I	10.059	-	10.069
XII 4	.926	MD	-2.1	-0.8	-1.4	734.2	I	10.212	10.242	10.227
21	.973	RG	-7.0	-4.7	-5.7	735.7	I	10.188	10.187	10.188

1982

DATE	τ	OBS.	Tz	Ti	Tv	Bo	GR.	φ_a	φ_b	φ_d
I 13	1982.036	RG	-6.5	-3.5	-5.1	754.8	I	10.205	10.090	10.148
II 4	.096	RG	-4.0	-3.2	-4.2	755.4	II	10.195	10.268	10.232
11	.115	RG	-2.0	-1.2	-2.0	751.8	II	10.207	10.245	10.226
12	.118	MD	-0.6	-1.0	-1.8	747.8	II	10.232	10.365	10.298
18	.134	RG	-0.0	-0.3	-0.9	743.3	II	10.250	10.284	10.267

Table 1 (continued)

DATE	τ	OBS.	Tz	Ti	Tv	Bo	GR.	φ_a	φ_b	φ_d
28	.162	RG	1.4	0.3	0.2	741.9	II	10.464	10.394	10.429
III 4	.173	RG	7.0	5.0	4.8	739.3	III	10.286	10.224	10.255
8	.184	MD	1.3	2.1	1.1	746.2	II	-	10.253	10.253
9	.186	RG	3.5	2.6	2.4	742.9	II	-	10.319	
	.187	RG	2.6	1.2	0.9	743.0	III	10.399	-	10.359
16	.206	RG	4.4	3.8	3.6	741.4	III	10.394	-	10.394
24	.228	MD	0.6	1.6	0.9	753.1	III	10.299	10.365	10.332
IV 1	.250	RG	7.0	7.4	7.0	742.8	III	10.430	10.231	10.330
5	.260	MD	11.1	11.6	10.9	744.0	III	10.504	-	10.504
8	.269	RG	17.1	15.7	15.6	731.8	III	10.346	10.196	10.271
V 3	.337	RG	17.0	14.9	15.0	741.2	III	-	10.331	
	.337	RG	15.4	13.5	13.8	742.0	IV	10.257	-	10.294
16	.373	RG	15.6	16.4	15.4	740.7	IV	10.264	10.554	10.409
18	.378	RG	19.1	19.0	17.9	741.0	IV	10.526	10.470	10.498
VI 1	.417	RG	19.2	20.2	19.1	745.3	IV	-	10.621	10.621
8	.436	RG	16.0	19.6	17.4	741.6	IV	-	10.583	10.583
VII 3	.504	RG	19.8	21.3	20.3	739.7	V	10.480	10.526	10.503
14	.534	RG	19.8	20.6	19.9	738.3	V	10.552	10.–	10.552
18	.545	RG	21.4	22.9	21.6	740.8	V	10.457	10.447	10.452
21	.554	RG	25.0	24.7	23.6	740.0	V	10.554	10.476	10.515
VIII 12	.614	RG	21.3	22.0	20.6	742.0	V	10.461	10.481	10.471
IX 5	.679	MD	22.4	22.4	21.6	743.2	V	-	10.582	
	.680	MD	20.6	20.2	19.6	743.4	VI	10.535	-	10.558
14	.704	MD	20.9	21.3	20.5	743.0	V	-	10.343	10.343
19	.718	MD	19.4	19.1	18.4	742.7	VI	10.313	-	10.313
20	.721	RG	18.4	18.4	17.9	742.0	VI	10.548	10.338	10.443
23	.729	RG	20.0	20.5	19.6	735.2	VI	10.406	10.472	10.439
28	.742	RG	21.1	20.9	20.2	741.7	VI	10.444	10.333	10.388
X 19	.800	RG	16.2	14.8	14.6	742.5	VI	10.333	-	10.333
22	.808	MD	14.2	13.8	13.4	740.8	VI	10.265	10.128	10.196
26	.819	RG	11.4	12.6	11.7	743.8	VI	10.313	10.288	10.300
XI 9	.858	RG	6.1	5.3	5.1	743.2	I	10.220	10.156	10.188
11	.863	RG	7.4	7.6	7.5	749.9	VI	-	10.420	
	.863	RG	6.6	5.3	5.0	749.9	I	10.303	-	10.362

Table 1 (continued)

DATE	τ	OBS.	Tz	Ti	Tv	Bo	GR.	φ_a	φ_b	φ_d
18	.882	RG	1.2	3.0	2.0	740.0	I	10.244	10.215	10.230
21	.890	RG	6.4	6.0	5.4	751.0	VI	-	10.170	
	.890	RG	5.6	4.8	4.4	751.0	I	10.099	-	10.134
22	.893	MD	6.4	5.0	4.8	750.2	I	10.024	10.205	10.114
25	.901	RG	11.7	9.2	9.5	741.1	I	10.213	10.167	10.190
26	.904	MD	2.8	5.0	4.1	739.0	I	10.329	10.197	10.213
XII 2	.920	RG	3.8	4.8	4.0	747.4	I	10.158	10.119	10.144
16	.959	RG	8.8	7.0	8.0	732.1	I	-	10.053	10.053
20	.970	MD	2.1	2.4	1.8	732.4	I	10.024	9.866	9.945
30	.997	RG	- 3.8	- 1.4	- 2.6	749.4	II	10.270	-	10.270
1983										
I 9	1983.024	RG	1.4	2.8	1.6	753.5	II	10.124	10.130	10.127
12	.033	RG	6.1	3.8	3.9	752.8	II	10.111	10.104	10.108
18	.049	RG	11.9	7.1	8.4	734.1	I	-	9.876	
	.049	RG	7.8	6.5	6.8	734.4	II	10.179	10.085	10.047
25	.068	RG	2.8	2.4	1.8	755.5	II	10.166	10.209	10.188
II 1	.087	RG	4.2	3.4	3.5	734.0	II	9.953	10.058	10.006
3	.093	MD	- 0.4	0.2	- 0.4	745.1	II	10.058	10.121	10.090
25	.153	MD	0.6	0.0	- 0.2	752.6	II	-	10.070	10.070
26	.156	RG	4.4	1.8	1.6	744.8	II	-	10.091	
	.156	RG	5.1	1.4	2.2	743.1	III	10.053	-	10.072
III 8	.183	RG	9.6	8.4	8.3	745.8	II	-	10.188	
	.183	RG	8.0	7.0	6.9	745.8	III	10.092	-	10.140
10	.188	MD	12.8	10.8	10.8	742.2	II	-	9.989	
	.189	MD	11.1	9.4	9.3	741.6	III	10.083	-	10.036
12	.194	RG	0.9	5.9	3.6	750.2	II	-	10.123	
	.194	RG	- 1.4	2.0	0.2	751.8	III	10.113	-	10.118
15	.202	MD	6.1	6.4	6.1	741.4	II	-	10.114	
	.202	MD	5.5	5.0	5.0	740.7	III	10.085	-	10.100
24	.227	RG	10.6	10.0	9.8	733.5	III	10.190	-	10.19[illegible]
IV 10	.274	RG	15.8	16.2	15.2	740.1	III	10.162	10.117	10.140
17	.293	RG	9.6	9.3	8.6	740.2	III	10.276	10.149	10.212
24	.312	RG	18.2	18.4	17.6	735.0	III	-	10.107	10.107
V 3	.336	RG	16.6	17.4	16.1	736.8	III	-	10.128	

Table I (continued)

DATE	τ	OBS.	Tz	Ti	Tv	Bo	GR.	φ_a	φ_b	φ_d
	.337	RG	13.6	14.7	13.7	737.9	IV	10.124	-	10.126
5	.342	RG	10.8	13.6	12.2	741.1	IV	10.103	-	10.103
10	.356	RG	11.9	12.8	11.8	732.2	IV	10.286	10.300	10.293
12	.361	RK	19.1	18.4	18.2	737.7	IV	9.900	-	9.900
17	.375	RG	20.5	21.0	20.3	738.4	IV	10.170	10.222	10.196
VI 2	.419	RG	21.8	22.1	21.0	741.7	IV	10.291	10.407	10.349
5	.427	RG	24.4	24.0	23.1	739.8	IV	-	10.441	10.441
26	.485	MD	22.7	20.8	20.1	740.4	V	10.420	-	10.420
VII 6	.512	MD	23.4	23.0	22.4	741.0	V	10.390	10.523	10.456
18	.545	RG	24.1	24.4	23.6	741.8	V	10.503	10.562	10.532
21	.553	RG	12.7	15.2	14.4	743.1	V	-	10.661	10.661
26	.566	RG	21.5	23.2	22.2	741.4	V	10.493	10.473	10.483
VIII 5	.594	SS	16.0	17.5	15.8	738.4	V	-	10.700	10.700
7	.599	SS	18.4	19.0	17.9	738.8	V	10.559	10.642	10.600
10	.608	MD	22.6	23.0	22.4	736.6	V	10.461	10.583	10.522
15	.621	MD	17.6	19.8	18.3	745.2	V	10.396	10.619	10.508
23	.643	RK	23.2	24.4	23.2	741.8	V	-	10.670	10.670
28	.657	RG	23.9	22.4	21.3	740.8	VI	10.649	10.583	10.616
IX 1	.668	RG	19.9	21.0	20.1	740.9	V	-	10.559	10.559
2	.670	MD	21.0	21.9	21.2	739.3	V	-	10.676	10.676
3	.673	RK	23.2	23.2	22.6	736.9	V	-	10.530	10.530
6	.681	RK	19.0	19.8	19.1	740.8	V	-	10.587	10.587
8	.687	RG	13.9	15.5	14.2	741.5	V	-	10.704	10.704
9	.690	MD	22.6	20.4	19.9	738.6	V	-	10.737	10.737
10	.692	RK	26.4	24.2	24.0	736.6	V	-	10.567	
	.693	RK	24.6	22.4	22.3	736.4	VI	10.704	-	10.636
13	.701	RK	13.6	15.7	14.6	744.4	VI	10.742	-	10.742
14	.703	SS	19.2	18.9	18.5	743.6	V	-	10.646	
	.704	SS	15.4	16.2	15.7	742.9	VI	10.662	-	10.654
15	.706	RG	18.2	17.9	17.2	738.0	VI	-	10.579	10.579
21	723	SS	15.3	15.6	15.1	740.6	VI	10.571	-	10.571
24	.731	RK	14.0	14.6	13.5	746.5	VI	10.742	-	10.742
27	.739	RK	14.1	13.6	12.9	747.4	VI	10.894	10.682	
	.739	RG	13.2	12.6	12.1	746.9	I	10.843	-	10.806

Table 1 (continued)

DATE	τ	OBS.	Tz	Ti	Tv	Bo	GR.	φ_a	φ_b	φ_d
28	.742	SS	14.6	15.2	14.5	742.6	VI	10.582	10.506	10.544
29	.744	RG	15.8	14.9	14.2	742.5	VI	10.723	-	10.723
X 2	.753	RG	7.7	11.0	9.4	749.1	VI	-	10.692	10.692
4	.758	RK	17.8	16.2	16.0	745.4	VI	10.737	10.694	10.716
5	.761	SS	18.6	18.6	18.6	743.6	VI	10.572	10.419	10.496
6	.764	RG	18.5	18.2	17.8	742.0	VI	10.746	10.687	10.716
7	.766	MD	14.2	15.5	14.4	744.2	VI	10.588	10.515	10.552
10	.775	SS	11.8	12.6	11.6	741.6	VI	10.786	10.636	10.711
11	.777	RK	18.2	16.6	16.8	737.2	VI	-	10.751	10.751
13	.783	RG	10.4	10.6	9.8	747.9	VI	10.476	10.552	10.514
14	.786	MD	12.5	11.4	11.2	746.2	VI	-	10.547	10.547
15	.788	RK	12.8	13.5	12.8	744.1	VI	-	10.625	10.625
16	.791	RG	16.8	15.1	15.0	738.9	VI	-	10.625	
	.791	RG	15.7	13.6	13.5	738.3	I	10.644	-	110.634
22	.808	RK	3.2	6.4	5.2	752.9	I	10.707	-	10.707
23	.810	MD	5.2	6.7	6.1	751.1	VI	-	10.502	10.502
25	.816	RK	4.4	5.6	5.0	747.2	VI	-	10.654	10.654
28	.824	ND	9.0	9.4	9.9	739.7	VI	10.363	-	10.363
XI 12	.865	RK	- 0.2	2.7	1.2	746.2	VI	10.403	10.585	10.494
13	.868	RG	- 1.6	0.6	- 0.5	745.5	VI	-	10.423	
	.868	RG	- 4.0	- 1.2	- 2.2	746.1	I	10.607	-	10.515
16	.876	SS	- 1.4	- 1.1	- 1.4	734.1	I	10.518	-	10.518
17	.879	RG	0.5	- 0.4	- 0.6	739.6	I	10.420	-	10.420
18	.881	ND	- 0.6	- 0.3	- 0.2	741.6	VI	10.497	-	
	.881	MD	- 1.7	- 1.7	- 2.0	742.2	I	10.393	-	10.445
19	.884	RK	- 3.4	- 1.3	- 2.2	744.9	VI	10.496	10.522	10.509
20	.887	RG	- 2.4	- 1.5	- 1.8	740.1	VI	-	10.513	
	.887	RG	- 2.2	- 2.4	- 2.9	738.9	I	10.497	-	10.505
23	.895	ND	0.7	0.4	0.4	745.8	VI	10.475	-	10.475
24	.898	RG	- 0.9	- 0.7	- 1.3	750.1	I	10.408	10.406	10.407
25	.900	ND	- 0.1	0.0	- 0.3	746.6	VI	10.455	-	10.455
XII 22	.974	RG	7.0	7.0	6.9	732.8	I	10.400	-	10.400
25	.982	RG	14.8	9.1	11.5	742.1	I	10.194	10.016	10.105
30	.996	MD	6.6	5.2	5.4	744.5	I	10.210	10.150	10.180

Table 1 (continued)

DATE	τ	OBS.	Tz	Ti	Tv	Bo	GR.	φ_a	φ_b	φ_d
1984										
I 3	1984.007	RG	11.0	7.6	8.6	736.6	I	10.159	9.996	10.078
31	.084	RG	4.4	1.9	2.4	737.5	I	-	10.033	10.033
II 2	.090	RK/RG	2.0	1.6	1.8	737.0	II	10.237	10.111	10.174
5	.098	RG	3.0	3.1	2.6	742.9	II	10.238	10.108	10.173
III 15	.204	RG	0.2	0.6	0.2	737.4	III	10.103	9.977	10.040
19	.215	MD	- 1.2	0.1	- 1.2	742.4	III	10.015	-	10.015
20	.218	RG	- 2.0	- 1.5	- 2.0	741.0	III	10.005	9.976	9.990
24	.229	RG	5.4	3.6	3.8	737.7	III	-	9.934	9.934
27	.237	RG	11.6	9.2	9.1	738.6	III	10.046	9.947	9.996
IV 7	.267	RG	12.8	12.6	12.0	733.7	III	9.940	10.052	9.996
14	.286	RG	10.9	11.6	10.8	742.3	III	-	9.986	
	.287	RG	9.4	10.0	9.4	742.4	IV	10.012	-	9.999
16	.292	SS	12.0	13.2	12.4	734.6	III	-	10.079	10.079
V 14	.369	RG	11.8	11.8	11.4	735.2	IV	10.165	10.150	10.158
18	.380	MD	17.2	15.8	16.0	739.2	IV	-	10.088	10.088
19	.382	SS	18.8	18.8	18.8	732.0	IV	10.065	10.221	10.143
21	.388	SS	17.2	16.8	15.8	733.6	IV	10.047	10.184	10.116
24	.396	RK	13.2	16.8	14.8	730.9	IV	10.212	-	10.212
28	.407	SS	16.4	17.2	16.2	734.0	IV	10.078	-	10.078
30	.412	SS	13.6	14.6	12.6	736.1	IV	-	10.181	10.181
31	.415	RK	14.1	15.6	14.6	735.6	IV	10.311	10.224	10.268
VI 2	.421	RG	19.5	17.6	17.4	739.4	IV	-	10.066	
	.421	RG	17.6	16.4	16.0	739.4	V	10.086	-	10.076
3	.423	ND	22.1	19.8	19.0	735.5	IV	10.036	-	10.036
5	.429	RK	22.0	21.2	20.8	736.6	IV	10.090	-	10.090
8	.437	ND	14.0	15.2	14.2	732.4	IV	-	10.181	10.181
10	.443	ND	15.6	16.6	15.5	743.1	IV	-	10.293	
	.443	ND	14.6	14.3	13.7	743.8	V	10.183	10.278	10.251
12	.448	RG	9.4	12.4	11.0	745.8	V	10.258	10.343	10.300
13	.451	SS	19.0	16.0	14.9	745.1	IV	-	10.240	
	.451	ND	13.8	12.9	12.2	746.0	V	-	10.313	10.276
14	.454	RK	20.0	19.0	18.5	742.1	IV	-	10.288	
	.454	RG	19.1	16.8	16.3	741.0	V	10.160	10.163	10.204
17	.462	MD	15.4	15.6	14.6	742.8	V	10.165	-	10.165
18	.465	RG	14.6	15.7	14.6	746.4	V	10.188	10.210	10.199

Table 1 (continued)

DATE		τ	OBS.	Tz	Ti	Tv	Bo	GR.	φ_a	φ_b	φ_d
	20	.470	SS	21.0	20.8	20.5	741.2	IV	-	10.225	10.225
	26	.487	RG	12.6	14.2	13.0	744.0	V	10.338	10.256	10.297
	27	.490	ND	15.8	15.3	15.0	742.7	V	10.277	10.338	10.308
VII	1	.500	ND	16.8	17.3	16.4	743.4	V	10.294	10.305	10.300
	9	.522	MD	18.8	17.6	16.8	741.2	V	10.091	10.157	10.124
	10	.525	ND	21.3	19.0	18.5	742.8	V	10.469	10.316	10.392
	11	.528	MD	23.6	21.6	20.8	742.8	V	10.064	-	10.064
	12	.530	ND	28.6	24.0	24.0	741.8	V	10.282	10.208	10.245
	15	.538	ND	25.8	25.2	24.6	731.1	V	10.464	-	10.464
	23	.560	RG	22.0	21.6	21.0	740.5	V	10.288	10.501	10.394
	25	.566	RG	18.8	20.2	19.0	739.4	V	10.426	10.281	10.354
	30	.580	RG	20.8	20.4	19.9	743.4	V	10.390	10.386	10.388
VIII	2	.588	RK	19.9	21.0	20.4	741.6	V	10.515	10.590	10.552
	3	.590	RK	20.2	21.8	20.8	742.6	V	10.362	10.576	10.469
	18	.632	ND	15.5	17.8	16.4	743.0	VI	-	10.754	10.754
	21	.640	RK	16.8	18.2	17.3	742.4	V	-	10.773	
		.640	ND	16.4	16.1	15.8	742.2	VI	10.596	10.640	10.670
	22	.642	ND	18.5	18.8	17.8	740.8	V	-	10.620	
		.643	MD	18.3	17.0	16.6	740.8	VI	10.465	10.426	10.504
	23	.645	RK	20.0	19.9	19.1	740.5	V	-	10.679	10.679
	28	.659	RK	12.8	17.2	15.6	744.7	V	-	10.479	10.479
	29	.662	ND	17.3	17.4	16.7	742.4	V	-	10.468	
		.662	MD	16.6	15.8	15.4	742.7	VI	10.461	10.558	10.496
	31	.668	ND	17.2	16.5	16.2	741.2	VI	10.648	10.588	10.618
IX	3	.676	MD	23.0	22.7	21.2	741.7	VI	10.506	10.402	10.454
	4	.678	RK	25.0	22.9	22.9	737.4	V	-	10.580	
		.678	RG	23.9	21.3	20.9	737.2	VI	10.532	10.493	10.535
	5	.681	ND	24.1	21.6	21.2	735.4	VI	10.642	10.464	10.553
	6	.684	RG	23.2	21.9	21.2	737.4	VI	10.588	10.484	10.536
	9	.692	MD	13.7	15.2	14.2	737.3	VI	10.628	10.595	10.612
	11	.698	RG	13.4	13.8	13.0	741.6	VI	10.697	10.591	10.644
	13	.703	RG	16.4	16.3	15.8	741.9	VI	-	10.658	10.658
	14	.705	ND	22.0	19.5	19.3	738.4	V	-	10.848	
		.706	ND	19.7	17.8	17.4	738.2	VI	10.756	-	10.802

Table 1 (continued)

DATE	τ	OBS.	Tz	Ti	Tv	Bo	GR.	φ_a	φ_b	φ_d
18	.716	RK	16.2	17.1	16.4	733.9	V	-	10.646	
	.716	RK/RG	15.5	15.6	15.4	734.4	VI	10.661	10.522	10.610
19	.719	ND	20.5	19.2	19.2	734.6	V	-	10.767	10.767
25	.736	RG	9.4	12.3	10.8	732.5	VI	-	10.658	10.658
26	.738	ND	9.8	11.8	10.6	740.0	VI	10.941	10.864	10.902
X 4	.760	RK	14.8	17.1	16.2	736.4	VI	-	10.656	
	.761	RG	17.7	15.3	15.2	735.4	I	10.512	10.435	10.534
9	.774	RK	11.0	12.6	12.0	750.0	VI	10.655	10.602	
	.774	RG	10.4	11.0	10.4	749.5	I	10.602	10.643	10.626
10	.777	ND	13.4	12.6	12.4	749.0	VI	10.697	-	10.697
13	.785	RG	8.2	10.9	9.6	748.3	I	10.639	-	10.639
17	.796	ND	6.0	7.2	6.2	746.4	VI	10.614	10.399	10.506
18	.799	RG	13.2	11.4	9.6	742.3	I	10.598	-	10.598
19	.801	MD	15.8	12.2	12.8	741.6	VI	10.454	10.491	10.472
22	.807	MD	11.8	11.8	11.3	745.4	VI	10.391	10.409	10.400
23	.812	RK	15.0	13.4	13.6	743.0	VI	-	10.680	
	.812	RG	15.6	13.0	13.1	743.0	I	10.667	10.580	10.642
24	.815	ND	15.0	12.6	12.4	743.4	VI	10.599	10.579	10.589
25	.818	RK	15.4	12.9	13.0	742.8	VI	10.642	10.664	
	.818	RG	15.8	12.5	12.9	742.5	I	10.586	-	10.631
27	.823	RG	14.3	14.1	14.0	742.2	VI	10.565	10.495	10.530
XI 1	.837	RG	5.6	7.0	6.9	747.8	I	10.576	10.406	10.491
2	.840	ND	5.2	5.8	5.2	746.2	VI	10.628	10.493	10.560
5	.848	MD	4.3	5.1	4.7	739.3	VI	10.491	10.584	10.538
6	.850	RG	10.1	8.2	8.8	739.4	VI	-	10.370	10.370
7	.853	ND	11.9	10.0	10.6	740.1	VI	10.350	10.348	10.349
8	.856	RG	11.0	9.8	9.7	740.6	VI	-	10.485	
	.856	RG	8.8	8.8	8.8	740.7	I	10.609	-	10.547
9	.858	ND	10.0	9.8	9.7	739.8	VI	10.618	10.484	
	.859	MD	8.1	8.2	8.2	740.1	I	-	10.416	10.506
11	.864	RG	2.2	5.9	4.0	747.9	I	10.436	10.416	10.426
12	.867	ND	1.2	4.2	3.4	746.1	VI	10.504	-	10.504
13	.870	RG	- 1.0	1.0	0.2	744.7	I	10.552	-	10.552
14	.872	ND	- 1.5	0.6	- 0.1	740.5	VI	-	10.470	10.470

Table 1 (continued)

DATE	τ	OBS.	Tz	Ti	Tv	Bo	GR.	φ_a	φ_b	φ_d
22	.894	RG	5.5	4.2	4.6	739.3	I	10.497	10.439	10.468
25	.903	RG	12.0	9.4	9.8	741.9	I	10.270	10.327	10.298
26	.905	ND	13.8	10.7	11.4	740.5	VI	-	10.303	10.303
28	.910	ND	3.2	5.0	4.0	750.5	VI	-	10.476	
	.911	MD	2.6	3.0	2.3	750.0	I	10.304	10.323	10.368
XII 3	.924	ND	3.2	3.2	3.2	745.2	VI	-	10.434	10.434
4	.927	ND	1.6	1.6	1.4	749.7	VI	-	10.611	10.611
5	.930	ND	1.4	1.4	1.3	749.7	VI	-	10.540	10.540
18	.966	ND	11.2	7.0	8.7	743.7	I	10.374	-	10.374
19	.968	RG	5.4	4.8	4.8	747.0	II	10.400	10.334	10.367
1985										
I 4	1985.012	ND	- 7.3	- 6.1	- 7.0	730.1	I	10.421	10.348	10.384
13	.037	RG	- 8.8	- 8.1	- 8.5	743.4	II	10.280	-	10.280
17	.048	RG	- 9.6	- 7.0	- 7.8	737.5	II	10.320	10.521	10.420
30	.083	ND	0.9	- 0.9	- 1.1	743.9	I	-	10.129	10.129
31	.086	RG	1.4	- 0.6	- 0.1	742.1	II	10.175	-	10.175
II 4	.097	RG	- 4.2	- 3.4	- 4.3	746.4	II	10.328	-	10.328
III 4	.174	ND	1.6	0.9	1.0	744.1	II	-	10.283	10.283
5	.176	RG	8.2	4.4	5.0	747.1	II	-	10.049	10.049
7	.182	RG	1.2	1.7	1.3	748.1	II	-	9.909	9.909
25	.231	ND	7.1	5.7	5.6	739.9	III	10.064	-	10.064
30	.245	RG	9.7	6.7	7.0	741.4	III	9.872	9.854	9.863
31	.248	RG	15.9	11.4	12.2	737.1	III	10.043	-	10.043
IV 1	.250	MD	11.0	10.4	10.2	741.5	III	-	9.879	9.879
3	.256	ND	13.0	12.2	12.0	743.6	III	10.106	10.126	10.116
4	.259	RG	15.2	13.0	13.0	739.7	III	10.126	10.026	10.076
5	.261	ND/MD	18.6	15.5	15.8	736.1	III	10.185	9.802	9.994
7	.267	ND	9.4	11.2	10.4	736.8	III	10.175	10.071	10.123
10	.275	ND	14.6	16.4	15.6	731.8	III	10.123	-	10.123
13	.283	RG	7.9	8.4	7.8	734.3	IV	10.179	-	10.179
20	.302	RG	10.8	10.2	10.1	739.4	III	-	9.962	
	.303	RG	9.1	8.5	8.0	739.7	IV	9.962	-	9.962
21	.305	ND	11.9	11.0	10.6	740.8	III	-	10.056	10.056
22	.308	MD	14.0	13.2	13.0	736.3	III	-	9.888	9.888

Table 1 (continued)

DATE	τ	OBS.	Tz	Ti	Tv	Bo	GR.	φ_a	φ_b	φ_d
23	.310	RG	16.1	14.6	14.6	730.6	III	-	10.015	10.015
V 7	.349	RG	13.2	14.8	13.8	737.2	IV	10.056	-	10.056
12	.363	ND	16.9	16.8	16.4	738.9	IV	9.961	10.159	10.060
28	.406	RG	21.5	20.4	19.5	737.3	IV	10.004	-	10.004
29	.409	ND	19.2	20.4	19.4	735.8	IV	10.030	-	10.030
VI 5	.428	MD	20.8	19.2	19.1	739.7	IV	9.892	10.079	
	.429	ND	19.7	18.2	18.0	739.3	V	9.989	-	9.987
6	.431	RG	24.5	22.0	21.9	737.8	IV	-	9.975	9.975
12	.443	ND	15.1	13.4	13.4	736.3	V	-	9.986	9.986
18	.464	RG	12.7	13.6	12.5	737.8	IV	-	10.149	
	.464	RG	11.1	11.8	11.5	738.4	V	9.970	-	10.060
26	.486	MD	19.6	18.2	18.0	742.2	IV	-	10.219	
	.486	ND	17.8	15.6	15.0	741.2	V	-	9.973	10.096
30	.497	ND	20.2	17.3	16.8	741.3	V	10.081	10.027	10.054
VII 5	.511	ND	15.4	16.2	15.4	739.6	V	10.205	10.157	10.181
6	.513	RG	15.7	16.6	15.5	741.0	V	10.038	-	10.038
9	.522	RG	15.6	16.2	15.3	740.2	V	10.009	10.167	10.088
11	.527	RG	16.7	17.3	16.2	741.8	V	10.089	10.140	10.114
12	.530	ND	18.9	18.4	17.9	743.3	V	10.264	10.217	10.240
13	.532	RG	19.8	20.0	19.0	744.0	V	9.913	10.306	10.110
14	.535	MD	21.0	20.0	19.4	743.0	V	10.172	10.096	10.134
15	.538	ND	22.0	21.2	20.4	742.6	V	10.229	10.217	10.223
16	.541	RG	23.4	22.0	21.3	742.0	V	10.136	10.121	10.128
19	.549	MD	21.8	22.2	21.4	737.7	V	10.093	10.237	10.165
20	.552	RG	25.2	23.6	23.0	737.6	V	10.090	10.153	10.122
22	.557	MD	17.0	18.2	16.8	746.6	V	10.017	10.120	10.068
23	.560	RG	20.7	19.9	19.4	743.9	V	-	10.257	10.257
25	.565	RG	21.0	21.1	20.4	740.8	V	-	10.262	10.262
26	.568	MD	23.5	22.4	21.6	738.4	V	10.190	-	10.190
27	.571	RG	27.6	23.8	24.0	737.0	V	-	10.179	10.179
28	.573	ND	27.2	24.4	23.6	737.2	V	10.161	-	10.161
30	.578	RG	29.1	26.6	26.2	734.7	V	10.230	-	10.230
VIII 1	.584	RG	19.8	22.4	20.4	738.6	V	10.309	-	10.309
11	.612	ND	23.3	21.6	20.7	741.8	V	-	10.285	10.285

Table 1 (continued)

DATE		τ	OBS.	Tz	Ti	Tv	Bo	GR.	φ_a	φ_b	φ_d
	12	.614	MD	22.6	22.0	21.7	742.8	V	-	10.188	10.188
	14	.620	MD	24.6	23.6	23.0	742.4	V	10.274	10.117	10.196
	17	.629	ND	22.6	21.9	21.6	737.4	VI	10.332	10.330	10.331
	21	.639	ND	20.4	21.6	20.7	743.3	V	-	10.357	10.357
	23	.645	ND	23.3	21.7	21.2	740.8	VI	10.388	10.360	10.374
	31	.667	RG	18.2	19.2	18.8	741.0	VI	10.513	-	10.513
IX	3	.675	RG	24.0	21.2	21.5	739.1	VI	10.294	-	10.294
	11	.696	ND	15.8	15.1	15.0	745.4	V	-	10.382	10.382
	12	.700	RG	12.0	14.0	13.1	743.4	VI	10.591	-	10.591
	13	.702	MD	11.4	12.2	11.6	743.0	VI	10.475	-	10.475
	19	.719	RG	17.2	16.6	16.4	744.6	VI	10.506	-	10.506
	24	.732	ND	21.3	19.1	19.0	740.4	VI	-	10.496	10.496
X	2	.754	RG	18.6	15.2	15.0	746.9	VI	-	10.463	10.463
	6	.765	RG	18.2	15.9	15.8	742.7	VI	-	10.524	10.524
	21	.806	MD	7.8	9.0	8.9	749.7	VI	-	10.582	10.582
	24	.814	RG	3.8	5.6	4.7	751.6	I	10.692	-	10.692
	25	.817	ND	6.4	5.5	5.2	751.0	VI	10.629	10.469	10.549
XI	7	.852	RG	5.2	4.9	4.5	737.5	VI	-	10.612	
		.853	RG	5.2	3.8	3.7	738.0	I	10.644	-	10.628
	9	.858	RG	9.4	8.0	8.2	741.6	VI	-	10.544	10.544
	10	.861	ND	15.8	10.2	11.8	734.6	VI	10.461	10.586	
		.861	ND	15.6	10.0	12.0	732.8	I	10.388	-	10.478
XII	3	.924	RG	10.9	7.5	9.0	746.8	I	-	10.657	10.657
	4	.926	ND	11.7	7.8	9.4	746.6	VI	-	10.302	
		.927	ND	11.6	7.8	9.0	746.1	I	10.621	10.658	10.527
	5	.929	RG	9.5	7.6	8.4	741.6	I	10.437	-	10.437
	6	.932	ND	10.2	8.1	9.2	742.5	I	10.583	10.466	10.524
	7	.935	RG	11.8	8.4	9.6	741.4	I	10.524	10.464	10.494
	8	.937	ND	10.3	6.9	7.4	742.3	I	10.615	10.464	10.540
	22	.976	ND	3.4	2.4	2.7	746.4	I	10.669	10.647	10.658
	23	.978	MD	0.5	0.7	0.3	742.0	I	10.513	10.312	10.412

LA LÉGENDE:

- Date: Année, mois et date d'observation.
- τ: Partie d'année tropique
- Obs.: Observateurs R. Grujić (RG), M. Djokić (MD), R. Krga (RK), S. Šegan (SŠ), N. Djokić (ND).
- Tz: Température à l'abri météorologique éloigné 50 m de l'instrument.
- Ti: Température de l'instrument.
- Tv: Température de l'air dans la salle d'observation (valuer moy. des lectures des thermomètres sud et nord).
- Bo: Lecture du baromètre en mm Hg (tenant compte de la température de baromètre).
- GR.: Numéro de la grupe.
- φa, φb La latitude de la sous–groupe *a*, resp. *b*.
- φd: La valuer moy. de la latitude de la nuit.

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BIBLIOGRAPHIE

Djokić, M.: 1985, *Publ. Astron. Obs., Belgrade,* **33**, 70.

Grujić, R., Teleki, G.: 1984, *Bull. Obs. Astron., Belgrade,* **134**, 26.

Grujić, R. et les autres: 1975, *Bull., de l'Obs. Astr. de Belgrade,* **126**, 22.

Milovanović, V. et les autres: 1970, *Bull. de l'Obs. Astr. de Belgrade,* **124**, 159.

Ševarlić, B., Teleki, G.: 1959, *Bull. de l'Obs. Astr. de Belgrade,* **24**, No. 3–4, 19.

Bull. Obs. Astron. Belgrade Nº 140 (1989), 83 -97.

UDC 524.388
Preliminary report

MICROMETER MEASUREMENTS OF TRIPLE STAR SYSTEMS
(Belgrade Micrometer Measurements of Double and Multiple Stars - Series No 43)

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SUMMARY: 326 measurements of triple systems from the Belgrade Survey of Triple Systems, IDS Catalogue (up to 200 pc) and from the Leningrad Programme of Nearby Triple Stars are communicated.

1. INTRODUCTION

Following a suggestion of I.P. Anosova in the beginning of 1987, the Belgrade micrometric measurements of triple stars systems were initiated with the Zeiss Refractor of Belgrade Observatory (65/1055 cm) according to a programme concerning nearby triple systems made in Leningrad (Anosova, I.P., 1986). In the early 1988 the „Survey of Triple Systems contained in the IDS catalogue closer then 200 pc" was finished (Popović, unpublished) and the observations of triple systems were extended to the systems contained in this survey. Since the most recent, still unpublished, observations of double stars which had been performed before the programme of triple star measurements was initiated, contain measurements of some triple star subsystems belonging to the Leningrad programme and from the Belgrade survey of nearby triple stars (up to 200 pc), it was decided that these measurements should be also included in the programme measurements of triple stars published under the present title but preserving the continuity of numbers of the Belgrade micrometric series of measurements (Zulević 1988).

[illegible] in this series measurements performed before the adoption of the programmes mentioned above are also included. For some systems there are only measurements of their subsystems instead of the complete triple systems. In our opinion it is better to present at least partial measurements, especially bearing in mind that such a measurement can be frequently decisive in deciding whether a triple system is real or not. In the present paper the authors communicate a total of 326 measurements of 80 triple systems out of which 21 systems belong to the Leningrad programme.

2. PRESENTATION OF MEASUREMENTS

The requirement that the micrometric double - star measurements should be published th the corrsponding errors, as well is fulfilled in the present paper and for the first time a complete insight into the accuracy of the obtained data is given in a series. The errors of the quantitaties θ and ρ measured in the observations of double and miltiple stars have acquired a special importance after extending a procedure of physical membership determination for system components (Anosova, J.P., 1987).

The reduction of observations and derivation of the weighted mean values for t, θ and ρ are not changed compared o the earlier series, but since in the present paper several errors are introduced, we shall give the explanations for all the data contained in Table 1.

In the course of measurements the position angle value (θ) is read 4–5 times and the same is valid for the parameters a and b appearing in the reduction through relations (1d) and (1e).

For each measured system the data are given in the title and in the thirteen columns of the table. In the case that a system has been measured more than once there is a special row containing the mean values.

System Title–Subsystem The title contains four following data: ADS number, the IDS number, the designation of the disvoverer and the designation of the measured multiple.

Column 1 contains the time of the observation: t.
Column 2 position angle : θ (rel. (1a))
Column 3 root–mean–square error of θ : σ_θ (rel. (1b))
Column 4 distance between components : ρ (rel. (1e))
Column 5 root–mean–square error of ρ : σ_ρ (rel. (1h))
Column 6 dispersion in the measurements θ $\sigma(\theta)$ (rel. (1c))
Column 7 error of a single measurements ρ $\sigma(\rho)$ (rel. (1f))
Columns 8, 9, 10 Estimated apparent magnitudes of primary and secondary components within a prior or apparent magnitudedifference Δm
Column 11 Sum of estimated image quality and quality of measurements: Q; the best mark is 3, the worst 1.
Column 12 Obserer initials: GP = Popović, DZ = Zulević.
Column 13 Letter N means that there is a note in Table 2.

Table 1

ADS	t	θ	σ_θ	ρ	σ_ρ	$\sigma(\bar{\theta})$	$\sigma(\rho)$	m_1	m_2	Δm	Q	Obs.	Note
684	00448N5005		BU 232	AB									
	86.865	241°.9	0°.72	0".79	0".012	1.61	0.024	*	*	0.2	4	GP	
	86.865	240.4	0.34	0.84	0.014	0.68	0.028			0.2	4	DZ	
	86.876	239.7	0.25	0.80	0.008	0.49	0.016	*	*	*	4	DZ	
	86.869	240.67	0.65	0.810	0.015	1.30	0.031					DZ2 GP1	N
1522	01494 N 2818		STF 183	AB–C									
	84.930	164.5	0.32	5.31	0.080	0.65	0.160	8.0	10.0	*	3	GP	
1548	01513N3032		A 813	AB									
	86.791	199.7	0.41	*	*	0.82	*	8.2	8.7	*	2	DZ	
	86.857	198.6	*	0.60	*	*	*	8.2	8.7	*	2	DZ	
	86.824	199.1	0.55	0.60	*	*	*					DZ2/1	N
1630	01578N4151		STF 205	A–BC									
	87.927	63.3	0.26	9.28	0.091	0.53	0.224	*	*	*	2	GP	
	88.012	63.5	0.17	9.65	0.085	0.34	0.171	3.0	7.0	*	3	GP	
	87.978	63.42	0.10	9.502	0.181	0.13	0.234					GP2	
1630	01578N4151		STT 38	BC									
	88.012	108.1	0.56	0.74	0.016	1.25	0.035	7.0	8.0	*	4	GP	N
2122	02418N1857		STF 305	AB									
	86.873	310.1	0.37	3.58	0.019	0.74	0.038	*	*	0.5	2	DZ	
	86.876	310.2	0.21	3.52	0.012	0.42	0.023	8.0	8.5	*	6	DZ	
	86.875	310.17	0.04	3.535	0.026	0.07	0.042					DZ2	N
2681	03352N0448		STF 430	AB									
	88.012	56.9	0.18	26.64	0.086	0.35	0.173	8.0	8.5	*	4	GP	
	88.091	56.8	0.16	26.45	0.239	0.35	0.535	8.0	9.0	*	2	GP	
	88.038	56.87	0.05	26.577	0.090	0.07	0.127					GP2	
2681	03352N0448		STF 430	AC									
	88.012	300.5	0.24	34.49	0.124	0.49	0.249	8.0	9.8	*	4	GP	
	88.091	300.6	0.20	34.57	0.143	0.45	0.320	8.0	9.0	*	2	GP	
	88.038	300.53	0.05	34.517	0.038	0.07	0.053					GP2	
2926	03550N2255		STF 479	AB									
	88.012	126.3	0.51	7.46	0.071	1.03	0.142	8.0	9.0	*	4	GP	
	88.032	127.0	0.39	7.59	0.068	0.79	0.152	8.0	9.0	*	3	GP	
	88.021	126.60	0.35	7.516	0.064	0.53	0.098					GP2	
2926	03550N2255		STF 479	AC									
	88.012	241.9	0.17	57.58	0.130	0.35	0.260	8.0	9.5	*	5	GP	
	88.032	242.0	0.10	57.87	0.215	0.20	0.430	8.0	9.5	*	3	GP	
	88.020	241.94	0.05	57.689	0.140	0.08	0.229					GP2	
3093	04108S0749		STF 518	AB									
	88.102	103.6	0.10	88.67	0.238	0.21	0.477	7.0	9.0	*	2	GP	
3093	04108S0749		STF 518	BC									
	88.102	340.0	0.29	8.10	0.128	0.59	0.286	9.0	11.0	*	2	GP	N
3991	05188S0058		WNC 2	A–BC									
	88.012	161.4	0.43	2.97	0.063	0.87	0.126	7.5	8.0	*	6	GP	N
4186	05305S0527		STF 748	CB									
	87.111	342.4	0.17	16.77	0.069	0.35	0.139	*	*	*	2	DZ	
	87.141	342.2	0.17	16.69	0.040	0.34	0.079	*	*	*	2	DZ	
	87.126	342.30	0.10	16.730	0.040	0.12	0.046					DZ2	

Table 1 (continued)

ADS	t	θ	σ_θ	ρ	σ_ρ	σ(θ)	σ(ρ)	m_1	m_2	Δm	Q	Obs.	Note
4186	05304S0527		STF 748	CD									
	87.111	62.2	0.42	13.33	0.073	1.10	0.192	7.0	8.0	*	3	GP	
	87.111	63.1	0.08	13.20	0.038	0.16	0.076	*	*	*	4	DZ	
	87.141	62.1	0.34	13.42	0.062	0.69	0.138	*	*	*	2	GP	
	87.141	62.4	0.23	13.02	0.030	0.46	0.059	*	*	*	2	DZ	
	87.198	61.5	0.41	13.38	0.055	0.91	0.123	*	*	*	3	GP	
	87.138	62.32	0.29	13.272	0.065	0.62	0.140					DZ2 GP3	
4186	05304S0527		STF 748	AB									
	87.111	32.1	0.31	8.93	0.052	0.81	0.138	*	*	*	3	GP	
	87.111	31.4	0.11	8.58	0.044	0.23	0.089	*	*	*	4	DZ	
	87.141	32.5	0.31	8.93	0.058	0.70	0.129	*	*	*	2	GP	
	87.141	31.7	0.56	8.93	0.049	1.12	0.098	*	*	*	4	DZ	
	87.198	31.7	0.31	8.70	0.089	0.71	0.200	*	*	*	2	GP	
	87.135	31.81	0.18	8.806	0.078	0.40	0.174					GP3 DZ2	
4186	05304S0527		STF 748	AC									
	87.111	131.0	0.27	12.72	0.064	0.72	0.169	*	7.0	*	4	GP	
	87.111	131.5	0.45	12.78	0.027	0.90	0.054	*	*	*	4	DZ	
	87.141	132.9	0.37	12.84	0.062	0.82	0.151	*	*	*	2	GP	
	87.141	131.4	0.31	12.48	0.040	0.62	0.081	*	*	*	4	DZ	
	87.198	131.6	0.33	12.77	0.068	0.73	0.151	*	*	*	3	GP	
	87.137	131.54	0.27	12.701	0.064	0.64	0.151					DZ2 GP3	
4186	05304S0527		STF 748	AE									
	87.111	351.2	0.32	4.19	0.063	0.86	0.179	*	*	*	3	GP	
4186	05304S0527		STF 748	DA									
	87.111	276.1	0.20	21.34	0.064	0.41	0.129	*	*	*	2	DZ	
	87.141	276.3	0.11	21.12	0.054	0.22	0.108	*	*	*	2	DZ	
	87.126	276.20	0.10	21.230	0.110	0.12	0.127					DZ2	
4186	05304S0527		STF 746	CF									
	87.111	123.2	0.55	3.78	0.048	1.45	0.126	7.0	12.0	*	3	GP	
4186	05304S0527		STF 748	DB									
	87.117	300.0	0.15	19.40	0.037	0.30	0.073	*	*	*	4	DZ	
	87.141	300.2	0.07	19.49	0.033	0.15	0.066	*	*	*	2	DZ	
	87.141	300.3	0.26	19.43	0.064	0.58	0.156	*	*	*	1+1	GP	
	87.199	299.2	0.27	19.35	0.070	0.61	0.157	*	*	*	1+1	GP	
	87.143	299.94	0.22	19.414	0.026	0.41	0.048					DZ2 GP2	
4329	05394N0347		STF 788	AB									
	87.209	87.4	0.83	7.28	0.079	1.85	0.176	8.0	10.0	*	2	GP	
4329	05394N0347		STF 788	AC									
	87.209	147.6	0.15	35.94	0.078	0.31	0.156	8.0	10.5	*	2	GP	
5107	0620S0658		STF 919	AB									
	88.157	131.4	0.50	7.17	0.066	1.31	0.175	*	*	*	3	GP	
5107	06240S0658		STF 919	BC									
	88.157	106.2	0.47	*	*	1.25	*	*	*	*	3	GP	
5871	07066N2724		STF 1037	AB									
	88.253	320.3	0.25	1.27	0.009	0.50	0.019	*	*	0.0	2	DZ	N

Table 1 (continued)

ADS	t	θ	σ_θ	ρ	σ_ρ	$\sigma(\theta)$	$\sigma(\rho)$	m_1	m_2	Δm	Q	Obs.	Note
6336	07377N6418		STF 1127	AB									
	87.196	339.9	0.32	5.49	0.057	0.65	0.114	7.5	9.0	*	3	GP	
	87.196	340.8	0.22	5.18	0.045	0.43	0.090	7.0	8.8	*	2	DZ	
	87.207	339.2	0.25	5.41	0.040	0.50	0.081	8.0	9.0	*	4	GP	
	87.207	341.0	0.31	5.15	0.036	0.62	0.071	*	*	*	4	DZ	
	87.203	340.16	0.44	5.313	0.084	0.91	0.174					GP2 DZ2	
6336	07377N6418		STF 1127	AC									
	87.196	175.0	0.48	11.62	0.142	0.96	0.284	7.5	10.0	*	3	GP	
	87.196	178.3	0.07	11.34	0.063	0.15	0.125	*	*	*	2	DZ	
	87.207	176.9	0.33	11.31	0.063	0.67	0.126	*	*	*	2+2	GP	
	87.207	177.7	0.24	11.39	0.045	0.49	0.089	*	*	*	4	DZ	
	87.203	176.92	0.67	11.411	0.069	1.39	0.143					GP2 DZ2	
6364	07411N3340		STF 1135	AB									
	88.272	215.1	0.49	19.82	0.105	0.98	0.210	6.0	10.5	*	3	GP	N
6364	07411N3340		STF 1135	AC									
	88.272	342.6	0.10	91.83	0.214	0.21	0.429	6.0	10.5	*	2	GP	
6650	08065N1757		STF 1196	AB									
	87.207	209.0	0.49	0.81	0.015	0.98	0.031	*	*	*	2	GP	
	87.207	209.2	0.70	0.70	0.016	1.39	0.031	*	*	*	2	DZ	
	87.262	208.2	0.81	0.76	0.010	1.81	0.021	8.0	8.2	*	2	GP	
	87.262	210.1	0.24	0.63	0.019	0.49	0.037	7.8	8.0	*	2	DZ	
	87.234	209.13	0.39	0.725	0.039	0.64	0.063					GP2 DZ2	N
6650	08065N1757		STF 1196	AC									
	87.207	81.9	0.42	5.76	0.063	0.84	0.141	*	*	*	2	GP	
	87.207	85.7	0.51	5.70	0.040	1.01	0.081	*	*	*	2	DZ	
	87.262	82.0	0.58	5.79	0.059	1.17	0.132	8.0	9.0	*	2	GP	
	87.262	80.8	0.20	5.66	0.057	0.39	0.115	7.8	8.5	*	2	DZ	
	87.234	82.60	1.07	5.727	0.029	1.74	0.048					GP2 DZ2	N
6700	08100N4072		ES 593	AB									
	87.262	342.0	0.26	20.38	0.068	0.58	0.135	9.0	10.0	*	3	GP	
	87.262	340.9	0.23	20.54	0.086	0.46	0.172	8.8	8.5	*	2	DZ	
	87.264	341.6	0.09	20.56	0.044	0.19	0.088	8.5	9.5	*	4	GP	
	87.264	341.7	0.24	20.54	0.040	0.49	0.079	9.0	9.7	*	2	DZ	
	87.263	341.60	0.21	20.504	0.044	0.41	0.084					GP2 DZ2	N
6700	08100N4072		ES 593	BC									
	87.262	213.0	0.79	4.30	0.062	1.76	0.125	10.0	10.7	*	3	GP	
	87.262	210.8	0.38	4.44	0.061	0.75	0.136	9.5	10.0	*	2	DZ	
	87.264	207.8	0.62	4.68	0.055	1.39	0.124	9.5	10.0	*	2	GP	
	87.264	210.8	0.26	4.57	0.072	0.51	0.144	9.7	10.0	*	2	DZ	
	87.263	210.87	1.10	4.476	0.085	1.90	0.148					GP2 DZ2	
6777	08178S1022		HU 116	AB									
	87.264	172.5	0.44	2.04	0.028	0.98	0.063	10.0	10.1	*	5	GP	
	87.264	170.0	0.27	1.41	0.056	0.53	0.112	10.0	10.3		3	DZ	
	87.264	171.56	1.21	1.804	0.305	1.98	0.498					GP DZ	

Table 1 (continued)

ADS	t	θ	σ_θ	ρ	σ_ρ	σ(θ)	σ(ρ)	m_1	m_2	Δm	Q	Obs.	Note
6777	08178S1022		HJ 784	AC									
	87.264	11.1	0.57	18.14	0.088	1.27	0.198	10.0	10.5	*	5	GP	
	87.264	10.8	0.23	17.46	0.120	0.46	0.240	10.0	10.5	*	3	DZ	
	87.264	10.99	0.15	17.885	0.329	0.24	0.538					GP DZ	
6811	0827N2452		STF 1224	A–BC									
	87.210	48.9	0.38	5.38	0.059	0.77	0.118	*	*	0.5	2	GP	
	87.210	50.1	0.69	5.49	0.060	1.38	0.119	8.5	9.0	*	2	DZ	
	87.262	48.6	0.10	5.83	0.059	0.21	0.132	6.5	7.0	*	4	GP	
	87.262	49.5	0.24	6.07	0.032	0.48	0.064	*	*	*	2	DZ	
	87.264	50.2	0.33	5.76	0.051	0.66	0.103	*	*	0.7	4	GP	
	87.264	49.5	0.15	5.66	0.026	0.30	0.052	7.0	7.4	*	4	DZ	
	87.297	49.8	0.22	5.67	0.041	0.50	0.091	8.0	8.5	*	3	GP	
	87.297	49.9	0.27	5.60	0.054	0.54	0.107	8.0	8.6	*	4	DZ	
	87.360	48.9	0.15	5.82	0.077	0.30	0.155	*	*	0.5	4	GP	
	87.360	50.2	0.10	5.62	0.045	0.21	0.089	7.1	7.6	*	4	DZ	
	87.287	49.56	0.19	5.698	0.051	0.63	0.170					GP5 DZ5	N
7049	08460N1230		STF 1287	AB									
	8.272	86.5	0.55	1.75	0.032	1.10	0.064	*	*	*	3	GP	
7049	08460N1230		STF 1287	AC									
	8.272	97.6	0.47	15.54	0.109	0.95	0.219	*	*	*	2	GP	
8100	11088N7361		STF 1516	AB									
	88.321	103.6	0.19	56.44	0.068	0.39	0.137	*	*	0.0	2	GP	
8100	11088N7361		STT 539	AC									
	88.321	321.5	1.17	6.30	0.189	2.35	0.378	*	13.0	*	2	GP	
8355	11511N3560		STT 241	AB									
	87.264	144.5	0.32	1.63	0.026	0.65	0.052	7.5	8.5	*	2	GP	
	87.264	143.1	0.77	1.63	0.026	1.54	0.052	7.5	8.5	*	2	DZ	
	87.297	143.8	0.36	1.51	0.029	0.73	0.059	8.5	10.0	*	3	GP	
	87.297	142.4	0.84	1.52	0.045	1.67	0.089	8.5	10.0	*	2	DZ	
	87.360	144.1	0.65	1.53	0.022	1.30	0.045	8.0	9.0	*	4	GP	
	87.360	141.7	0.74	1.48	0.017	1.48	0.033	7.0	8.5	*	4	DZ	
	87.429	138.7	0.37	1.47	0.019	0.73	0.039	8.0	9.2	*	3	GP	
	87.429	141.7	0.48	1.58	0.021	0.96	0.042	7.7	9.0	*	4	DZ	
	87.440	146.0	0.53	1.48	0.014	1.06	0.027	8.0	9.5	*	2	DZ	
	87.440	139.1	0.65	1.44	0.028	1.72	0.075	*	*	*	3	GP	
	87.366	142.30	0.71	1.522	0.020	2.20	0.061					GP4 DZ5	N
8440	12043S1118		STF 1604	AB									
	88.321	84.8	0.39	8.94	0.187	0.78	0.374	7.5	10.0	*	2	GP	N
8440	12043S1118		STF 1604	AC									
	88.321	49.9	0.22	12.05	0.129	0.45	0.259	7.5	9.0	*	2	GP	
8506	12136N1181		STF 1628	AB									
	88.354	239.4	0.43	9.63	0.153	0.87	0.306	*	*	0.2	2	GP	
	88.354	239.0	0.17	9.78	0.122	0.34	0.243	8.5	8.9	*	2	DZ	
	88.354	239.20	0.20	9.705	0.075	0.23	0.087					GP DZ	
8506	12136N1181		STF 1628	AC									
	88.354	346.4	0.18	45.92	0.152	0.36	0.305	*	*	*	2	GP	
	88.354	346.2	0.23	45.56	0.059	0.45	0.118	*	*	1.2	2	DZ	
	88.354	346.30	0.10	45.740	0.180	0.12	0.208					GP DZ	

Table 1 (continued)

ADS	t	θ	σ_θ	ρ	σ_ρ	$\sigma(\theta)$	$\sigma(\rho)$	m_1	m_2	Δm	Q	Obs.	Note
8539	12194N2568		STF 1639	AB									
	8.414	324.2	0.97	*	*	1.94	*	6.6	7.8	*	2	DZ	N
8601	12300N0760		STF 1658	AB									
	88.411	16.1	0.80	2.59	0.042	1.80	0.093	8.0	9.5	*	3	GP	
	88.412	16.2	0.30	2.66	0.021	0.61	0.043	7.5	9.0	*	4	DZ	
	88.412	16.16	0.05	2.630	0.035	0.08	0.053					GP DZ	
8601	12300N0760		STF 1658	AC									
	88.411	265.2	0.07	124.07	0.080	0.15	0.160	8.0	8.5	*	3	GP	
8695	12484N2147		STF 1687	AB									
	88.401	175.1	0.81	0.93	0.023	1.62	0.047	*	*	2.5	2	GP	
	88.401	165.5	0.72	0.95	0.021	1.44	0.042	5.0	6.4		1+1	DZ	
	88.401	170.30	4.80	0.940	0.010	5.54	0.012					GP DZ	N
8695	12484N2147		STF 1687	AC									
	88.401	126.4	0.26	28.76	0.127	0.52	0.254	*	10.0	*	2	GP	
9136	14056N2664		STF 1808	AB									
	86.473	78.2	0.55	2.44	0.030	1.24	0.068	*	*	0.5	2	GP	
	87.298	78.4	0.13	2.41	0.047	0.27	0.095	*	*	1.0	3	GP	
	87.360	78.9	0.17	2.55	0.025	0.34	0.050	9.5	10.0	*	4	GP	
	87.360	80.7	0.26	2.44	0.015	0.51	0.031	8.8	9.0	*	4	DZ	
	87.379	78.0	0.66	2.40	0.057	1.62	0.140	*	*	0.7	2	GP	
	87.232	79.07	0.51	2.458	0.029	1.15	0.064					GP4 DZ1	
9136	14056N2664		STF 1808	AC									
	87.379	111.0	0.48	59.20	0.115	1.19	0.282	*	*	*	2	GP	
9338	14360N1651		STF 1864	AB									
	87.459	109.7	0.35	5.59	0.036	0.70	0.072	*	*	0.5	2	GP	
	87.459	111.5	0.29	5.48	0.050	0.57	0.100	*	*	*	2	DZ	
	87.459	110.60	0.90	5.535	0.055	1.04	0.064					GP DZ	
9372	14406N2730		STF 1877	AB									
	88.510	342.8	0.54	2.40	0.070	1.08	0.140	*	*	*	2	GP	
9372	14406N2730		STF 1877	AC									
	88.510	255.7	0.26	176.45	0.530	0.52	1.061	*	*	*	2	GP	
9514	15036S0036		STF 3090	AB									
	88.412	281.0	0.14	1.01	0.028	0.27	0.040	8.3	8.7	*	2	DZ	
	88.576	275.9	0.62	0.83	0.017	1.23	0.034	8.3	8.7	*	2	DZ	
	88.494	278.45	2.55	0.920	0.090	2.94	0.104					DZ2	
9514	15036S0036		STF 3090	AB–C									
	88.412	128.1	0.18	91.11	0.171	0.36	0.342	*	*	*	2	GP	
	88.576	128.5	0.12	91.02	0.128	0.25	0.256	*	*	*	3	GP	
	88.510	128.34	0.20	91.056	0.044	0.25	0.057					GP2	
9626	15207N3742		STF 28	AB									
	88.576	171.3	0.11	108.94	0.080	0.22	0.179	5.0	8.0	*	3	GP	
	88.576	171.4	0.06	108.48	0.040	0.11	0.080	*	*	*	4	DZ	
	88.576	171.36	0.05	108.677	0.228	0.08	0.348					GP DZ	

Table 1 (continued)

ADS	t	θ	σ_θ	ρ	σ_ρ	σ(θ)	σ(ρ)	m_1	m_2	Δm	Q	Obs.	Note
9626	15207N3742		STF 1938	BC									
	88.576	11.1	0.40	2.08	0.046	0.81	0.093	8.0	8.5	*	3	GP	
	88.576	12.4	0.42	2.26	0.042	0.85	0.083	7.2	7.8	*	4	DZ	
	88.476	11.84	0.64	2.183	0.089	0.98	0.136					GP, DZ	N
9695	15296N2663		STF 1955	AB									
	88.401	238.1	0.10	7.36	0.188	0.21	0.376	*	*	*	2	GP	
	88.401	237.0	0.44	8.05	0.050	0.89	0.10	8.7	9.3	*	2	DZ	
	88.488	238.1	0.29	7.74	0.035	0.64	0.079	*	*	0.3	4	GP	
	88.444	237.82	0.34	7.723	0.173	0.55	0.282					GP2, DZ1	
9695	15296N2663		JAR	AC									
	88.401	34.9	1.04	19.87	0.330	2.09	0.661	*	*	*	2	GP	N
	88.488	37.0	0.36	19.74	0.172	0.73	0.384	*	*	*	2	GP	N
	88.444	35.95	1.05	19.805	0.065	1.21	0.075					GP2	
9716	15325N3968		STT 298	AB–C									
	88.570	327.7	0.06	122.27	0.066	0.12	0.133	*	*	*	4	GP	
	88.573	328.1	0.05	122.09	0.093	0.10	0.209	*	*	*	3	FP	N
	88.571	327.8[illegible]	0.20	122.193	0.089	0.30	0.136					GP2	
9861	15540N4157		STT 1991	AB									
	88.567	194.9	0.42	2.78	0.035	0.84	0.070	8.5	9.2	*	4	DZ	
	88.568	199.8	0.55	2.51	0.051	1.11	0.103	8.5	9.5	*	4	GP	
	88.567	197.35	2.45	2.645	0.135	4.00	0.220					DZ, GP	
9861	15540N4157		STT 1991	C–AB									
	88.568	267.6	0.07	94.59	0.163	0.15	0.364	7.8	*	*	4	GP	
9865	15545N2165		STF 1990	AC									
	87.361	59.6	0.14	59.61	0.156	0.28	0.312	8.5	9.0	*	2	GP	
9865	15589S1106		STF 1990	CB									
	87.361	206.8	0.27	3.76	0.045	0.54	0.091	9.0	9.1	*	2	GP	
	87.361	205.4	0.30	3.92	0.031	0.61	0.062	9.5	9.5	*	2	DZ	
	87.361	206.10	0.70	3.840	0.080	0.81	0.092					GP, DZ	
9909	15589S1106		STF 1998	AB									
	87.429	36.0	0.55	0.97	0.029	1.22	0.065	*	*	0.2	2	GP	
	87.429	36.0	0.25	0.95	0.017	0.51	0.034	4.8	5.1	*	2	DZ	
	87.432	33.3	0.94	1.07	0.029	2.11	0.065	*	*	*	2	GP	
	87.432	32.6	0.73	1.04	0.036	1.46	0.072	*	*	*	2	DZ	
	87.431	34.47	0.89	1.007	0.028	1.46	0.046					GP2, DZ2	N
9909	1558951106		STF 1998	AC									
	87.429	47.2	0.70	7.89	0.050	1.57	0.111	*	*	3.0	2	GP	
	87.429	49.0	0.31	7.83	0.077	0.61	0.154	4.8	7.2	*	2	DZ	
	87.432	46.8	0.38	7.61	0.080	0.76	0.160	*	*	*	2	GP	
	87.432	47.4	0.82	7.72	0.165	1.65	0.330	*	*	*	2	DZ	
	87.431	47.60	0.48	7.763	0.062	0.79	0.101					GP2, DZ2	
9969	16086N1348		STF 2021	AB									
	88.354	352.6	0.24	4.06	0.098	0.48	0.196	*	*	0.0	2	GP	
	88.354	352.7	0.14	4.19	0.062	0.28	0.124	6.7	6.8	*	2	DZ	
	88.401	353.5	0.44	4.04	0.088	0.88	0.177	*	*	*	3	GP	
	88.401	352.0	0.55	4.08	0.022	1.11	0.045	8.5	8.5	*	4	DZ	
	88.516	352.3	0.17	4.15	0.023	0.34	0.046	6.7	6.9	*	2	DZ	
	88.404	352.59	0.28	4.095	0.027	0.58	0.055					DZ3, GP2	

Table 1 (continued)

ADS	t	θ	σ_θ	ρ	σ_ρ	$\sigma(\theta)$	$\sigma(\rho)$	m_1	m_2	Δm	Q	Obs.	Note
9969	16086N1348		STF 2021	AC									
	88.354	119.0	0.06	210.05	0.194	0.11	0.336	*	*	*	3	GP	
	88.401	118.6	*	209.75	*	*	*	*	*	*	3	GP	N
	88.377	118.80	0.20	209.900	0.150	0.28	0.212					GP2	
10036	16198N3335		BU 951	AB–C									
	88.568	38.2	0.19	1.15	0.015	0.38	0.031	*	*	1.0	2	GP	
10075	16245N1837		STF 2052	AB									
	87.462	130.7	0.20	1.43	0.014	0.39	0.028	7.9	8.0	*	2+2	DZ	
	87.551	129.6	0.38	1.56	0.030	0.75	0.059	7.8	7.8	*	2+2	DZ	
	88.554	130.4	0.17	1.53	0.014	0.33	0.027	7.8	7.8	*	3+3	DZ	
	87.955	130.26	0.31	1.510	0.037	0.66	0.080					DZ3	N
10193	16412N3555		STF2097	AB									
	88.565	81.2	0.54	1.91	0.032	1.04	0.064	8.5	8.7	*	1+1	GP	
	88.565	81.1	0.45	1.99	0.026	0.89	0.051	9.6	9.8	*	1+1	DZ	
	88.567	81.7	0.34	1.95	0.023	0.67	0.047	9.6	9.8	*	1+1	DZ	
	88.568	81.7	0.26	1.88	0.034	0.52	0.069	8.5	8.7	*	1+2	GP	
	88.566	81.46	0.16	1.927	0.024	0.28	0.042					GP2, DZ2	
10193	16412N3555		STF 2097	AC									
	88.565	6.9	0.12	159.07	0.064	0.25	0.128	8.5	7.0	*	1+1	GP	
	88.568	6.9	0.06	159.39	0.063	0.13	0.127	8.5	8.0	*	1+2	GP	
	88.567	6.90	0.00	159.262	0.157	0.00	0.202					GP2	N
10216	16435N2549		WEI 31	AB									
	87.448	318.4	0.26	4.77	0.044	0.59	0.098	9.0	9.1	*	2+2	GP	
	87.451	319.9	0.39	4.74	0.055	0.78	0.111	9.5	9.6	*	1+2	GP	
	87.451	318.5	0.36	4.97	0.044	0.72	0.088	9.5	9.5	*	1+1	DZ	
	87.536	317.5	0.68	4.78	0.069	1.37	0.138	*	*	0.0	1+1	GP	
	87.544	317.4	0.43	4.83	0.040	0.86	0.080			0.1	1+1	DZ	
	87.477	318.47	0.45	4.805	0.038	0.93	0.079					GP3, DZ2	
10216	16435N2549		WEI 31	BC									
	87.448	259.2	0.21	30.41	0.102	0.42	0.205	9.0	9.2	*	2+1	GP	
	87.451	258.9	0.36	30.37	0.146	0.73	0.293	9.5	9.7	*	1+1	GP	
	87.449	259.08	0.15	30.394	0.020	0.19	0.025					GP2	
10216	16435N2549		WEI 31	AC									
	87.451	249.2	0.17	28.19	0.070	0.34	0.140	9.5	10.3	*	1+1	DZ	
10235	16479N2850		STF 2107	AB									
	85.650	91.1	0.56	1.38	0.008	2.10	0.021	*	*	*	1+1	GP	
	87.462	92.9	0.73	1.11	0.010	1.47	0.021	7.0	8.8	*	1+1	DZ	
	88.516	89.1	0.19	1.35	0.008	0.39	0.016	6.5	8.0	*	1+1	DZ	
	88.551	92.6	0.69	1.19	0.012	1.38	0.024	6.7	8.2	*	2+2	DZ	
	88.554	93.0	0.12	1.24	0.007	0.25	0.014	6.7	8.2	*	2+2	DZ	
	87.977	92.04	0.67	1.243	0.044	1.46	0.094					DZ3, GP1	N
10345	17033N5436		STF 2130	AB									
	88.510	34.5	0.68	2.18	0.035	1.36	0.070	*	*	*	1+1	GP	N
10394	17078N2121		STF 2135	AB									
	88.354	191.0	0.22	8.13	0.067	0.45	0.135	8.0	9.2	*	1+1	GP	N
	88.354	191.2	0.53	8.29	0.056	1.07	0.111	7.1	8.1	*	1+1	DZ	
	88.354	191.10	0.10	8.210	0.080	0.12	0.092					GP, DZ	

Table 1 (continued)

ADS	t	θ	σ_θ	ρ	σ_ρ	σ(θ)	σ(ρ)	m_1	m_2	Δm	Q	Obs.	Note
10781	17415S0111		STF 2211	AB									
	88.488	114.5	0.32	10.40	0.068	0.72	0.151	*	*	*	2+2	GP	
10781	17415S0111		STF 2211	AC									
	88.488	196.7	0.11	105.86	0.181	0.23	0.362	*	*	*	1+2	GP	
11046	18004N0232		STF 2272	AB									
	87.462	254.5	0.23	1.53	0.009	0.46	0.018	*	*	2.0	1+1	DZ	
	88.516	252.7	0.25	1.82	0.027	0.49	0.055	4.1	6.1	*	1+1	DZ	
	88.551	252.6	0.30	1.70	0.017	0.60	0.034	4.1	6.1	*	1+1	DZ	
	88.554	251.0	0.32	1.51	0.014	0.72	0.028	4.1	6.1	*	2+2	DZ	
	88.327	252.36	0.75	1.614	0.072	1.37	0.132					DZ4	N
11353	18221N0008		STF 2316	AB									
	88.576	320.2	0.37	3.58	0.044	0.74	0.088	*	*	*	1+2	GP	
	88.576	320.2	0.50	3.70	0.060	1.00	0.119	5.5	7.8	*	1+1	DZ	
	88.647	318.7	0.64	3.60	0.061	1.43	0.136	6.0	9.0	*	1+2	GP	
	88.603	319.64	0.51	3.618	0.034	0.84	0.056					GP2, DZ1	N
11483	18314N1654		STT 358	AB									
	87.462	162.4	0.23	1.66	0.009	0.45	0.018	*	*	0.2	1+1	DZ	
	88.551	159.4	0.34	1.57	0.020	0.67	0.040	6.8	7.0	*	1+1	DZ	
	88.554	160.2	0.18	1.56	0.015	0.40	0.030	6.8	6.9	*	3+3	DZ	
	88.677	158.0	0.26	1.58	0.023	0.52	0.046	7.0	7.2	*	2+2	DZ	
	88.680	159.5	0.10	1.67	0.018	0.21	0.036	7.0	7.2	*	1+1	DZ	
	88.464	159.74	0.66	1.592	0.021	1.52	0.049					DZ5	N
11632	18418N5927		STF 2398	AB									
	88.666	169.9	0.16	13.55	0.023	0.32	0.046	8.0	8.5	*	2+2	GP	N
11632	18418N5927		STF 2398	AD									
	88.666	100.3	0.10	91.53	0.180	0.21	0.361	8.0	11.0	*	2+2	GP	N
11667	18413S0064		STF 2379	AB									
	88.732	120.6	0.06	12.87	0.113	0.13	0.226	7.5	8.5	*	1+2	GP	N
11667	18413S0064		STF 2379	AC									
	88.732	145.3	0.36	24.80	0.115	0.73	0.258	7.5	12.0	*	1+2	GP	
11811	18505N3715		BU 137	AB									
	88.571	159.8	0.46	1.67	0.041	0.92	0.082	8.0	8.3	*	1+1	GP	
	88.571	159.0	0.56	1.63	0.020	1.12	0.040	8.2	8.3	*	2+2	DZ	
	88.573	155.4	0.47	1.68	0.046	1.06	0.103	*	*	*	1+1	GP	
	88.573	156.4	0.32	1.44	0.023	0.64	0.046	8.2	8.4	*	1+1	DZ	
	88.572	157.92	0.98	1.610	0.050	1.80	0.092					GP2, DZ2	
11811	18505N3715		BU 137	AC									
	88.571	146.3	0.75	23.91	0.267	1.50	0.534	*	*	*	1+1	GP	
	88.573	146.2	1.03	23.83	0.130	2.06	0.260	*	*	*	1+1	GP	
	88.572	146.25	0.05	23.870	0.040	0.06	0.046					GP2	
11902	18545N1329		STF 2424	AB									
	88.661	296.4	0.10	18.95	0.100	0.21	0.200	6.0	9.0	*	2+2	GP	
11902	18545N1329		STF 2424	AC									
	88.661	268.5	0.23	78.27	0.343	0.46	0.686	*	*	*	1+1	GP	
11916	18553N1244		STF 2426	AB									
	88.661	261.0	0.20	16.35	0.149	0.40	0.298	8.0	9.0	*	1+2	GP	N

Table 1 (continued)

ADS	t	θ	σ_θ	ρ	σ_ρ	$\sigma(\theta)$	$\sigma(\rho)$	m_1	m_2	Δm	Q	Obs.	Note
11971	18576S0051		STF 2434	AB									
	88.647	96.4	0.11	26.05	0.032	0.27	0.079	*	*	*	1+2	GP	N
12026	19008N1343		BU 287	AC									
	88.729	76.7	0.13	160.75	0.164	0.27	0.366	3.0	12.0	*	1+2	GP	N
12026	19008N1343		*	AD									
	88.729	151.0	0.13	202.34	0.177	0.26	0.395	3.0	10.0	*	1+2	GP	
12029	19009N0624		STF 2446	AB									
	87.672	153.8	0.36	9.44	0.092	0.81	0.205	8.0	10.0		1+1	GP	
	87.672	152.8	0.16	9.45	0.080	0.32	0.160	8.0	9.8	*	1+1	DZ	
	87.708	150.3	0.43	9.55	0.086	0.87	0.172	7.0	9.0	*	1+1	GP	
	87.708	152.7	0.19	9.48	0.075	0.38	0.150	7.5	9.0	*	1+1	DZ	
	87.690	152.40	0.74	9.480	0.025	1.21	0.041					GP2, DZ2	
12029	19009N0624		STF 2446	AC									
	87.672	344.8	0.34	36.10	0.195	0.76	0.437	*	*	*	1+1	GP	
	87.672	344.4	*	36.65	*	*	*	8.0	13.0	*	1+1	DZ	
	87.708	347.6	0.27	36.21	0.109	0.53	0.218	9.0	11.0	*	1+1	DZ	
	87.708	345.7	0.40	36.50	0.087	0.81	0.174	7.0	9.5	*	1+1	GP	
	87.690	345.62	0.71	36.365	0.127	1.16	0.207					GP2, DZ2	
12071	19040N2939		STF 2466	AB									
	88.565	103.7	1.17	2.40	0.031	2.35	0.063	*	*	*	1+1	GP	
	88.565	103.7	0.59	2.36	0.032	1.18	0.064	8.5	9.0	*	1+1	DZ	
	88.567	104.9	0.26	2.58	0.029	0.52	0.058	8.0	8.5	*	3+3	DZ	
	88.568	101.7	0.25	2.29	0.022	0.50	0.044	8.0	8.3	*	3+3	GP	
	88.567	103.52	0.84	2.421	0.074	1.95	0.171					GP2, DZ2	
12071	19040N2939		STF 2466	AC									
	88.568	140.9	0.08	98.79	0.150	0.17	0.301	8.0	10.0	*	2+2	GP	
12240	19127N4954		STF 2496	AB									
	88.666	80.3	0.61	2.01	0.015	1.37	0.033	7.0	11.0	*	1+2	GP	
12240	19127N4954		STF 2496	AC									
	86.666	241.7	0.05	185.70	0.105	0.12	0.234	7.0	10.0	*	1+2	GP	N
12708	19332N0007		BU 249	AB									
	88.571	118.6	0.78	0.64	0.013	1.56	0.026	7.5	9.6	*	1+1	DZ	
	88.737	115.9	0.47	0.91	0.009	0.94	0.017	7.5	9.5	*	2+2	DZ	
	88.740	115.8	0.26	0.89	0.010	0.53	0.020	7.2	9.2	*	2+2	DZ	
	88.705	116.40	0.78	0.848	0.074	1.42	0.135					DZ3	
12880	19418N4453		STF 2579	AB									
	88.737	230.4	0.19	2.42	0.013	0.39	0.026	3.0	8.0	*	2+2	DZ	
	88.740	230.2	0.07	2.43	0.016	0.13	0.033	*	*	*	2+2	DZ	
	88.738	230.30	0.10	2.425	0.005	0.16	0.008					DZ2	N
12913	19426N3330		STF 2580	AB									
	88.647	69.3	0.05	26.36	0.097	0.12	0.218	*	*	*	1+2	GP	N
12913	19426N3330		STF 2580	AC									
	88.647	128.6	0.04	115.74	0.052	0.09	0.104	*	*	*	1+2	GP	
13464	20076N5639		ES 132	AB									
	88.737	84.1	0.07	5.46	0.080	0.14	0.179	9.0	9.1	*	1+2	GP	
	88.737	84.2	0.42	5.45	0.090	0.83	0.202	8.6	8.7	*	1+2	DZ	
	88.737	84.15	0.05	5.455	0.005	0.07	0.007					GP, DZ	

Table 1 (continued)

ADS	t	θ	σ_θ	ρ	σ_ρ	σ(θ)	σ(ρ)	m_1	m_2	Δm	Q	Obs.	Note
13454	20076N5639		ES 132	AC									
	88.737	63.0	0.16	33.92	0.080	0.32	0.179	9.0	8.8	*	1+2	GP	
	88.737	61.8	0.16	33.84	0.115	0.31	0.258	*	*	*	2+2	DZ	
	88.737	62.31	0.59	33.874	0.040	0.91	0.060					GP, DZ	
13524	20123N7725		STF 2675	AB									
	88.729	121.0	0.41	6.91	0.079	0.83	0.159	4.0	11.0	*	1+2	GP	N
13524	20123N7725		STF 2675	AC									
	88.729	335.0	0.11	173.02	0.149	0.23	0.334	4.0	10.0	*	1+2	GP	
13728	20166N3905		STF 2668	AB–C									
	88.748	282.3	0.51	3.23	0.064	1.13	0.144	8.0	10.0	*	1+1	GP	N
	88.748	284.2	0.24	3.16	0.031	0.48	0.061	7.0	9.0	*	1+1	DZ	
	88.748	283.25	0.95	3.195	0.035	1.10	0.040					GP, DZ	
13886	20237N1826		HO 131	AB									
	88.732	330.3	0.86	3.49	0.044	1.93	0.098	8.0	12.0	*	3+2	GP	N
13886	20237N1826			AD									
	88.732	97.4	0.13	88.07	0.154	0.26	0.344	8.0	10.5	*	3+2	GP	N
13886	20237N1826		HO 131	AC									
	88.732	73.5	0.10	74.32	0.214	0.20	0.429	8.0	10.5	*	2+2	GP	
14186	20390N4951		ES 91	AB									
	88.567	185.2	0.97	4.70	0.047	1.94	0.094	9.5	9.7	*	1+1	DZ	
	88.568	186.7	0.36	3.90	0.006	0.72	0.013	9.8	10.0	*	1+1	GP	
	88.567	185.95	0.75	4.300	0.400	0.87	0.462					DZ, GP	
14186	20390N4951		ES 91	AC									
	88.567	235.7	0.44	17.42	0.113	0.62	0.160	*	*	*	1+1	DZ	
	88.568	236.2	0.84	17.43	0.232	1.68	0.465	9.8	9.9	*	1+1	GP	
	88.567	235.95	0.25	17.425	0.005	0.29	0.006					DZ, GP	
14233	20402N1157		STF 2723	AB									
	86.780	129.4	0.37	1.05	0.012	0.74	0.024	7.2	8.8	*	1+1	DZ	
	86.793	125.7	0.25	0.97	0.016	0.51	0.032	6.9	8.7	*	1+1	DZ	
	86.859	125.5	0.13	1.03	0.008	0.27	0.016	7.0	8.5	*	2+2	DZ	
	86.823	126.52	1.18	1.020	0.021	1.92	0.035					DZ3	
	88.571	131.4	0.88	1.05	0.020	1.97	0.044	7.5	9.0	*	1+1	GP	
	88.571	129.6	0.27	1.04	0.009	0.54	0.018	6.9	8.7	*	1+1	DZ	
	88.573	126.7	0.55	1.15	0.030	1.11	0.061	7.7	8.0	*	1+1	GP	
	88.573	131.4	1.33	1.08	0.017	3.25	0.033	6.9	8.7	*	1+1	DZ	
	88.572	129.77	1.11	1.080	0.025	1.81	0.041					GP2, DZ2	
14296	20435N3607		STT 413	AB									
	86.709	16.8	1.21	0.84	0.019	3.20	0.043	*	*	1.0	1+1	GP	
	88.740	13.2	0.86	1.00	0.011	1.92	0.023	5.0	6.5	*	1+1	GP	
	88.740	15.5	0.47	0.97	0.014	0.95	0.028	5.0	6.3	*	1+1	DZ	
	88.743	14.8	0.23	0.89	0.009	0.46	0.018	*	*	*	1+1	DZ	
	88.741	14.50	0.68	0.953	0.033	0.96	0.046					DZ2, GP1	N
14296	20435N3607		S 765	AC									
	88.740	105.7	0.32	83.36	0.109	0.64	0.219	5.0	10.0	*	1+1	GP	

Table 1 (continued)

ADS	t	θ	σ_θ	ρ	σ_ρ	$\sigma(\theta)$	$\sigma(\rho)$	m_1	m_2	Δm	Q	Obs.	Note
14573	20580N0108		STF 2744	AB									
	86.864	125.6	0.66	1.26	0.015	1.32	0.029	*	*	0.4	1+1	DZ	
	86.865	121.8	0.32	1.42	0.018	0.64	0.037	*	*	0.5	1+2	GP	
	86.867	121.6	0.19	1.38	0.041	0.38	0.082	*	*	0.7	1+2	GP	
	86.875	124.2	0.34	1.26	0.015	0.68	0.030	*	*	0.4	2+2	DZ	
	86.869	123.18	0.19	1.330	0.041	1.80	0.082					DZ2, GP2	N
	88.551	127.6	0.22	1.21	0.010	0.44	0.021	7.0	7.5	*	1+1	DZ	
	88.554	126.6	0.21	1.20	0.008	0.43	0.015	7.0	7.5	*	2+2	DZ	
	88.563	127.2	0.19	1.28	0.009	0.37	0.018	7.0	7.5	*	2+2	DZ	
	88.677	125.9	0.27	1.21	0.019	0.54	0.038	7.0	7.3	*	1+1	DZ	N
	88.577	126.85	0.32	1.230	0.021	0.64	0.041					DZ4	
14773	21096N0936		STF 2777	AB–C									
	88.721	337.8	0.17	60.35	0.067	0.34	0.149	*	*	*	1+2	GP	N
14889	21166N3202		STT 437	AB									
	88.675	25.0	0.34	2.16	0.012	0.68	0.025	7.0	7.2	*	1+1	DZ	
	88.677	25.2	0.26	2.04	0.009	0.53	0.018	6.9	7.6	*	2+2	DZ	
	88.743	24.8	0.50	2.12	0.066	1.00	0.147	8.0	8.5	*	1+1	GP	
	88.743	24.5	0.37	2.21	0.024	0.74	0.048	6.9	7.6	*	1+1	DZ	
	88.746	25.3	0.51	2.10	0.021	1.02	0.043	7.5	8.0	*	2+2	GP	
	88.746	25.0	0.11	2.17	0.025	0.23	0.050	6.9	7.6	*	2+2	DZ	
	88.757	27.4	0.47	2.14	0.028	1.04	0.063	*	*	0.5	1+1	GP	
	88.757	25.5	0.16	2.08	0.055	0.33	0.110	6.8	7.5	*	1+1	DZ	
	88.728	25.29	0.27	2.121	0.020	0.73	0.054					DZ5, GP3	
14889	21166N3202		STT 437	AC									
	88.743	141.8	0.11	80.71	0.067	0.23	0.134	8.0	10.0	*	1+1	GP	
	88.746	142.2	0.09	80.43	0.108	0.19	0.216	7.5	10.0	*	2+2	GP	N
	88.746	141.4	1.20	80.99	0.050	0.41	0.100	6.9	10.5	*	2+2	DZ	
	88.745	141.80	0.25	80.710	0.177	0.46	0.323					GP2, DZ1	
14954	21202N0857		STF 2793	AB–C									
	88.737	242.2	0.05	26.62	0.050	0.11	0.101	8.0	9.0	*	2+2	GP	N
15007	21240N1039		STF 2799	AB									
	88.675	263.2	0.25	1.72	0.012	0.51	0.025	7.5	7.5	*	1+1	DZ	
	88.677	265.2	0.32	1.86	0.016	0.64	0.031	7.5	7.5	*	1+1	DZ	
	88.797	265.1	0.84	1.67	0.024	1.87	0.053	*	*	*	1+1	GP	
	88.797	264.5	0.30	1.71	0.010	0.59	0.021	7.5	7.5	*	1+1	DZ	
	88.737	264.50	0.46	1.740	0.041	0.75	0.068					DZ3,GP1	N
15896	22188N2021		STF 2900	AC									
	88.647	309.8	0.06	86.10	0.098	0.13	0.239	*	*	*	1+2	GP	
16317	22474N6109		STF 2950	AB									
	86.788	286.8	0.25	1.53	0.022	0.57	0.050	*	*	1.0	1+2	GP	
	86.788	287.3	0.68	1.48	0.018	1.35	0.037	*	*	1.0	1+1	DZ	
	86.791	288.8	0.43	1.51	0.033	0.87	0.067	*	*	0.5	3+3	GP	
	86.791	289.2	0.30	1.38	0.007	0.60	0.014	*	*	0.4	3+3	DZ	
	86.856	287.1	0.31	1.44	0.008	0.63	0.017	*	*	1.1	1+1	DZ	
	86.859	285.8	0.62	1.57	0.037	1.24	0.074	*	*	0.8	1+1	GP	
	86.859	286.7	0.43	1.59	0.023	0.85	0.047	*	*	1.0	1+1	DZ	
	86.808	287.92	0.48	1.482	0.029	1.34	0.080					DZ4, GP3	

able 1 (continued)

ADS	t	θ	σ_θ	ρ	σ_ρ	$\sigma(\theta)$	$\sigma(\rho)$	m_1	m_2	Δm	Q	Obs.	Note
16345	22492N4413		BU 382	AB									
	88.740	212.3	1.33	1.00	0.017	3.27	0.034	7.5	8.5	*	1+1	GP	
	88.740	211.1	0.47	0.89	0.024	0.94	0.047	6.0	8.0	*	1+1	DZ	
	88.740	211.70	0.60	0.945	0.055	0.69	0.064					GP, DZ	N
16345	22492N4413		HJ 1828	AC									
	88.740	359.0	0.27	28.80	0.037	0.54	0.074	*	*	*	1+1	GP	
	8.740	358.6	0.38	28.87	0.076	0.75	0.153	6.0	9.0	*	1+1	DZ	
	88.740	358.80	0.20	28.835	0.035	0.23	0.040					GP, DZ	
16649	231255S0164		BU 79	AB									
	86.712	22.9	0.41	1.58	0.024	0.92	0.048	*	*	1.5	2+2	GP	
	86.862	22.7	0.92	1.60	0.112	2.05	0.250	*	*	1.2	1+1	GP	
	86.862	20.8	0.44	1.51	0.019	0.87	0.037	*	*	1.0	1+1	DZ	
	86.865	23.4	1.10	1.82	0.044	2.21	0.089	*	*	1.5	1+1	GP	
	86.865	20.3	0.41	1.55	0.027	0.82	0.053	*	*	1.0	1+1	DZ	
	86.813	22.17	0.59	1.607	0.050	1.17	0.100					GP3, DZ2	N
16928	23363N3201		BU 858	AB									
	86.780	233.3	0.85	0.80	0.018	1.70	0.037	8.0	8.5	*	1+1	GP	
	86.780	231.6	0.50	0.77	0.014	1.00	0.028	7.5	8.5	*	2+1	DZ	
	86.791	231.7	0.83	0.79	0.008	1.85	0.017	*	*	0.5	2+2	GP	
	86.791	230.1	0.36	0.78	0.012	0.71	0.023	*	*	0.5	2+2	DZ	
	86.856	230.5	0.13	0.86	0.009	0.26	0.019	7.4	8.9	*	1+1	DZ	
	86.859	231.1	0.25	0.84	0.012	0.51	0.024	*	*	1.0	1+1	GP	
	86.859	230.8	0.41	0.86	0.010	0.82	0.019	*	*	0.5	1+1	DZ	
	86.809	231.25	0.38	0.806	0.014	0.95	0.035					DZ4, GP3	
17149	23544N3310		STF 3050	AB									
	86.728	316.5	0.23	1.72	0.027	0.46	0.054	*	*	0.1	2+2	GP	
	86.774	316.6	0.37	1.60	0.017	0.73	0.034	7.2	7.2	*	2+2	DZ	
	86.775	315.7	0.67	1.60	0.029	1.35	0.059	*	*	0.0	1+2	GP	
	86.777	315.3	0.37	1.66	0.028	0.82	0.056	7.0	7.0	*	2+2	GP	
	87.777	316.1	0.10	1.64	0.012	0.20	0.024	7.0	7.0	*	3+3	DZ	
	86.856	316.5	0.10	1.64	0.013	0.20	0.027	*	*	0.0	2+2	DZ	
	86.859	317.1	0.32	1.73	0.036	0.64	0.081	*	*	0.1	2+2	GP	
	86.859	316.5	0.25	1.69	0.029	0.51	0.058	*	*	0.0	2+2	DZ	
	86.800	316.29	0.19	1.661	0.017	0.64	0.056					GP4, DZ4	N

In relations (1) m is the number of readings (settigns); later 0 denotes the value of the micrometer revolution for a given temperature of observations. In the reductions the errors of the micrometer screw are also taken into account, as earlier.

The well-known relations in this case acquire a following form

$$\theta = \frac{\sum_{i=1}^{m} \theta_i}{m} \qquad (1a)$$

$$\sigma_\theta = \frac{\sigma(\theta)}{\sqrt{m}} \qquad (1b)$$

$$\sigma(\theta) = \sqrt{\frac{\Sigma(\theta_i - \theta)^2}{m-1}} \qquad (1c)$$

$$\bar{a} = \frac{\sum_{i=1}^{m} a_i}{m}, \quad \bar{b} = \frac{\sum_{i=1}^{m} b_i}{m} \qquad (1d)$$

$$\rho = \frac{O}{2}(\bar{a} - \bar{b}) \qquad (1e)$$

$$\sigma_{(\rho)} = \frac{O}{2}\sqrt{\epsilon_a^2 + \epsilon_b^2} \qquad (1f)$$

$$\epsilon_{\bar{a}} = \sqrt{\frac{\sum_{i=1}^{m} (a_i - \bar{a})^2}{m-1}}, \qquad \epsilon_{\bar{b}} = \sqrt{\frac{\Sigma\,(b_i - \bar{b})^2}{m-1}} \qquad (1g)$$

$$\sigma_\rho = \frac{\sigma(\rho)}{\sqrt{m}} \qquad (1h)$$

The results of measurements performed on several days (evenings) are presented through the weighted mean values in a special row under the ones of individual measurements ordered in the following way.

First row number contains the weighted mean value of the observation time: t, (rel.(2a).

Second row number contains the weighted mean value of θ from n observation evenings: $\bar{\theta}$ (rel. (2b)).

Third row contains the mean error of the weighted mean $\bar{\theta}$: $\sigma_{\bar{\theta}}$ (rel. (2c)).

Fourth row contains weighted mean of ρ from n observation evenings: $\bar{\rho}$ (rel. (2d)).

Fifth row contains mean error of the weighted mean $\bar{\rho}$: $\bar{\sigma}_\rho$, (rel. (2e)).

Sixth row contains dispersion of θ measurements corresponding to a single evening: $\sigma(\theta(i))$, (rel. (2f))

Seventh row contains dispersion of ρ measurements corresponding to a single evening: $\sigma(\rho(i))$, (rel. (2g)).

In relations (2f) and (2g) instead of the quantity Q from column 11 of Table 1 we substitute Q/3 = p achieving in this way that a measurement from an observationally average evening has the weight p = 1. Namely, in such evenings the image quality is most frequently equal to 1 or 2 which is also valid for the marks of the quality of measuring. In this way the value of the sum Q is most frequently equal to 3, i.e. p = 1

If θ, ρ and t from (1) are denoted as $\theta(i)$, $\rho(i)$, t(i), (i = 1 to n, n is number of nights), then the treatment of the weighted mean values one can present with a following set of relations

$$t = \frac{\sum_{i=1}^{n} p_i\, t(i)}{\sum_{i=1}^{n} p_i} \qquad (2a)$$

$$\bar{\theta} = \frac{\sum_{i=1}^{n} p_i\, \theta(i)}{\sum_{i=1}^{n} p_i} \qquad (2b)$$

$$\sigma_{\bar{\theta}} = \frac{\sigma(\theta(i))}{\sqrt{\sum_{i=1}^{n} p_i}} \qquad (2c)$$

$$\bar{\rho} = \frac{\sum_{i=1}^{n} p_i\, \rho(i)}{\sum_{i=1}^{n} p_i} \qquad (2d)$$

$$\sigma_{\bar{\rho}} = \frac{\sigma(\rho(i))}{\sqrt{\sum_{i=1}^{n} p_i}} \qquad (2e)$$

$$\sigma(\theta(i)) = \sqrt{\frac{p_i\,(\theta(i) - \bar{\theta})^2}{n-1}} \qquad (2f)$$

$$\sigma(\rho(i)) = \sqrt{\frac{p_i\,(\rho(i) - \bar{\rho})^2}{n-1}} \qquad (2g)$$

The derivation of the weighted mean values could also be on the basis of the errors derived for individual measurements (from which the weights could be derived), but with regard that each of our measurements has already estimated weight Q, i.e. p we use these estimated weights which seem to be real in the final data treatment.

3. NOTES

The notes from this section are comments of the observers expressed during the observations. Comparisons of the present observations to the ephemeris of 25 orbital pairs contained in this series (Couteau, P, Morel. P.J., Fulconis, M., 1986) are also given.

Table 3. Notes

ADS		Notes
684	AB	Baize, 1964: +0°9, − 0".05
1548	AB	Zulević, 1981: +0°4, +0".11
1630	BC	Muller, 1957: +1°.8, +0".18
2122	AB	Rabe, 1961: +1°.6, −0".13
3093	BC	Heintz, 1964: +0°.9, −0".87
3991	BC	BC round (Bos, 1962: ρ (1988.0) = 0".17)

Table 3 (continued)

ADS		Notes
5871		Karmel, 1939: +2°6, –0."03.
6364	AB	$m_B = m_C$ (IDS: m_B = 11.4, m_C = 10.4)
6650	AC	Gasteyer, 1954: +4.5, –0."20 (The orbital elements corresponding to the multiple AB–C).
6700	AB	The measurements reported here don't fit well into the measurements of IDS Catalogue: IDS: AB 1908, 1957, n = 2, θ: 230°, 250°; ρ: 19."8, 20."4 IDS: AC 1894, 1957, n = 3, θ: 211, 208; ρ:4.6, 6.1
6811	A–BC	BC single.
8355	AB	The component P (m_C = 7^m.0, ρ_{AC} = 30.4) is not seen in four nights (GP, DZ).
8440	AB	The component C is brighter than B.
8539	AB	Aller, 1951: – 0°7, –.
8695	AB	Heintz, 1973: –1°1, –0."15.
9626	BC	Baize, 1952: –0°.5, –0."04
9695	AC	The component C barely visible.
9716	AB–C	AB not noticed as a double. According to Orbit (Couteau, 1966) ρ_{AB} for 1988.0 is 0."29.
9909	AB	Baize, 1942: –0°4, 0."10
9969	AC	Measurement from 1988.401 based on only one setting.
10075	AB	Siegrist, 1950: +0°7, –0."14 Scardia, 1984: –6°.0, –0."18
10193	AC	Measured component C (7^m.0) does not correspond to he component given in Catalogue IDS (12^m.4). We have been probably unsuccessful in registrating the component mentioned in the Catalogue. The component reported here is as distant as four times then the catalogue one.
10235	AB	Rabe, 1927: –0°.1, –0."16.
10345	AB	Heintz, 1981: +1°.4, 0."08. C unseen.
10394	AB	θ(AC) = 207°9.
11046	AB	Heintz, 1973: +1°.3, –0."01
11353	AB	Component P not noticed.
11483	AB	Heintz, 1954: +4°.2, +0."12
11632	AB	Heintz, 1968: +0.2, –0."01
11632	AD	Pair AD measured in conviction that it was AC. However, after derivation of rectilinear trajectory of AC ephemeris of C for 1988.666 found to be θ = 160°.26, ρ = 194."3 (1950), hence our measurement done for AC.
11667	AB	System's surroundings with no stars.
11916	AB	A is redish; C unseen.
11971	AB	C hardly seen in pair BC.
12026	AC	Close pair AB unseen. D component joined the system and measured for the first time; it is brighter than C.
12240	AC	There are two faiter stars at significantly smaller distance to C.
12880	AB	Baize, 1973: + 2°.5, – 0."01
12913	AB	B component seems to be double.
13524	AB	B fainter than C.
13728	AB–C	System is a member of a star cluster.
13886	AB	Clear point core.
13886	AC	Measurement not agree with earlier ones.
13886	AD	This pair has not been registrated yet. It is possible that the components C and D are mixed up.
14296	AB	Baize, 1983: +1°.6, +0."04
14573	AB	Hopmann, 1960: +4°4, – 0."21 Popović, 1969: +6.5, –0."02
14773	AB–C	Most likely wrong pair measured.
14889	AB	In immediate surroundings another triple system registrated Its close being measured by Popović: 1988.743 204°.1 7."30.
14954	AB–C	AB not seen.
15007	AB	Popović, 1987: –1°1, +0."04.
16345	AB	Muller, 1954: –1°.9, –0."04. Rabe, 1961: –2°.9, –0."09
16649	AB	Heintz, 1962: +0°.6, +0."08
17149	AB	Heintz, 1974: –2°.0, +0."05

REFERENCES

Anosova, J.P.: 1988, *Bull. Obs. Astron. Belgrade,* **138**, 13.

Anosova, J.P.: 1987, *Astrofizika,* **27**, 535.

Couteau, P., Morel, P.J., Fulconis, M986, *Cinquieme catalogue d'ephemerides d'etoiles doubles visuelles,* Publ. Obs. de Nice.

Zulević, D.J.: 1988, *Bull. Obs. Astron. Belgrade,* **138**, 63.

Table 1 (continued)

ADS	Disc. IDS	Mult.	Epoch 1900+	P	ρ	Est. Mag.	n	Notes
1615	STF 202		86.873	280.°6	1.″69	4.2–5.2	1	
	01569N0217		86.876	283.3	1.75	Δm = 0.8	1	
			86.875	281.9	1.72		2	Rabe, 1943: +6.°1, +0.″09
								Scardia, 1981: +1.7, –0.18.
2034	STT 43		86.873	5.4	0.94	Δm = 0.8	1	
	02349N2612		86.876	5.1	0.93	8.0–8.7	1	
			86.875	5.2	0.93		2	Heintz, 1962: +0.°3, –0.″07.
2377	STT 50	AB	86.876	163.2	1.06	8.5–8.5	1	Popović, 1972: +0.°3, +0.″04.
	03027N7110							
2446	STT 53		86.876	256.5	0.82	8.0–8.8	1	Rave, 1948: –5.°3, –0.″02
	03113N3816							Zulević, 1984: –2.°1, –0.″03.
4193	STF 752		87.141	141.9	10.93	3.2–7.3	1	
	05305S0559							
6175	STF 1110		88.253	320.3	1.27	Δm = 0.0	1	
	07282N3206							
7092	STF 3120		88.245	0.3	1.29	8.0–9.5	1	
	08494N4404							
7286	STF 1333		88.253	50.5	1.93	6.4–6.7	1	
	09123N3547							
7685	STT 213		88.253	125.9	0.84	Δm = 1.5	1	Heintz, 1962: +1.°5, –0.″07.
	10075N2755							
7704	STT 213		88.253	182.2	1.36	7.3–7.4	1	Wierzbinski, 1956: +0.°4, –0.″07.
	1010N1814							
8119	STF 1523		88.253	75.7	1.74	4.4–4.9	1	Heintz, 1967: 0.°0, +0.″07.
	11128N3206							
8148	STF 1536		88.253	132.1	1.88	4.5–7.0	1	Baize, 1951: –3.°3, –0.″20
	11187N1105							
8189	STT 234		87.429	144.3	0.52	8.0–8.0	1	Couteau, 1965: 4.°0, +0.″11
	11254N4150							
8252	STT 237		87.297	250.4	1.72	8.0–9.5	1	
	11336N4142		87.360	247.5	1.89		1	
			87.439	248.4	1.65		1	
			87.431	249.3	1.92		1	
			87.379	248.9	1.79		4	
8655	A 1783		87.297	217.9	1.54	9.5–9.5	1	
	12402N4358		87.360	219.3	1.78		1	
			87.431	215.3	1.63		1	
			87.442	215.9	1.76		1	
			87.377	217.1	1.67		4	
8680	HU 640		87.360	157.7	0.53	8.5–8.6	1	Baize, 1983: –2.°5, –0.″03
	12458N2105							
8709	A 2000		88.401	50.6	1.02	9.1–9.3	1	
	12517N4333							
9031	STF 1785		87.462	163.0	3.21	Δm = 0.2	1	Strand, 1955: –1.°7, –0.″20
	13445N2729							

Table 1 (continued)

ADS	Disc. IDS	Mult.	Epoch 1900+	P	ρ	Est. Mag.	n	Notes
9563	A 1366		87.434	80°.5	3".75	8.5–10.0	1	
	15122N3440		87.440	84.3	4.12		1	
			87.437	82.4	3.94		2	
9566	STT 1929		87.434	4.6	6.58	9.0–10.1	1	
	15126N3361		87.440	8.3	6.56		1	
			87.437	6.5	6.57		2	
9174	STF 1816		87.360	89.9	0.72	7.5–7.6	1	
	14095N2934							
9413	STF 1888	AB	87.442	328.1	7.15	5.0–6.0	1	
	14468N1931		87.461	327.3	7.14		1	
			87.451	327.7	7.14		2	Wielen, 1962: +0°.1, +0".05
9423	BU 31	AB	87.442	217.1	1.85	8.2–9.5	1	
	14479N1869		87.451	215.3	1.65		1	
			87.541	220.6	1.70		1	
			87.544	216.4	1.66		1	
			87.494	217.4	1.72		4	
9880	STT 303		88.354	165.9	1.35	7.4–7.7	1	
	15562N1335							
9910	STF 1999	AB	87.429	100.1	11.63	7.8–8.0	1	
	15589S1110							
9982	STF 2026		88.516	22.9	2.65	8.6–9.1	1	Heintz, 1963: +1°.1, −0".35
	16111N0737							
10036	BU 951	AB–C	88.565	38.3	1.10	8.2–8.7	1	
	16198N3335		88.567	36.3	0.97		1	
			88.566	37.3	1.03		2	
10070	STF 2049		88.516	197.8	1.32	6.5–7.5	1	
	16238N2572							
10071	BU 813		88.516	173.5	1.07	8.4–8.4	1	
	16239N2646							
10285	STF 3107	AB	87.451	79.9	1.43	9.0–9.1	1	
	16539N0367		88.571	80.3	1.47		1	
			88.573	80.0	1.37		1	
			88.680	79.0	1.61		1	
			88.569	79.8	1.47		4	
10312	STF 2114		88.557	191.5	1.22	6.7–7.7	1	
	16572N0836		88.562	190.6	1.25		1	
			88.559	191.0	1.23		2	
10429	A 2984		88.557	1.6	0.82	4.9–7.9	1	
	17114S0020		88.562	1.6	0.94		1	
			88.559	1.6	0.88		2	
10769	STF 2205		88.557	343.8	1.41	8.5–8.9	1	
	17413N1745		88.562	341.1	1.45		1	
			88.559	342.5	1.43		2	
10795	STF 2215		88.557	261.7	0.59	6.2–7.0	1	
	17427N1744		88.562	261.4	0.65		1	
			88.559	261.5	0.62		2	

Table 1 (continued)

ADS	Disc. IDS	Mult.	Epoch 1900+	P	ρ	Est. Mag.	n	Notes
10814	HU 1182		88.557	322°.6	0".56	9.3–9.5	1	
	17451N3538		88.562	324.0	0.66		1	
			88.559	323.3	0.61		2	
11001	STF 2267		88.571	264.5	0.78	8.0–8.0	1	
	17584N4011		88.573	261.7	0.77		1	
			88.572	263.1	0.78		2	
11568	STF 2384	AB	88.677	308.3	0.53	8.6–9.1	1	Heintz, 1975: −4°.9, +0".13.
	18385N6702							
11635	STF 2382	AB	88.551	356.1	2.33	5.1–6.1	1	
	18410N3934		88.554	353.2	2.38		1	
			88.674	351.2	2.66		1	
			88.680	352.3	2.61		1	
			88.615	353.2	2.49		4	Guntzel–Lingner, 1956: +0°.2, −0".14
11635	STF 2383	CD	88.551	87.0	2.50	5.1–5.4	1	
	18410N3934		88.554	87.6	2.22		1	
			88.674	86.9	2.53		1	
			88.680	87.5	2.50		1	
			88.615	87.2	2.44		4	Guntzel–Lingner, 1956: +0°.5, +0".15.
11711	STF 2400	BC	88.557	204.5	0.84	8.2–1.1	1	
	18444N1609		88.562	204.5	0.71		1	
			88.559	204.5	0.77		2	
	STF 2400	AB	88.557	160.8	8.46	8.0–10.5	1	
	18444N1609		88.562	160.9	8.44		1	
			88.559	160.9	8.45		2	
11805	Ho 89		88.573	169.5	5.88	8.5–12.5	1	
	18499N3721							
11897	STF 2438		88.677	3.8	0,91	7.0–7.2	1	Jastrzebski, 1959: +3°.0, +0".00.
	18558N5805							
12050	STF 2455	AB	88.557	32.1	7.90	7.4–8.4	1	
	19026N2201		88.563	32.1	7.97		1	
			88.560	32.1	7.93		2	
12447	STF 2525		88.551	292.3	1.74	8.5–8.7	1	
	19225N2707		88.554	292.1	1.76		1	
			88.674	293.0	1.82		1	
			88.680	292.0	1.74		1	
			88.615	292.3	1.77		4	Job Tamburini, 1967: +0°.3, −0".17.
12618	A 597		86.782	95.6	1.66	8.5–10	1	
	19305N4208		86.791	98.4	1.55		1	
			86.786	97.0	1.60		2	
12889	STF 2576	AB	87.675	172.0	2.30	Δm = 0.1	1	
	19418N3322		88.551	171.2	2.32	9.3–9.3	1	
			88.554	170.1	2.29		1	
			88.674	172.8	2.22		1	
			88.677	172.1	2.29		1	
			88.426	171.6	2.28		5	Rabe, 1948: +2°.2, −0".03
12930	HU 758		88.554	145.3	0.78		1	
	19432N3307							

Table 1 (continued)

ADS	Disc. IDS	Mult.	Epoch 1900+	P	ρ	Est. Mag.	n	Notes
12972	STT 387		88.737	155°.2	0″.62	7.2–8.2	1	
	19450N3504		88.740	154.8	0.62		1	
			88.738	155.0	0.62		2	Baize, 1961: +1°.5, +0″.02
13649	BU 984		86.774	252.7	0.78	8.7–9.0	1	
	20134N2604		86.777	250.5	0.70		1	
			86.780	250.5	0.66		1	
			86.777	251.3	0.71		3	
13866	J 559		86.777	269.2	2.20	Δm = 0.1	1	
	20223N0928		88.680	271.6	2.28		1	
			87.728	270.4	2.24		2	
13878	AG 256	AB	88.680	350.7	5.03	9.5–9.7	1	
	20231N0938		88.748	351.5	5.22		1	
			88.714	351.1	5.12		2	
14286	BU 364		86.780	242.3	1.13	9.1–9.2	1	
	20427N2503		86.782	241.4	1.00		1	
			86.856	242.2	0.99		1	
			86.859	241.8	1.00		1	
			86.819	241.9	1.03		4	
14360	STF 2729	AB	86.862	14.9	0.95	Δm = 0.5	1	Heintz, 1982: +0°.8, +0″.00
	20461S0560							
14424	BU 367	AB	86.862	124.3	0.50	Δm = 0.2	1	Heintz, 1962: +0°.2, 0″.00
	20508N2743							
14499	STF 2737	AB	86.785	286.5	0.79	Δm = 0.2	1	
	20541N0355		86.788	285.5	0.90		1	
			86.791	287.4	0.93		1	
			87.787	285.4	1.00		1	
			87.013	286.2	0.91		4	Van den Bos, 1933: +0°.3, −0″.11
	STF 2737	AC	86.791	67.2	10.25	7.5–8.7	1	
	20541N0355		87.787	66.0	9.95		1	
			87.289	66.6	10.10		2	
14783	H 48		86.862	255.6	0.48	7.1–7.3	1	
	21117N6400		86.875	254.5	0.50		1	
			88.677	257.0	0.52		1	
			87.471	255.7	0.50		3	Baiz4, 1983: −1°.9, +0″.11
14880	BU 838		86.793	143.0	1.63	8.5–10.5	1	
	21159N0242		86.859	143.3	1.54		1	
			86.875	145.4	1.44		1	
			86.833	143.9	1.54		3	
15215	STT 448		86.780	197.2	0.68	8.0–8.5	1	
	21366N2853		86.856	197.7	0.68		1	
			86.875	193.3	0.53		1	
			86.837	196.1	0.63		3	
15270	STF 2822	AB	86.863	299.5	1.80	5.5–6.8	1	
	21397N2817		86.875	300.8	1.94		1	
			86.878	300.2	1.84		1	
			87.784	302.6	1.95		1	
			87.787	301.4	1.94		1	
			88.674	301.5	1.82		1	
			87.475	301.0	1.88		6	Heintz, 1966: −3°.2, +0″.26

solar rotation turn, $\Delta\lambda$, depends on the inclination of the solar equator, i, as

$$\Delta\lambda = \frac{\cos(L_2 - L_1) - \sin^2 i \sin L_1 \sin L_2}{\sqrt{(1-\sin^2 i \sin^2 L_1)(1-\sin^2 i \sin^2 L_2)}} \quad (3)$$

where L_1 and L_2 are the heliocentric longitude of the Earth at the begining and at the end of the considered synodic solar rotation turn, measured from the ascending node of the solar equator. Severe changes occur when i approaches 90° what is, of course, looking from the Earth, only a fictive case. At the same time, the mean value of $\Delta\lambda$ within a six–month interval (or in any number of six–month intervals) is constant and equals to $L_2 - L_1$. Such a dependence of $\Delta\lambda$ on i restricts the validity of relation (2) to the mentioned long–period mean values and prevents us to interpret the quantities in equation (2) as angular velocities.

In the parallel research strive the angular velocities of solar rotation and Earth's revolution have been taken as vectors. The first vectorial solution (Kubičela and Karabin, 1982) has been based on a projection of the effect of the mean angular velocity of the Earth's orbital motion, $\vec{\omega}_2$, in Figure 1 (which is a vector equal, but with opposite orientation, to the angular velocity vector of the actual Earth's orbital motion) onto the direction of solar rotation axis, OP. The obtained rotational effect of the Earth's revolution, $\vec{\omega}_3$, amounting to 1.97507×10^{-7} rad s^{-1}, is for 1.59×10^{-9} rad s^{-1} (or for 1 ms^{-1} at the solar equator) smaller than in the classical approach.

Vector $\vec{\omega}_3$ can be readily added to the sidereal solar rotation velcoity, $\vec{\omega}_1$, or their intensities can be subtracted as scalars. However, an angular velocity perpendicular to the rotation axis and equivalent to the apparent yearly precession of the Sun, $\vec{\omega}_4$, remained. Its existence as a constant vector required an elaborate and somewhat tensile interpretation.

The crucial step in developing the vectorial approach consisted in applying a straight addition of vectors $\vec{\omega}_1$ and $\vec{\omega}_2$ in Figure 1 (Kubičela and Karabin, 1983). The result is simply the vector $\vec{\omega}_S$ – the angular velocity of synodic solar rotation. However, this elementry opearation of vector algebra introduces a considerable principle change in our understanding of synodic solar rotation: the direction of solar synodic rotation axis, OP_S, is separated from the direction of solar sidereal rotation axis, OP! The same is valid for the synodic and sidereal solar equators and the corresponding heliographic coordinate systems. This implies that we, looking from the Earth, see only the rotation of the Sun around OP_S and not around OP. The adopted inclination of the solar rotation axis, i = 7°25, is the angle πOP_S and not the angle πOP. Also, a new relation among the involved angular velocities followed:

$$\omega_1^2 = \omega_2^2 + \omega_S^2 + 2\omega_2\,\omega_S \cos i\,. \quad (4)$$

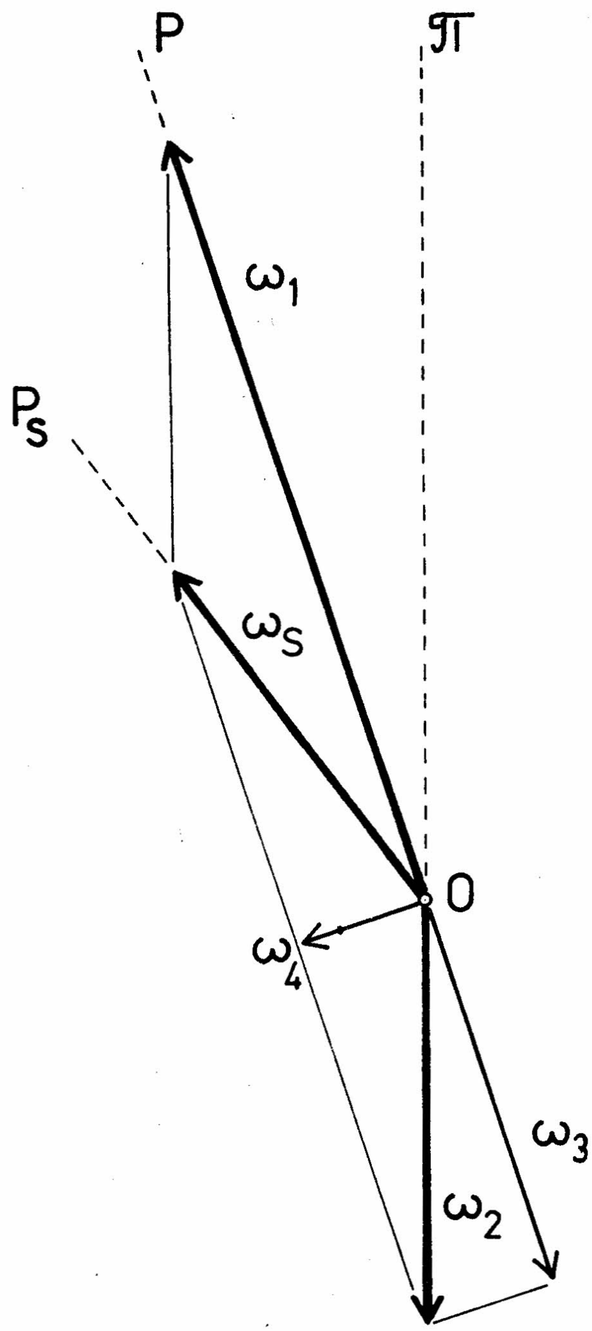

Fig. 1. Vectorial treatment of solar rotation velocities. $O\pi$ = direction toward the ecliptic pole. $\vec{\omega}_1$ = solar sidereal angular rotation velocity, $\vec{\omega}_2$ = angular velocity effect of Earth's revolution, $\vec{\omega}_3$ and $\vec{\omega}_4$ = the orthogonal components of $\vec{\omega}_2$, and $\vec{\omega}_S$ = solar synodic angular rotation velocity. OP = solar sideral and OP_S = solar synodic rotation axes.

It has to be taken as a generalization of the relation (2). Besides, the angle between the two rotation axes, POP_S, turned out to be about 0.°5: the sidereal rotation axis is for this amount closer to the ecliptic pole than the visible synodic rotation axis.

4. A COMPLEX PICUTRE OF SYNODIC SOLAR ROTATION

Recently, the concept of double solar rotation axes has been elaborated in more detail (Kubičela, 1986). The angular velocities ω_1 and ω_2, as well as the angle πOP, have been considered as variable.

Indeed, ω_1 changes across the solar disk with sidereal heliographic latitude according to (1). As the latitude gradient of ω_1 is always present (solar differential rotation), a whole continuum set of synodic rotation axes with the corresponding poles, as well as with the equators and the synodic coordinate systems, has to co-exist. Given a set of values of sidereal heliographic latitudes and using relation (1), one finds the corresponding values of sidereal angular velocities. Knowing the Earth's orbital angular velocities and the inclination of the mean observed (synodic) rotation pole, one can find the positions of all synodic poles. Taking i = 7.°25 as an observed inclination of the mean synodic pole that corresponds to the low sidereal heliogaphic latitudes ($10^o < \varphi_* < 20^o$), the synodic pole positions as shown in Figure 2 have been calculated. The influence of differential solar rotation is seen in a spread of synodic pole positions within an interval of about 0.°23 along the abscissa in Figure 2. Each of the synodic poles (synodic equators or synodic coordinate systems) is valid only for the given sidereal heliographic latitude, φ_*.

Due to the constant orientation of the ecliptic plane, variability of the effect of the Earth's revolution is limited to the intensity of vector $\vec{\omega}_2$. The quantity ω_2 changes according to Kepler's second law which causes an annual oscillation of the inclination of the synodic rotation axis. The amplitude of this oscillation is shown in Figure 2 as shifts of the whole set of synodic pole positions for the two extreme cases, „APHELION" and „PERIHELION", with respect to the mean pole positions, „MEAN".

As it can be seen, the effects introduced by the vectorial approach into the synodic pole position are small. They are approximately at the level of the observational errors in determination of the synodic pole position. The smallest nominal error up to now, amounting to ± 0.°017, has been claimed by Balthasar et al. (1986), but usually they are larger by one order of magnitude. Still better accuracy can be certainly reached if one organizes his observational material in the way that the low heliographic latitudes in summer (aphelion) can be distinguished from the high latitudes in winter (perihelion). Such a material would, probably, aslo confirm the concept of two solar rotation axes.

Another way of noticing the existence of the two rotation axes might be found in the fact that the circles of equal synodic and equal sidereal heliographic latitudes are intersecting each other (their planes subtend an angle

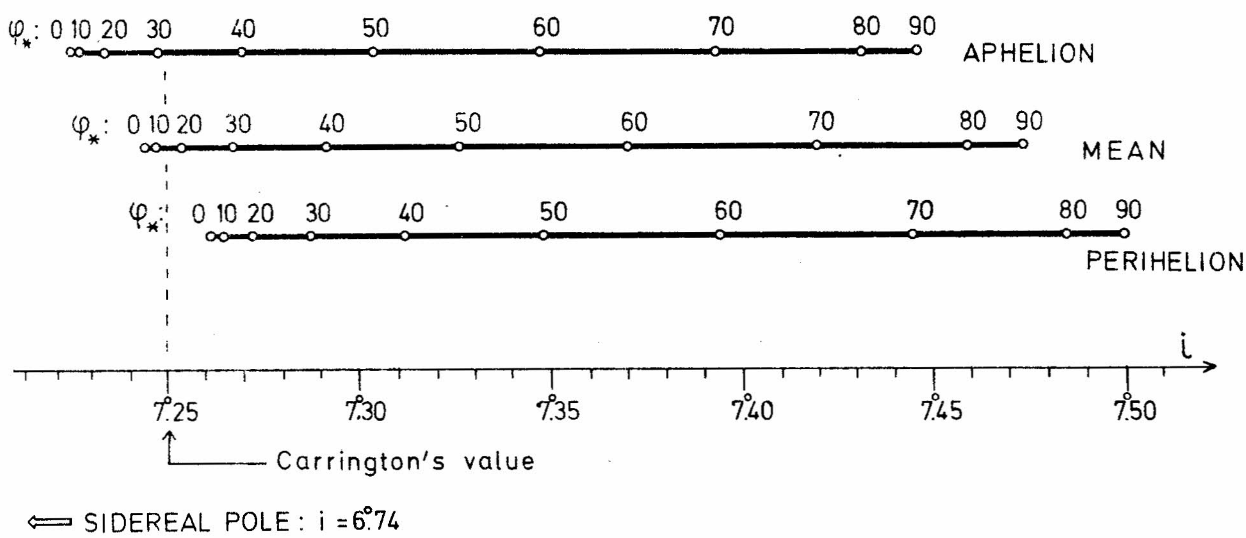

Fig. 2. One-dimensional diagram of the elongation, i, of synodic rotation poles from the ecliptic pole for the mean angular velocity of the Earth's revolution, „MEAN", and for two extreme cases: „APHELION" and „PERIHELION". The sidereal heliographic latitude, φ_*, is shown in degrees. In this scale, the unique sidereal rotation pole is at i = 6.°74.

equal to Δi). A photospheric tracer of constant sidereal heliographic latitude, during a solar rotation turn, would follow a sine–wave curve with an amplitude $\pm \Delta i$ in the synodic heliographic coordinate system.

5. VARIOUS HELIOCENTRIC ORBITS

Vector $\vec{\omega}_1$ is always oriented along the sidereal solar rotation axis and vector $\vec{\omega}_2$ is directed toward one pole or a planet's orbit. In the Earth's case they subtend a constant angle. There is, however, a need to set up one or more solar observatories revolving around the Sun much closer than the Earth does, and having the orbits with considerable inclination with respect to the solar equator.

To evaluate the parameters of synodic solar rotation seen from such an artificial planet, one should take various values for angle i in the realtion (4). As an example, the case of a circular heliocentric orbit with the radius r = 0.3 a.u. has been calculated. Syndonic angular velocity of the solar rotation, ω_s, and the angle between the synodic and sidereal axes, i = arc sin (ω^{-1}_s ω_2 sin i), has been found and shown in Table I for sidereal heliographic latitudes φ_* = 0°, 30°, 60° and 90°.

Table 1. Sidereal and synodic rotation angular velocities and the angle between the two rotation axes for an artificial planet at r = 0.3 a.u. and i = 60°
(angles in degrees, velocities in μ rad s^{-1})

φ_*	ω_1	ω_s	Δi
0	2.835	2.464	25.2
30	2.718	2.359	26.4
60	2.308	2.000	31.6
90	2.015	1.757	36.6

It is seen that the synodic angular velocity of solar rotation is lower than the sidereal one and approximately follows its latitude gradient. But the range of the angle between the two rotation axes for the latitude interval of 90°, being 25°.0 $\leqslant \iota \leqslant$ 36°.6, is striking compared with the corresponding Earth's interval, 0°.5 $\leqslant \Delta i \leqslant$ 0°.7.

Another claculation, namely for r = 0.17 a.u., can reveal a heliostationary (ω_s = 0) artificial planet, Or, for r < 0.17 a.u. some cases where the synodic solar rotation has the opposite sense of rotation with respect to he sidereal one can be found. Among such cases one can also find those with the vectors $\vec{\omega}_1$ and $\vec{\omega}_s$ mutually perpendicular.

All these circumstances would require an elaborate way of following solar rotation from a heliocentric, especially an out–of–ecliptic orbit at a small heliocentric distance.

6. THE „STELLAR" CASE

The difference along i–axis between the aphelion and perihelion synodic pole sets in Figure 2 grows with increasing the eccentricity of the planet's orbit. Apart from the Earth's case and the examples of various inner planetary orbits, it is interesting to consider the shift of the aphelion pole set (i.e. the ω_2–changes) in a limiting case: when a planet is being moved to stellar distances.

Then, from second Kepler's law

$$\omega_2 = 2\pi abT^{-1}r^{-2},$$

increasing the semiaxes of the planetary orbit, a and b, the revolution period, T, and the intensity of the radius vector, r, ad infinitum, one obtains

$$\lim_{\substack{a\to\infty \\ b\to\infty \\ T\to\infty \\ r\to\infty}} \omega_2 = 0. \quad (5)$$

Relation (5) introduced in (4) irrespective of the inclination, i, yields

$$\omega_1 = \omega_s \quad (6)$$

which means that the synodic pole has reached the position of the sidereal one – far out to the left in Figure 2. Here we should notice that the spread of synodic aphelion poles, depending on φ, is not influenced by (5) and it is understood that ω_s in (6) corresponds to a certain heliographic latitude or its interval.

Equality (6) gives us a posteriori the right to interpret the sidereal pole as the synodic one for an indefinitely distant observer. In this way the general case of separate sidereal and synodic rotation axes has been reduced and connected to the simple, up to now used, approximation of one common rotation axis – at least as far as the topocentric character of the phenomenon is concerned.

7. CONCLUSION

The study of synodic solar rotation at Belgrade Astronomical Observatory and Department of Astronomy of Belgrade Faculty of Sciences during the past ten years has resulted in a new view of the problem with the following main components:

1) Separated axes of synodic and sidereal solar rotation.

2) Evaluated new quantitative relations between kinematic parameters of synodic and sideral solar rotations.

3) Suggested possibility to detect the effect of the existence of two rotation axes seen from the Earth and to improve determination of the inclination of the synodic rotation axis.

4) Demonstrated variety of synodic rotation parameters that can occur in some artificial planets' cases when the vectorial approach will be unavoidable.

What has to be still done is the formal mathematical transformation of coordinates between the synodic and siderela heliographic coordinate systems.

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REFERENCES

Alen, C.W.: 1964, *Astrophysical Quantities*, The Athlone Press, London. 179.

Balthasar, H.: 1984, Ph. D. Thesis, Univ. Göttingen.

Balthasar, H., Lustig, G., Stark, D. and Wohl, H.: 1986, *Astron. Astrophys.* **160**, 277.

Beckers, J.M.: 1978, Proc. *Workshop on Solar Rotation*, Catania, 26–29 Sept. 1978, Belvedere, G. and Paterno, L. eds., 166.

Carrington, R.C.: 1863, *Observation of the Spots on the Sun*, Willimas and Norgate, London.

Kubičela, A.: 1986, Solar Phys. **106**, 403.

Kubičela, A. and Karabin, M.: 1977a, *Solar Phys.*, **54**, 505.

Kubičela, A. and Karabin, M.: 1977b, *Solar Phys.*, **52**, 199.

Kubičela, A. and Karabin, M.: 1981, *Publ. Dept. of Astron. Beograd*, **11**, 35.

Kubičela, A. and Karabin, M.: 1982, *Sun and Planetary System*, Fricke W. and Teleki G. eds., D. Reidel, Dordrecht, 73.

Kubičela, A. and Karabin, M.: 1983, *Solar Phys.*, **84**, 389.

Livingston, W.C. and Duvall, T.L.: 1979, *Solar Phys.* **66**, 167.

Snodgrass, H.B. and Howard, R.: 1985, *Solar Phys.* **95**, 221.

Wohl, H.: 1978, *Astron. Astrophys.* **62**, 165.

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Review paper

STARK BROADENING IN ASTROPHYSICS

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SUMMARY: The importance of Stark broadening in astrophysics is briefly reviewed. A short review of results of Yugoslav research workers on this field is also presented.

1. INTRODUCTION

As the typical information in astronomy is obtained by analyzing the radiation, the understanding of astrophysical spectral line shapes is of great importance. Spectral line shapes are an important research field particularly in special laboratories and institutions found in order to provide basic physical data to astronomers, e.g. JILA (Joint Institute for Laboratory Astrophysics) in Boulder Colorado. Stark and other broadening mechanisms of lines in astrophysical spectra are also investigated within the comission 14 of the IAU for fundamental spectroscopic data.

Spectral line shapes enter the analysis of a stellar spectrum essentially in two ways:

a) Selected lines from which we may derrive information about stellar parameters require reliable line shape theory and data of high accuracy for the contribution of the main broadening mechanism.

b) For the bulk of ($\gtrsim 10^6$) lines, as well as for smaller contributions to the main broadening mechanisms, broadening parameters of only modest accuracy are sufficient. Such lines only add together to the total absorption coefficient, which determines the atmospheric stratification, and we need only the good average accuracy while the accuracy for a particular line is not so important.

Stellar spectroscopy depends on very extensive list of elements and line transitions with their atomic and line broadening parameters. It is difficult to state in general terms which are the relevant transitions since the atmospheric composition of a star is not known a priori, and many interesting groups of stars exist with very peculiar abundances as compared to the Sun.

The interest for a very extensive list of line broadening data is stimulated also by spectroscopy from space. After the launch of Copernicus in 1972, it became possible to study the ultraviolet spectra of the brighter stars at very high spectral resolution. These studies were extended to considerably fainter objects with the launch of the International Ultraviolet Explorer (IUE) on January 26, 1978. A number of projects to follow up the achievements made in the space spectroscopy have been discussed The most advanced project is the Space Telescope (ST), a 2.4 m telescope (f/24) for studies at ultraviolet and optical wavelength. Using space spectroscopy, an extensive amount of spectroscopic information over large spectral regions of all kind of celestial objects has been and will be collected, stimulating spectral–line–shape research.

2. STARK BROADENING IN ASTROPHYSICS

Among the various pressure broadening mechanism, broadening due to interaction between emitter and charged particles (Stark broadening) is dominant in several cases. The relevant physical parameters for stellar plasma are most conveniently expressed in terms of the Hertzsprung–Russel diagram in which luminosity is plotted against effective surface temperature (figure 1). For $T_{eff} \geq 10^4$ K, hydrogen, the main constituent of a stellar astmosphera is mainly ionized, electron pressure, total pressure and the main collisional broadening mechanism for spectral lines is the interatomic Stark effect. We can see in Fig. 1 that this is the case for white dwarfs and hot stars of O, B and A0 type. Even in cooler stars atmospherae as e.g. Solar one Stark broadening may be important in some cases. In figure 2 is presented temperature as a function of height in the Solar atmosphera according to VAL model (Vernaza et al, 1981) as well as regions of formation of a number of Solar lines. We can see that far line wings of e.g. H_α line are formed in deeper atmospheric layers where the electron concentration is sufficiently high and Stark broadening contribution is not a priori negligible. On the other hand, the influence of Stark broadening within a spectral series increases with the increase of the principal quantum number of the upper level (Dimitrijević, Sahal–Bréchot, 1984ab; 1985) and Stark broadening contribution may become significant in the Solar spectrum (Vince et al. 1985abc).

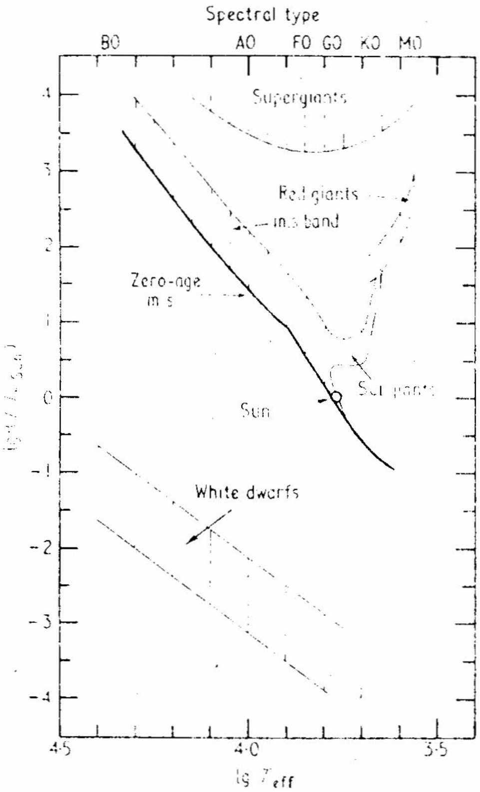

Figure 1. Schematic Hertzsprung–Russell diagram: m.s., main sequence.

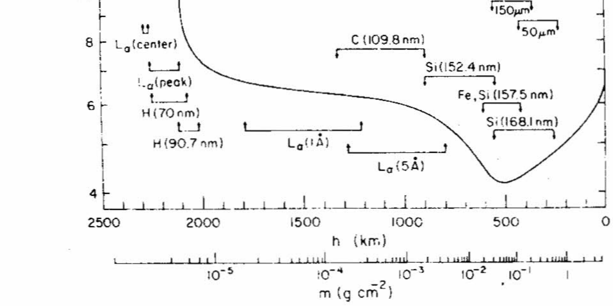

Figure 2. The average quiet–Sun temperature distribution derived from the EUV continuum, the Lα line, and other observations. The approximate depths where the various continua and lines originate are indicated.

Another case where the Stark broadening is the dominant pressure broadening mechanism are radio recombination lines from interstellar clouds of ionized and neutral hydrogen. The range of principal quantum numbers over which radio recombination lines have been observed is $56 \leqslant n \leqslant 253$ which corresponds in frequency to a range from 37.5 to 0.40 GHz. In such atoms the optical electron is far from the nucleus and very sensitive to the weak electric field fluctuations. The Stark broadening is the main collisional broadening mechanism in this case.

For example Stark broadening has been detected in the radio frequency recombination lines emitted by the emission nebula W51 (Lang and Willson, 1978). In figure 3 are given observed linewidths $\Delta\nu_L$, plotted as a function of principal quantum number, n. The solid curves illustrate the convolution of Stark and Doppler broadening for different values of electron density, N_e. The dashed lines correspond to $N_e = 10^3 \cdot cm^{-3}$ and Stark broadening which varies as $n^{4.0}$ and $n^{5.0}$. Under the assumption that the Stark broadening varies as $n^{4.4}$, these data indicate that $N_e = 10^{3.0 \pm 0.1}\ cm^{-3}$.

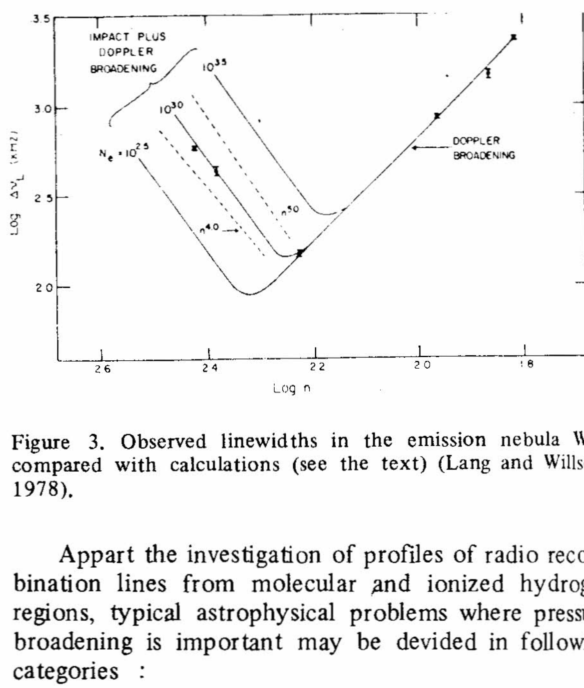

Figure 3. Observed linewidths in the emission nebula W51 compared with calculations (see the text) (Lang and Willson, 1978).

Appart the investigation of profiles of radio recombination lines from molecular and ionized hydrogen regions, typical astrophysical problems where pressure broadening is important may be devided in following categories :

a) Understanding of qualitative effects that one can see on spectrograms.

b) Determination of temperature (T) and electron concentration (N_e) of an astrophysical plasma and surface gravity in stars.

c) Determination of abundances of elements from profiles or equivalent widths of absorption lines.

d) Radiative transfer through astrophysical plasmas.

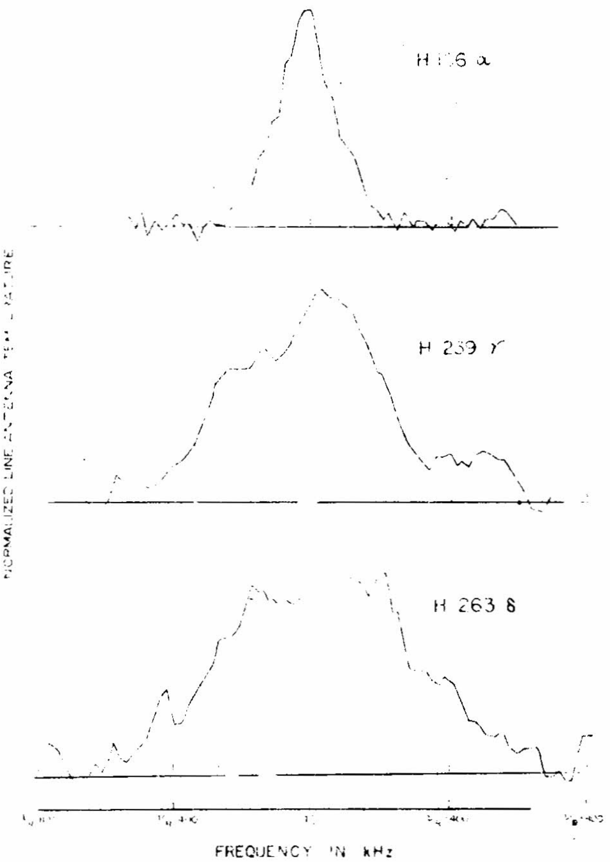

Figure 4. Observed Stark andDoppler broadened profiles in the emission nebula W 51 (Lang and Willson, 1978).

In order to explain astrophysical spectra, the knowledge about the pressure broadening is often needed. An example is the Stark shift in the spectra of white dwarfs which made difficulties in the interpretation of the Einstein shift, determined using helium lines (Wiese and Kelleher, 1971)

As another example one can mention the Solar limb effect. Careful measurements of the Fraunhofer lines show a small but systematic red shift across the Solar disk (as compared with their wevelength at the center) reaching a maximum on the limb. Appart from radial current hypothesis for explanation of this effect (see e.g. Hart, 1974) there are attempts to explain it partially or completely as a consequence of collisions between the absorbing atoms and surrounding particles (see e.g. Hart 1974 or Vince et al. 1985c). Calculations (Vince et al 1985c) of linewidths and relative line shifts across the Solar disk for Na I 3p–6s line are presented in figures 5 and 6. Relative lineshifts are compared also with simple radial current theory predictions (Hart, 1974). As an illustration, in figure 6 are given averaged observations for Fe I 525.02 nm line (Labonte and Howard, 1982). We can notice that Stark broadening contribution is not negligible.

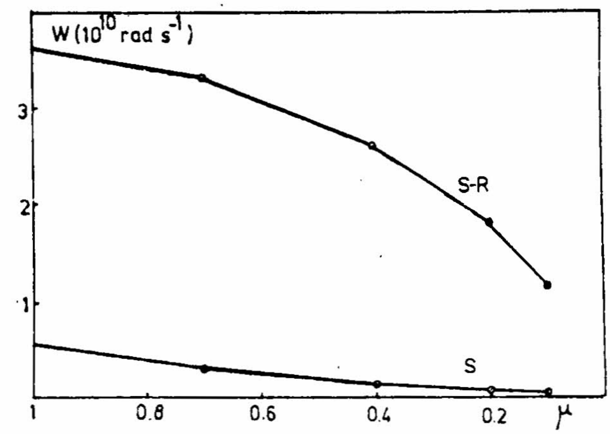

Figure 5. The full halfwidth for Na I 3p–6s line due to collisions with neutral (S–R) and charged particles (S) as a function of the heliocentric angle ($\mu = \cos\theta$).

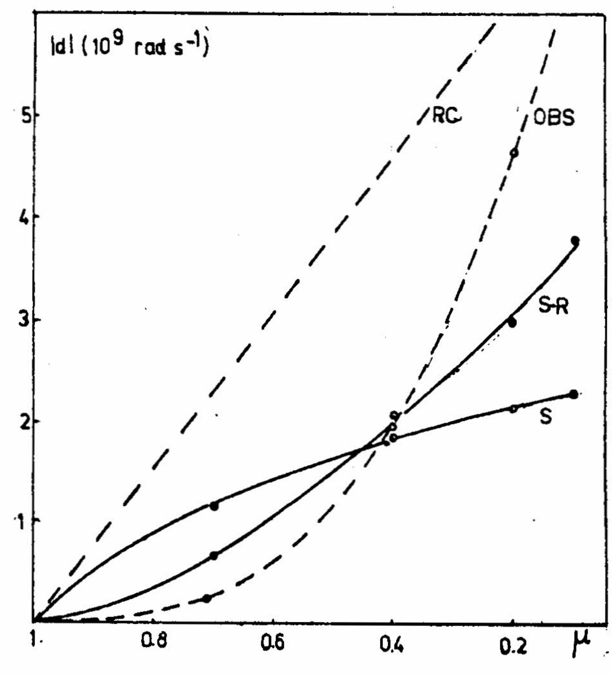

Figure 6. Relative Na I 3p–6s line shifts (shift at the Solar disk centre is taken as zero) as a function of the heliocentric angle ($\mu = \cos\theta$) of observed points; RC – the shift according to the radial current hypothesis (see e.g. Hart, 1974); OBS – averaged observation for Fe I 525.02 nm line (Labonte and Howard, 1982); S–R – Relative shift due to Na–H collisions using Smirnov–Roueff potential; S– Relative shift due to collisions with charged particles.

Observed spectral lines may be used also for determining the electron temperature and the concentration in astrophysical sources. Especially Balmer line profiles are a powerful diagnostic tool in studying stellar atmospheres. In cooler stars, such as the Sun, the line intensity is a good measure of the effective temperature. as can be seen from Fig. 7, line widths of higher members of the Balmer sequence are very sensitive to the change of electron density. In atmospheres of O and B stars, and also of some white dwarfs and A0 type stars ($T_{eff} \geqslant 10^4$ K) hydrogen is mainly ionized and the main collisional broadening mechanism for spectral lines is the impact broadening by electrons (Stark broadening). In such case the atmospheric pressure P is proportional to the electron concentration N_e at a fixed temperature. From the hydrostatic equation we can now deduce the surface gravity g. Total pressure P is given by $P \cong g^k$ (the coefficient k is different for different particles).

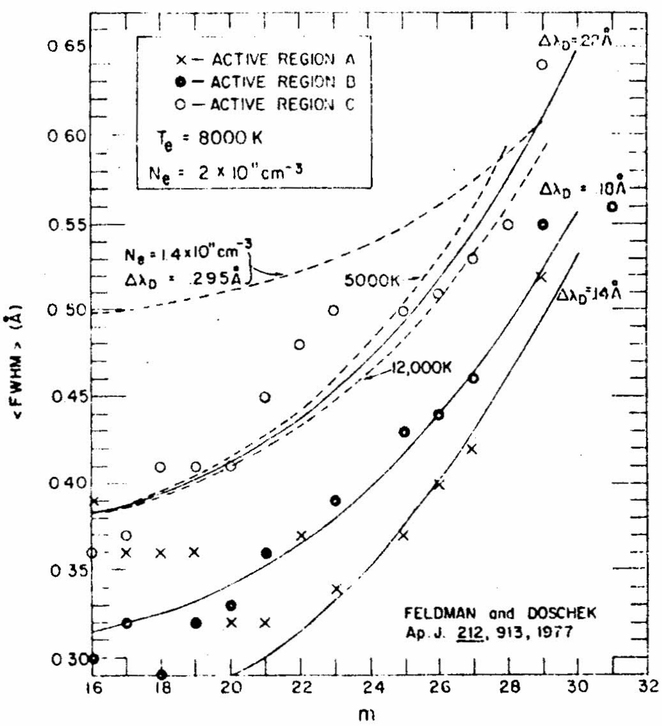

Figure 7. Stark broadening of high member series lines at 2'' above the limb over active regions. The density of 2 x 10^{11} cm^{-3} is an average of the actual values. The dashed curve with a density of 1.4 x 10^{11} cm^{-3} is fitted to the data at m = 29.

The important problem for which we need good pressure broadening data is that of determining abundances of elements from equivalent widths (W) of absorption lines. If the line is very weak, the problem is quite straightforward, since W (in wavelength units) is proportional to the abundance ratio of the element to hydrogen, multiplied by the oscillator strength of the transition

$$\left(\frac{W}{\lambda}\right)_{weak} = X \equiv \frac{N_M}{N_H}\, f\lambda \int_0^\infty \phi(\tau)d\tau$$

where $\phi(\tau)$ is a contribution function depending on the structure of the stellar atmosphere and the relevant states of excitation and ionization and τ is the optical depth in the continuum. If the line is not weak, the situation is much more complicated. The relationship between X and (W/λ) is described by the curve of growth, whose shape depends on the amount of line broadening due to both Doppler and pressure effects. The curve has three main branches:

Linear (unsaturated): $(W/\lambda) = X$

Flat (saturated): $(W/\lambda) \cong 3 v_D / c$

Damping branch: $(W/\lambda) = (\lambda X \gamma / \pi c)^{1/2}$

Here, γ is damping (pressure broadening) constant and v_D the velocity corresponding to the given Doppler width.

Pressure broadening data are also required for the estimation of the radiative transfer through the stellar plasma In this case data for a great number of lines are often needed. For such large scale calculations high accuracy of every particular value is not so important. In such cases, tedious calculations can be avoided if one uses simple, approximative formulae with good average accuracy (for Stark broadening see e.g. Dimitrijević (1982) and references therein).

3. LINE SHAPES INVESTIGATIONS IN YUGOSLAVIA 1962–1985

Since the first article on this topic (Vujnović et al., 1962) 371 publications concerning line shapes investigations have been published by 68 Yugoslav authors. The number of published articles, authors and, articles published in international journals are given in Table 1 for every year. We can see that 113 articles are published in international journals during the considered period. Also, 12 theses for Mr.Sc. degree and 9 doctoral theses have been done. Among the published articles, 15 are in Astronomy and Astrophysics and 1 in Astrophysical Journal.

Up to date, a large experimental work on Stark broadening for nonhydrogenic emitters has been done in the world and in Yugoslavia, in laboratory

Table 1: Number of articles, authors and articles in international journals, published by Yugoslav research workers in the period 1962–1985

Year	Number of articles published	Number of authors	Number of articles in international journals
1962	1	1	1
1963	0	0	0
1964	2	2	0
1965	1	1	1
1966	0	0	0
1967	0	0	0
1968	2	4	1
1969	4	4	0
1970	15	13	4
1971	11	9	4
1972	10	11	4
1973	10	13	3
1974	16	16	4
1975	14	15	5
1976	23	16	4
1977	13	14	7
1978	23	16	8
1979	17	14	7
1980	30	19	6
1981	26	17	4
1982	46	19	9
1983	31	19	10
1984	41	22	13
1985	35	21	7
Total	371		102

plasmas with $N_e = 2 \times 10^{13} - 4 \times 10^{17}$ cm^{-3} and $T=2 \times 10^3 - 6 \times 10^4$ K. In Yugoslav laboratories, Stark line widths are measured for 352 lines for 58 different kinds of emitters. Stark shifts for lines of non hydrogenic emitters are measured for 187 lines and 33 different emitters. The plasma sources were: a) The source of Josephson type (Figure 8) (e.g. J.Purić et al, 1970). Here, a condenser battery was discharged via a triggered spark gap. The discharge between the ring and cylindrical electrode in the source is pinched, causing the shock wave to propagate along the expansion tube; b) Pulsed arc (figure 9) (e.g. Konjević et al, 1971) and very similar Z pinch; c) Electromagnetically driven T–tube (figure 10 (Konjević et al, 1970) and d) Wall stabilized arc (figure 11) (Đurović, 1979). We can see in figure 11 that the arc channel was formed by a series of water cooled coopper discs with a central hole. The end parts of the arc chamber were closed by two brass discs in each of which there was a centrally bored hole for end–on plasma observations.

Theoretical research of Stark broadening was performed using quantum mechanical (the first strong coupling calculation for a non–hydrogenic neutral atom line, Li I 2s–2p, Dimitrijević et al. 1981) and semiclassical (BrI,

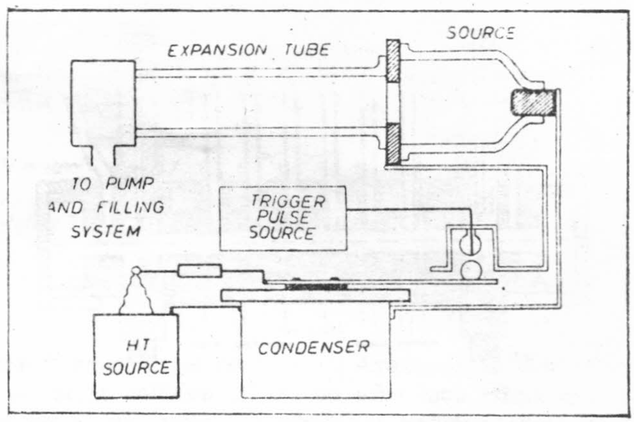

Figure 8. The palsma source of Josephson type.

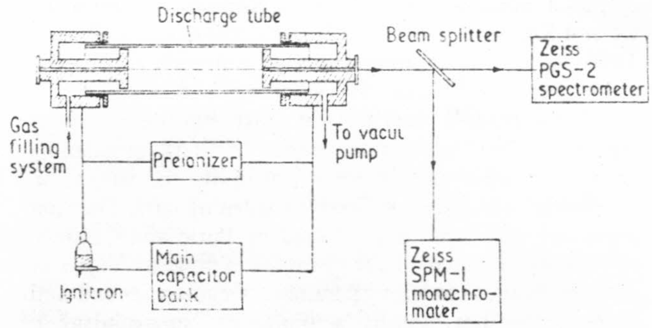

Figure 9. Pulsed arc

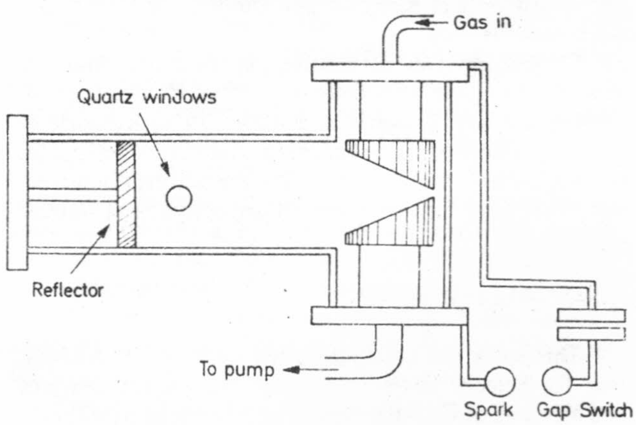

Figure 10. Electromagnetically driven T tube.

CdI, GeI, HgI, PbI, RbI, SnI, ZnI, FI, OII, TiII, MnII, ArIII, ClIII, SiIII, SIII, NIII, CIII, OIII, ArIV, SiIV, CIV, NIV, SIV etc, see e.g. Dimitrijević, 1982 and references therein) approaches. Also, approximative approaches useful for large scale calculations or quick estimates, have been investigated. The modified semi-

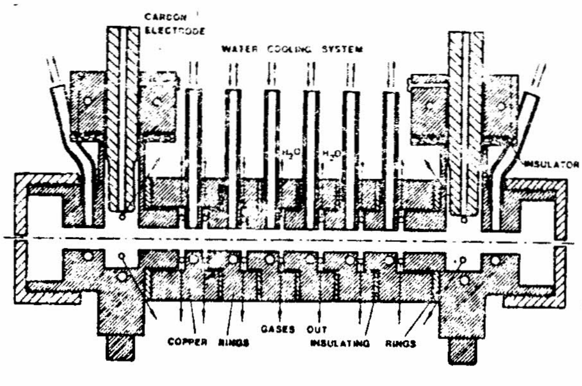

Figure 11. Wall stabilized arc.

empirical approach for ion lines is formulated (Dimitrijević and Konjević, 1981; 1977; Dimitrijević and Kršljanin, 1986) as well as an approximative approach for neutral atom lines (Dimitrijević, and Konjević, 1986).

When reliable data do not exist, knowledge about regularities and systematic trends of Stark broadening parameters offer an additional possibility for estimation or critical evaluation of Stark broadening data. The first paper on this topic is published by Purić and Ćirković (1973) and up to date a lot of work is done by Yugoslav authors. Stark broadening parameters regularities and similarities of lines within a multiplet, supermultiplet, transition arry, spectral series, izoelectronic sequences and for homologous emitters have been investigated (see e.g. review article: Konjević and Dimitrijević (1981) and references therein).

Critical reviews of existing experimental data for neutral (Konjević and Roberts, 1976; Konjević et al. 1984a) and ion (Konjević and Wiese, 1976; Konjević et al. 1984b) lines Stark broadening parameters and tables for doubly and triply charged ion line widths (Dimitrijević, 1988) may also be useful in astrophysics as sources of basic data.

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REFERENCES

Dimitrijević, M.S.: 1982a, *Astron. Astrophys.* **112**, 251.
Dimitrijević, M.S.: 1982b, in *The Physics of Ionized Gases*, ed G.Pichler, Inst. Phys. University, Zagreb, 397.
Dimitrijević, M.S.: 1988, *Astron, Astrophys. Suppl. Ser.*, **76**, 53.
Dimitrijević, M.S, Feautrier, N. and Sahal–Bréchot,S.: 1981, *J. Phys.* B. **14**, 2559.
Dimitrijević, M.S. and Konjević, N.: 1981a, *J. Quant. Spectrosc. Radiative Transfer* **24**, 451.
Dimitrijević, M.S., and Konjević, N.: 1987, *Astron. Astrophys.*, **172**, 345.
Dimitrijević, M.S. and Konjević, N. : 1986 *Astron. Astrophys.*, **163**, 297.
Dimitrijević, M.S. and Kršljanin, V.: 1986, *Astron. Astrophys.*, **165**, 269.
Dimitrijević, M.S. and Sahal–Bréchot, S.: 1984a, *J. Quant. Spectrosc. Radiat. Transfer*, **31**, 301.
Dimitrijević, M.S. and Sahal–Bréchot, S.: 1984b, *Astron. Astrophys.* **136**, 289.
Dimitrijević, M.S. and Sahal–Bréchot, S.: 1985 *J.Quant. Spectrosc. Radiat. Transfer* **34**, 149.
Djurović, S.: 1979, *Rev. Research Fac. Sci. Univ. Novi Sad*, **9**, 307.
Feldman, U. and Doschek, G.A.: 1977, *Astrophys. J.* **212**, 913.
Hart, M.H.: 1974, *Astrophys. J.:* **187**, 393.
Konjević, N. and Dimitrijević, M.S.: 1981, in *Spectral Line Shapes I* ed. B.Wende, W. de Gruyter, Berlin, New York, 241.
Konjević, N., Dimitrijević, M.S. and Wiese, W.L.: 1984a, *J. Phys. Chem. Ref. Data* **13**, 619.
Konjević, N., Dimitrijević, M.S. and Wiese, W.L.: 1984b, *J. Phys. Chem. Ref. Data* **13**, 649.
Konjević, N., Labat, J., Ćirković, Lj. and Purić, J.: 1970, *Z. Physik* **235**, 35.
Konjević, N., Platiša, M. and Purić, J.: 1971, *J. Phys.* B. **4**, 1541.
Konjević, N. and Roberts, J.R.: 1976, *J.Phys. Chem. Ref. Data* **5**, 209.
Konjević, N. and Wiese, W.L.: 1976, *J. Phys. Chem. Ref. Data* **5**, 259.
Labonte, B.J. and Howard, D.R.: 1982, *Solar Phys.* **80**, 361.
Lang, K.R. and Willson, R.F.: 1978, *Mon. Not. Roy, Astr. Soc.* **183**, 5p.
Purić, J.M. and Ćirković, Lj.M.: 1973, *XI Int. Conf. Phen. Ioniz. Gases*, Prag 398.
Purić, ,J., Labat, J., Ćirković, Lj. and Konjević, N.: 1970, *Fizika* **2**, 67.
Vernazza, J.E., Avrett, E.H. and Loeser, R.: 1981 *Astrophys. J. Suppl. Series* **45**, 635.
Vince, I. and Dimitrijević, M.S.: 1985a, *Publ. Obs. Astron. de Belgrade* No. 33, 15.
Vince, I., Dimitrijević, M.S. and Kršljanin, V.: 1985b, in *Spectral Line Shapes III*, ed. F.Rostas, W. de Gruyter, Berlin, New York, 649.
Vince, I., Dimitrijević, M.S. and Kršljanin, V.: 1985c, in *Progress in Stellar Spectral Line Formation Theory*, eds. J. Beckman and L. Crivelari, D. Reidel, Dordrecht, Boston, Lancaster, 373.
Vujnović, V., Harrison, J.A. and Crags, J.D.: 1962, *Proc. Phys. Soc.* (London) **80**, 516.
Wiese, W.L. and Kelleher, D.E.: 1971, *Astrophys. J.* **166**, L59.

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Review paper

INVESTIGATION OF THE COLLISIONAL LIMB EFFECT AND SHAPE OF SOLAR SPECTRAL LINES AT THE ASTRONOMICAL OBSERVATORY IN BELGRADE

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SUMMARY: Besides other research programs, at the Belgrade Astronomical Observatory we investigate the absorber–perturber collision effects on solar limb effect and on spectral line profile. A short review of our method of calculation and some examples of our results of the work on effect of atomic collision processes on the solar limb effect and solar spectral line bisectors are given here.

INTRODUCTION

My intention in this report is to review the results of e work at the Astronomical Observatory in Belgrade ı effect of atomic collision processes on the solar limb fect and solar spectral line bisectors.

The limb effect and asymmetry of solar spectral ıes are, among other, caused by a spectral line shift ıich is determined by physical conditions in atmoheric layers in which spectral lines are formed. Each rticular layer in which one can take that the local ıysical conditions are practically constant has its own cal shift of the spectral lines determined by these nditions. Consequently the emergent spectral lines ıve to be shifted and asymmetric too.

Which part of the limb effect and line asymmetry is ıe only to collision effects? This question is very ıportant, because the line shifts and asymmetries come a very usefull diagnostic tool of the convective yer not only in the case of the Sun but in the case of her stars (Dravins et al., 1981; Dravins, 1987).

The theory of collisional broadening and shift ogressed enormously in the past decade and reliable lculations now exist for many spectral line profiles of trophysical interest.

In view of both, the importance of the problem and ıe development of the collisional theory, it seems ɔpropriate at present time to study the behaviour of effect f collisional processes on the solar limb effect and ɔectral line profiles.

LIMB EFFECT AND LINE BISECTORS

The solar limb effect is a well known phenomenon ı solar physics since 1907 when Halm reported his first investigation on an unusual shift of spectral lines as a function of position on the apparent solar disk (Halm, 1907). We can define the limb effect as a spectral line wavelength change between the center and the limb of the solar disk which is a function of the distance from the center only.

The Fraunhofer lines can be considered symmetric only at low accuracy level of measuring. Otherwise, the solar line profiles are asymmetric. The asymmetry of a spectral line profile can be described using the line bisectors. The bisector of the spectral line is the loci of points midway between equal intensity points on blue and red side of the line profile.

Figure 1. shows six limb effect curves obtained by different authors for different spectral lines. Spectral line shifts are expressed in velocity units (m/s) versus cosine of heliocentric angle (θ). The limb effect curves can be divided into two classes: a) those with a monotonic increase of the red shift when going to the solar limb (curves a, b, f), and b) those for which a small increase in the blue shift is found. The blue shift reaches a maximum at $\cos\theta \cong 0.85$ (curves b, c, e).

The Figure 2. shows nice examples of the observed bisectors of three Fe I spectral lines. One can recognize the well–known „C"–shape of the bisectors.

Figure 3. illustrates, schematically, the origin of the solar disk center spectral line profile and its shift caused by velocity and radiation intensity fields (temperature fluctuations in convective cells) in the case of a low spatial resolution of spectroscopic observations. The spectral line becomes asymmetric and blue–shifted. Since both the temeprature and the velocity fluctuations change with height in the solar atmosphere one would expect a change of the line shift (the blue shift is generally decreasing towards the limb) and in the line profile towards the solar limb.

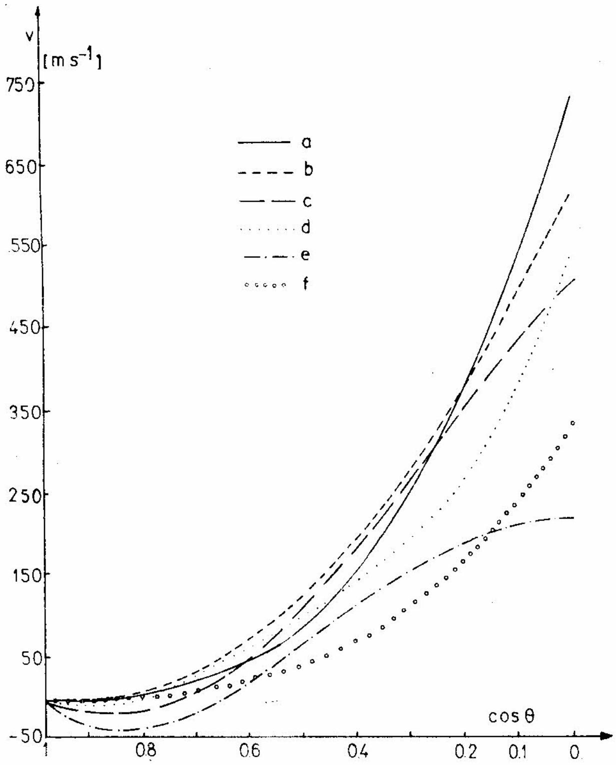

Fig. 1. Limb effect of different spectral lines observed by different authors:
a – Howard et al. (1980), FeI 525.0 nm,
b – Plaskett (1973), FeI lines ≈ 630 nm,
c – Bruning (1981) FeI 525.0 nm,
d – Kubičela et al.(1985), FeI 630.25 nm,
e – Bruning (1981), FeI 557.6 nm,
f – Howard and Harvey (1970), FeI 525.0 nm.

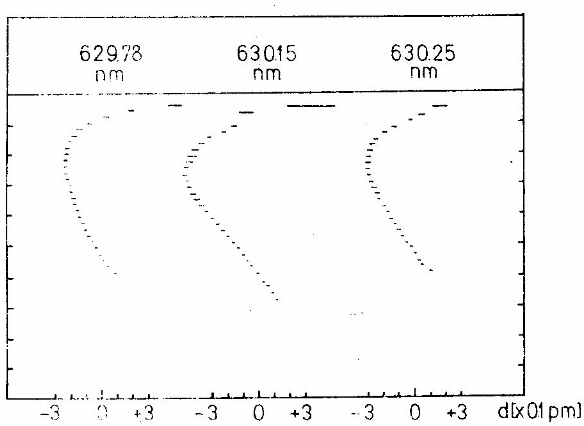

Fig. 2: Bisectors for three FeI solar spectral lines (from Adam et al., 1976).

Because of the good qualitative agreement of synthetic spectral line shifts and asymmetries calculated from numerical simulation of the granular convection with observation, one should conclude that other contributors are negligible. But for some spectral lines collision shifts may be significant (Hart, 1974, Vince et al., 1985).

3. THE METHOD OF OUR CALCULATION

In order to investigate the influence of collision processes on the limb effect and on the spectral limb asymmetry we calculated the so–called syntethic limb effects and spectral line bisectors for spectral lines of neutral sodium atom due only to collisions with atomic hydrogen, electrons and protons, whose particles are the main sources of broadening in solar atmosphere.

The synthetic spectral line profile is determined from the equation of radiative transfer

$$I_\lambda(0, \mu) = \int_0^\infty S(\tau_\lambda) \cdot e^{-\tau_\lambda/\mu} \cdot d\tau_\lambda/\mu\,, \qquad (1)$$

where $I_\lambda(0, \mu)$ is the emergent intensity, $S(\tau_\lambda)$ is the source function, τ_λ is the optical depth and μ is the cosine of heliocentric angle. The optical depth is a function of the absorption coefficient. We assume that the absorption coefficient have a Voigt profile which is defined by the following dimensionless parameters

$$a = 2\,w/\Delta\lambda_D \text{ and } v = (\lambda - \lambda_o + d)/\Delta\lambda_D,$$

$\Delta\lambda_D$ is the Doppler width, λ and λ_o are the wavelengths in the profile and at the center of the unshifted profile respectively. In the case of the solar atmosphere the impact approximation is valid. The collision spectral line profile is then lorentzian and is defined by two parameters, the width 2w and the shift d.

The broadening and shift of spectral lines due to collisions with neutral perturbers are usually related to the interaction potential. We calculated it using the Smirnov–Roueff exchange potential, which takes into account the overlap at an intermediate absorber–perturber distance of the electronic orbitals (Roueff, 1975). The broadening and shift caused by charged particles are calculated from Stark broadening theory (Dimitrijević and Sahal–Bréchot, 1985).

The emergent spectral line shift and asymmetries, whithin NaI $3p^2P^o$–ns^2S series, across the solar disk we obtained from equation (1) using the HSRA model of the solar atmosphere (Gingerich et al., 1971).

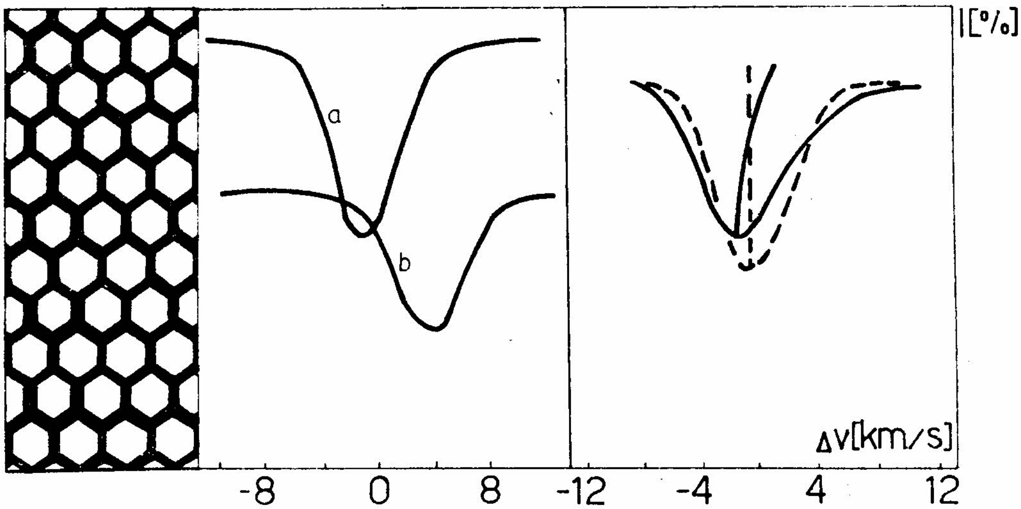

Fig. 3. Illustration of the origin of spectral line shift and asymmetry. Left: Schematic image of solar granulation. Center: Spectral line profiles of the granules (a) and intergranular lanes (b). Right: The resulting profile and bisector (solid curve) and the undisturbed (Without granulation) spectral line profile (dashed curve). (From Dravins et al., 1981).

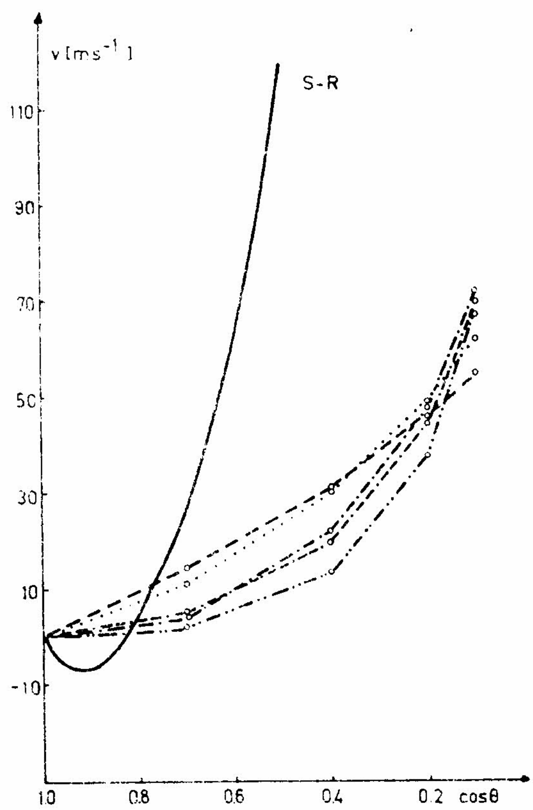

Fig. 4. Calculated NaI limb effect curves (signs: ---- λ616 nm, ... λ615 nm, .-. λ515 nm, .. - λ475 nm, --. λ454 nm; solid curve: The observed limb effect).

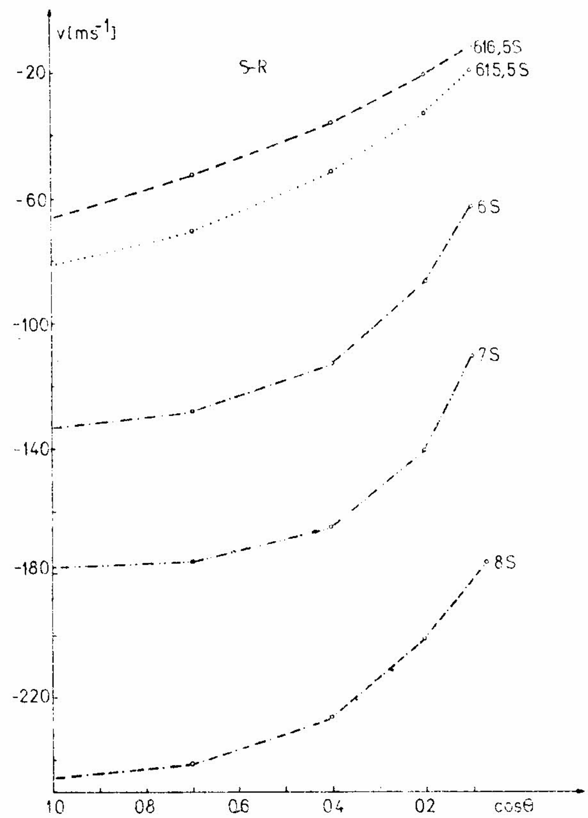

Fig. 5. Absolute line shifts as a function of cosine of heliocentric angle. (The signs are the same as in Fig. 4.).

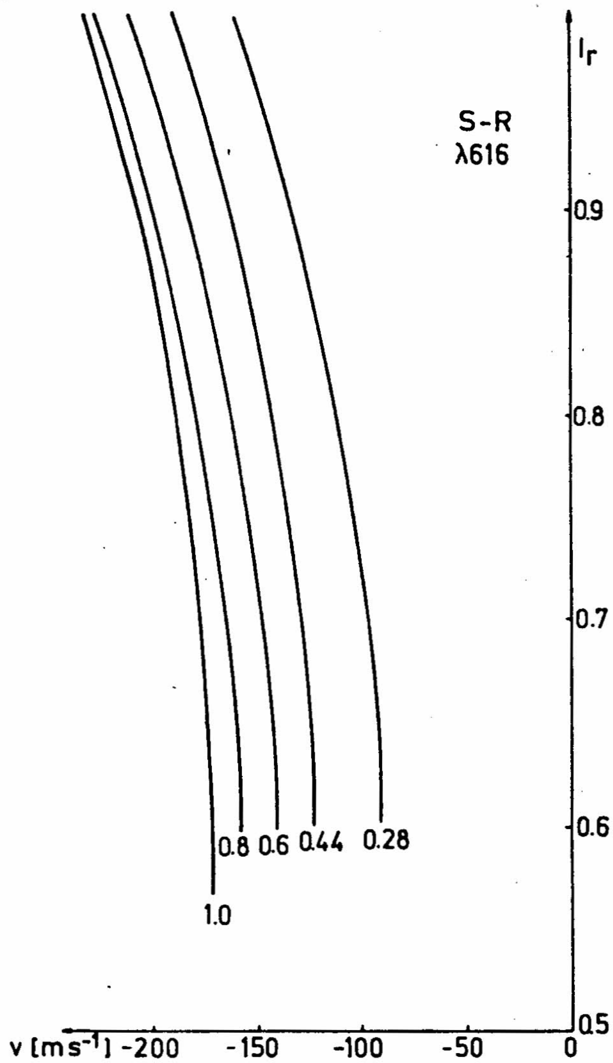

Fig. 6. Spectral line bisectors of synthetic NaI λ615 nm line for cos θ = 1, 0.8, 0.6, 0.44, 0.28 (θ is the heliocentric angle).

4. SOME RESULTS

Some characteristic results of our calculations of the collisional limb effect and line bisectors are shown in Figures 4. to 6.

Figure 4. is a plot of relative shifts (the shift at the solar disk centre is taken as zero) of five sodium atom spectral lines against the cosine of heliocentric angle, together with the observed limb effect cuvre (the averaged data from Figure 1).

A comparison between the calculated limb effect results and observations shows that in the case of the investigated NaI line the collision shift is not the dominant cause of the limb effect, but it is also not a negligible part of it.

It should be noticed that the absolute shifts of spectral lines due to collisions (Figure 5.) are more significant then the relative shifts if one takes that the typical observed shifts of weak line attain 400 to 500 m/s.

The variations of NaI λ616 nm synthetic line asymmetries, i.e. bisectors from the center to the limb are shown in Figure 6. for five values of cosine of heliocentric angle. The comparison of the spectral line bisectors of the synthetic and observed NaI λ616 nm (Figure 7.) shows that collisional processes have an important role in creation of the spectral line asymmetries.

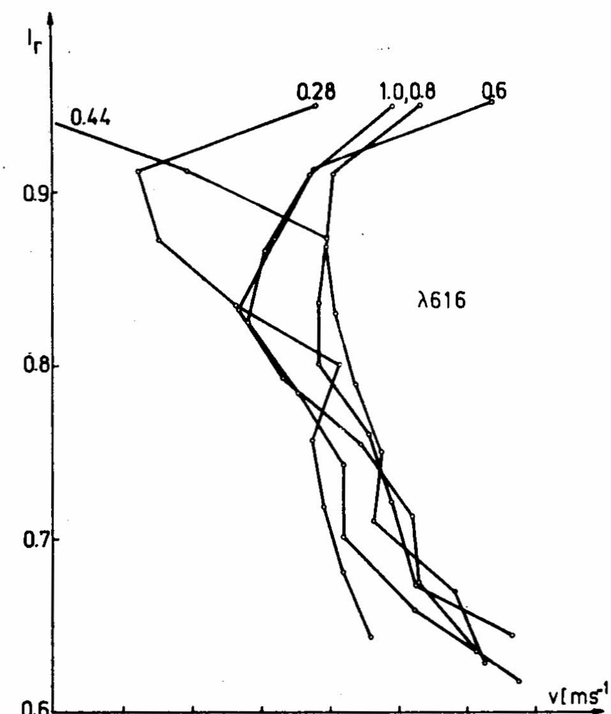

Fig. 7. Spectral line bisectors of the observed NaI λ615 nm line for cos θ = 1, 0.8, 0.6, 0.44, 0.28 obtained from the spectral line profile data taken from Gurtovenko et al. (1976).

5. CONCLUSION

A procedure was described by which, under certain assumptions, the synthetic spectral line shifts and shapes can be derived for examination of the effect of atomic collisions on the limb effect and on the asymmetry of spectral line profile.

It has been shown that there are spectral lines for which the collisional processes take an important part in observed limb effect and spectral line asymmetry. Therefore, the results of our investigations suggest that for the diagnostic of the solar plasma by analysing the observed spectral lines it is necessary to have accurate informations on the collisional–sensitivity of the used spectral lines.

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REFERENCES

Adam, M.G., Ibbetson, P.A., and Petford, A.D.: 1976, *Monthly Notices RAS* **117**, 687.

Bruning, D.H.: 1981, *Solar Phys.* **71**, 233.

Dimitrijević, M. and Sahal–Bréchot, S.: 1985, *J. Quant. Spectrosc. Radiat. Transfer* **34**, 149.

Dravins, D.: 1987, *Astron. Astrophys.* **172**, 200.

Dravins, D., Lindegren, L., and Nordlund, A.: 1981, *Astron. Astrophys.* **96**, 345.

Gingerich, O., Noyes, R.W., Kalkofen, W., and Cuny Y.: 1971, *Solar Phys.* **18**, 347.

Gurtovenko, E.A., Kostik R.I., Orlova, T.V., Troyan, V.I., and Fedorchenko, G.L.: 1975, *Profili izbrannih Fraunhoferovih linii dlya raznyh polozheniy centr-kray na diske Solnca,* Naukova dumka, Kiev.

Halm, J.: 1907, *Astron. Nachr.* **173**, 273.

Hart, M.H.: 1974, *Astrophys. J.* **187**, 393.

Howard, R., Boyden, J.E., and La Bonte, B.J.: 1980, *Solar Phys.* **66**, 167.

Howard, R. and Harwey, J.: 1970, *Solar Phys.* **12**, 23.

Kubičela, A., Vince, I., and Ivanović, Z.: 1985, *Bull. Obs. Astron. Belgrade* **135**, 21.

Plackett, H.H.: 1973, *Monthly Notices RAS*, **163**, 183

Roueff, E.: 1975, *Astron. Astrophys.* **38**, 41

Vince, I., Dimitrijević, M., and Kršljanin, V.: 1985, *Seventh International Conference on Spectral Line Shapes* (ed. Rostas, F.), Walter de Gruyter, Berlin, New York, 649.

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Review paper

THE SPECTRAL LINE SYNTHESIS STUDY IN BELGRADE*

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SUMMARY: Investigation of both solar and stellar atmospheres using the spectral line synthesis method in the Astrophysical group of the Belgrade Astronomical Observatory started in 1983. The study of the pressure broadening in the astrophysical plasma and related topics are the main research orientation. Corresponding computer programs are developed. A review of the first results and the currend investigations concerning line asymmetries and shifts caused by pressure, abundance determinations and microturbulence is given here.

1. INTRODUCTION

Recently, the study of the pressure line broadening in astrophysics, in the Astrophysical group of the Belgrade Astronomical Observatory, directed by Dr. Milan S. Dimitrijević, started. The investigations (both experimental and theoretical ones) of the pressure broadening, especially of the Stark broadening, in Yugoslavia have been successfuly performed for several years (see e.g. Dimitrijević 1985, 1989).

Together with the Doppler broadening, the pressure broadening is the main cause of the line broadening in the stellar atmospheres, and consequently, very important creator of the solar and stellar line shapes and shifts. Starting from the well–established pressure broadening theory, one can investigate various properties in stellar atmospheres, such as: temperature, pressure, electron concentration, abundances of the chemical elements, ionization balance, surface gravities, and indirectly, less studied „hot" topics such as: turbulence, radiative tranfser, granular and wave motion, stellar winds.

The synthesis of the spectral lines, as a method for investigation of the solar and stellar atmospheres, based on the pressure broadening theory, has been used in the Astrophysical group of the Belgrade Astronomical Observatory, since 1983. In this paper a brief review of the obtained results is presented.

2. THE METHOD

Two computer programs SINLINE (Vince and Kršljanin, 1984) and ZVEZDALIN (serbocroat acronim, equivalent to „starline" – Kršljanin and Vince, 1986) are developed for radiative transfer equation solution (in LTE conditions) along the stellar atmosphere and output intensity and flux emergent line profiles, respectively. Work on non–LTE problems is reported by Atanacković–Vukmanović and Simonneau (1987). The programs also compute continuum and line absorption coefficients from the input model atmosphere, and evaluate various emergent line profile parameters like: equivalent width, effective depth of the formation of each point of the computed profile, and of the line as a whole. The programs also output line shifts, line bisectors, coefficients of the asymmetry and excess etc. It is possible in principle to fit the computed profile with the observed one using various free parameters such as: turbulent velocities, rotational velocity, enhancement factor for pressure broadening, abundance of the absorber etc.

The pressure broadening effects have been taken into account via line absorption coefficient, more precisely via the Voigt function:

$$H(a, u) = \frac{a}{\pi} \int_{-\infty}^{\infty} \frac{e^{-y^2}\, dy}{a^2 + (u-y)^2}$$

where

$$u = \frac{(\lambda - \lambda_o + d)}{\Delta\lambda_D} \qquad \text{and} \qquad a = \frac{2w}{\Delta\lambda_D}$$

Here, λ is the wavelength, λ_o is unperturbed (laboratory) line wavelength, $\Delta\lambda_D$ is the Doppler broadening parameter.

The pressure broadening parameters obtained from the theory, half–half width and shift (in wavelength

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units) are denoted by w and d, respectively. In stellar atmospheres the pressure varies for several orders of magnitude. Consequently, the integration along the atmosphere simultaneously results in broadening, asymmetry and shift of the spectral line.

3. PRESSURE BROADENING AND LIMB EFFECT

Quantitative analysis of the pressure broadening contribution to the limb effect (dependence of the line shift and shape on the heliocentric position angle) is the major research topic, untill now. For more details see preliminary reports (Vince 1989, Vince et al. 1985a,b, Vince and Kršljanin 1985).

4. MICROTURBULENCE

The hypothetic, unobservable motion, with characteristic dimensions less than the photon mean free path, is currently used in astrophysical spectroscopy to explain the fact that the computed stellar line equivalent widths are often less than the observed ones. The problems about establishing of such an approach are discussed elsewhere (Kršljanin 1985).

We investigated quantitatively the sensitivity of the shapes of several NaI moderate and weak lines, via different line profile parameters, to microturbulent velocity variations (Kršljanin and Vince 1986). Sodium is the element with well known atomic structure and accurate pressure broadening parameters (Dimitrijević and Sahal–Brechot 1985, Roueff 1975, 1976), even in the case of broadening due to collisions with H atoms (the broadening agent often difficult to determine). The small microturbulence sensitivity found for NaI 3p–ns and 4p–ns lines makes them suitable for abundance determinations.

Similar behaviour of the line profiles in the case of weak lines with microturbulence and pressure broadening variations should be especially emphasized (Kršljanin and Vince 1986). It suggests caution in microturbulent velocity determinations, because the uncertainty in broadening due to collisions with atomic perturbers (almost always understimation) may produce significant errors in microturbulent velocity (overestimation). Evans et al.(1975) already demonstrated that the macroturbulence is suffiecient to describe profiles of strong and moderate lines.

5. ABUNDANCE DETERMINATION

Starting from the suitability of NaI 3p–ns and 4p–ns lines for abundance determinations (Kršljanin and Vince 1986), we used these lines to redetermine abundance of sodium in solar photosphere (Kršljanin and Vince 1985). The determination was done by fitting the synthetic line profiles with the observations of Pierce and Slaughter (1982). The fitting was performed three times, independently, via (far) wings, central intensity and equivalent width of the line. For the first time in such determinations, the broadening due to collisions with neutral atoms was described using Smirnov–Roueff exchange interaction potential (Smirnov 1967, Roueff 1970), and determinations were for the first time performed in five positions on the solar disk.

The result obtained, $A_{Na} = 6.46 \pm 0.05$ (in logarithmic scale, where $A_H = 12$) is greater than one usualy used (6.32 ± 0.07, Lambert and Luck 1978), but it agrees with the one obtained from Na D lines (Lambert and Luck 1978) using molecular potential for Na–H interaction (Lewis et al. 1971).

Our results on Na abundance in more extensive form will be published elsewhere.

6. PRESSURE BROADENING AND SHIFTS IN VERY HOT STELLAR ATMOSPHERES

We investigate the shapes and shifts of the UV ion lines starting from the modified semiempirical Stark broadening theory (Dimitrijević and Konjević 1980, Dimitrijević and Kršljanin 1986), in order to measure the pressure broadening contribution to the observed blue shifts of resonance lines in hot stellar atmospheres, and to the gravitational metal line redshifts in the atmospheres of hot white dwarfs.

The very hot ($T_{eff} \geqslant 20\,000$ K) stellar (including main sequence stars, subdwarfs, white dwarfs and nuclei of the planetary nebulae) atmospheres are suitable for this kind of investigation because the Stark broadening is the absolutely dominant pressure broadening mechanism in such atmospheres, and the lines of atoms in several ionization stages are present.

The Stark shifts should contribute measurably to the observed shifts and/or the asymmetries in the deep photospheric layers of the main sequence stars and subdwarfs, and should contribute significantly to the observed redshifts in the white dwarf atmospheres. For quantitative determination of these contributions, one should evaluate the depth of the line formation and the accurate abundances of the absorbing elements (especially in the case of white dwarfs).

Investigation of pressure broadening effects is of the great importance for the interpretation of the now generally available IUE data, and (we hope) the soon available Space Telescope UV data.

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REFERENCES

Atanacković–Vukamnović, O., Simonneau, E.: 1987, *Bull. Obs. Astron.Belgrade* **137**,66

Dimitrijević, M.S.: 1985, *Publ.Obs.Astron. Belgrade* **33**, 11.

Dimitrijević, M.S.: 1989, this volume

Dimitrijević, M.S., Konjević, N.: 1980, *J.Q.S.R.T.* **24**, 451.

Dimitrijević, M.S., Sahal–Brechot, S.: 1985, *J.Q.S.R.T.* **34**, 149.

Dimitrijević, M.S., Kršljanin, V.: 1986, *Astron. Astrophys.*, **165**, 269.

Evans, J.C., Ramsey, L.W., Testerman, L.: 1975, *Astron. Astrophys*, **42**, 232.

Kršljanin, V.: 1985, *Publ. Astr. Soc. „R.Bošković"* **4**, 177.

Kršljanin, V., Vince, I.: 1985, *VIII kongres MFAJ–saopštenja*, ed. G. Teleki, SD MFAJ, Priština, 340 (abstract).

Kršljanin, V., Vince, I.: 1986, *Bull. Obs. Astron. Belgrade* **136**, 12.

Kršljanin, V., Vince, I.: 1986, unpublished.

Lambert, D.L., Luck, R.E.: 1978, *M.N.R.A.S.* **183**, 79.

Lewis, E.L., McNamara, L.F.,Michels, H.H.: 1971, *Phys. Rev.* **A3**, 1939.

Pierce, A.K., Slaughter, Ch. S.: 1982, *Astrophys. J.Suppl.* **48**, 73

Roueff, E : 1970, *Astron.Astrophys.* **7**, 4.

Roueff, E.: 1975. *Astron. Astrophys.* **38**, 41.

Roueff, E.: 1976, *Astron. Astrophys.* **46**, 149.

Smirnov, B.M.: 1967, *Sov.Phys. J.E.T.P.* **24**, 314.

Vince, I., Kršljanin, V.: 1984, unpublished.

Vince, I., Kršljanin, V.: 1985, *VIII kongres MFAJ–saopštenja*, ed. G.Teleki, SD MFAJ, Priština, 341 (abstract).

Vince, I., Dimitrijević, M.S., Kršljanin, V.: 1985a, in *Spectral Line Shapes*, Vol. 3, ed. F. Rostas, W. de Gruyter, Berlin, New York, 649.

Vince, I., Dimitrijević, M.S., Kršljanin, V.: 1985b, in *Progress in Stellar Spectral Line Formation Theory*, eds. J.E. Bekcman and L.Crivellari, D.Reidel, Dordrecht, Boston, Lancaster, 373.

Vince, I.: 1989, this volume.

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Review paper

NON–LTE RADIATIVE TRANSFER

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SUMMARY: A brief review is given of some basic points in the development of non–LTE radiative transfer theory along with some remarks concerning the activity in this field at Belgrade Observatory.

As the work in the non–LTE theory of radiative transfer and its applications are still at the very beginning at Belgrade Observatory, I would like to outline some basic points in the development of radiative transfer theory and some of our projections concerning future work in this field.

1. THE PROBLEM. LTE AND NON–LTE APPROACHES

The basic problem of the theory of stellar atmospheres is to determine the physical state of the atmospheric gas from the study of the emergent spectrum.

To solve this problem, it is necessary to take into consideration all of the physical processes giving rise to the spectral lines and continuum and to develop the method for computing the radiation field emerging from a gas of a given structure. The postulated atmospheric model and the applied theory of radiative transfer have to be modified until required agreement of the computed and the observed spectrum is reached.

Hence, radiative transfer is a fundamental problem in the theory of stellar atmospheres and in the diagnostics of stellar properties. Many scientists have tried to solve it for more than seventy years. In order to give an interpretation of the emission and absorption lines in stellar spectra, Schuster was the first to formulate in 1905 the problem of radiative transfer within the frame of „pure scattering" assumption. Schwarzschild introduced in 1914 the concept of „pure absorption" or LTE approximation (Athay, 1972). These two extreme approaches neglected a great deal of reality in the physical picture of line formation in order to simplify the solution of the radiative transfer equation.

Generally speaking, problem is solved when the distribution functions of all the particles of gas composing the atmosphere and of the photons are known.

In LTE approximation, widely applied in astrophysical literature for many, many years, the particles of the gas are, by assumption, in detailed equilibrium, ie. their distributions over bound and free levels are characterized by local values of temperature and density. The condition that has to be fulfiled for this assumption to be valid is that collisional processes dominate over the radiative ones. The simple fact that radiation emerges from the surface of the star into space implies that the intensity of radiation (photon distribution function) deviates from its equilibrium Planckian value and, therefore, has to be determined as the solution of the radiative transfer equation.

The LTE approximation gives satisfactory results in the analysis of continuum and of the most of the weak lines originating in deeper layers of the stellar atmospheres, where, because of a great number of electronic collisions, the main condition for its validity is realized.

However, in the case of strong lines, formed in the upper atmospheric layers (where the electronic density is much lower and, hence, collisional processes less frequent), the contribution of radiative processes to level populations must not be neglected. As the state of the gas, i.e., the distribution of atoms over levels in fact depends strongly on the radiation field, the combined effect of collisional and radiative processes should be treated, without making any a priori assumption about either radiation or particles distribution functions. Hence, this problem requires more consistent approach than the assumption of LTE.

In this more general and so called non–LTE radiative transfer problem, atomic level populations has to be determined from the statistical equilibrium condition, describing the equilibrium among all of the elementary processes (collisional C_{ij} and radiative R_{ij} ones) populating and depopulating levels under consideration. In the statistical equilibrium equations for N–level atom:

$$n_i \sum_{j \neq i}^{N} (R_{ij} + C_{ij}) = \sum_{j \neq i}^{N} n_j (R_{ji} + C_{ji}),$$

where n_i is the number density of atoms in the level i, the dependence on the radiation field is given through the radiative rates R_{ij}.

The radiation field of specific intensity $I_\nu(\vec{n})$, in its turn, depends on the level populations through the emission $\epsilon_\nu(\vec{n})$ and absorption $k_\nu(\vec{n})$ coefficients in the radiative transfer equation:

$$\frac{dI_\nu(\vec{n})}{ds} = -k_\nu(\vec{n})I_\nu(\vec{n}) + \epsilon_\nu(\vec{n}) = -k_\nu(\vec{n})(I_\nu(\vec{n}) - S_\nu(\vec{n})),$$

where $S_\nu(\vec{n}) = \epsilon_\nu(\vec{n})/k_\nu(\vec{n})$ is the source function.

Because of the coupling between radiation field and the state of the gas, it is necessary to solve radiative transfer and statistical equilibrium equations simultaneously. Jefferies and Thomas (1958) were the first to formulate the radiative transfer problem in this self–consistent manner for two–level atom gas.

Very detailed discussion on different numerical solutions of the problem can be found in a paper of Hummer and Rybicki (1967) and in Mihalas' book (1978). Numerous examples of departure from the LTE in stellar atmospheres and its consequences on the relative abundance determinations are presented in a paper of Mihalas and Athay (1973) and in the literature cited therein.

Generally speaking, there are two directions in the solution of the non–LTE radiative transfer problem. The first of them, evaluates, within the frame of some approximations. the importance of particular physical processes and their effects on the behaviour of the system of photons and particles, indicating the necessary changes in the postulated model or in a theory. The second one develops new methods for the solution of the coupled set of equations and applies them in some more realistic conditions.

2. THE TWO–LEVEL ATOM. SCATTERING

In the treatment of radiative transfer problem, it is customary to use two-level atom model. Though representing a considerable simplification of the reality, this model is of major importance in understanding the basic physical processes engendering the spectral lines.

These processes can be divided into two main groups: pure absorption (emission) and scattering. The former consists of all those mechanisms that transform the kinetic energy of a gas into the radiation field energy and vice versa, thus establishing the local equilibrium between particles and radiation. By scattering process (the absorption of a photon followed by re–emission of a photon of the same (coherent scattering) or slightly altered frequency (non–coherent scattering) in the same spectral line) the radiation field energy is only partial or non transformable into the energy of gas. The most frequent cases of non–coherent scattering are Doppler redistribution caused by the atomic motion and redistribution due to momentum changing collisions.

The physics of scattering process is contained in the redistribution function $R(\nu', \vec{n}', \nu, \vec{n})$ defined such that $R(\nu', \vec{n}', \nu, \vec{n})\, d\nu' (d\Omega'/4\pi)\, d\nu\, (d\Omega/4\pi)$ gives the probability that the absorption of a photon from the solid angle $d\Omega'$ and the frequency range $(\nu', \nu' + d\nu')$ is followed by re–emission of a photon into the solid angle $d\Omega$ and frequency range $(\nu, \nu + d\nu)$ in the same line.

As the absorption and subsequent re–emission are, generally, to a certain extent, correlated processes, the form of redistribution function can be very complex. In the astrophysical literature, this correlation is designated as partial redistribution. To solve the transfer problem in this case, it is necessary to find level populations and the explicit form of the redistribution function, or, equivalently, the form of the emission profile coefficient. In the standard problem of partial redistribution (Hubeny, 1984), the emission profile for two– level atom is given as follows:

$$\psi(\nu, \vec{n}) = \frac{B_{12} \int\!\!\oint I(\nu', \vec{n}')\, R(\nu', \vec{n}', \nu, \vec{n})\, d\nu' (d\Omega'/4\pi) + C_{12}\phi(\nu, \vec{n})}{B_{12} \int\!\!\oint I(\nu', \vec{n}')\, \phi(\nu', \vec{n}')\, d\nu' (d\Omega'/4\pi) + C_{12}}$$

where B_{12} is the Einstein coefficient for absorption and C_{12} is the collisional excitation constant.

Hence, the emission profile generally depends on the excitation (radiative/collisional) and on the redistribution process, i.e., on the previous history of the atom.

The redistribution function describing the scattering part of the source function S_ν determines its frequency dependence in the following way (Hummer, 1965):

$$S_\nu = (1 - \epsilon)\frac{1}{\phi_\nu} \int\!\!\oint I(\nu', \vec{n}')\, R(\nu', \vec{n}', \nu, \vec{n})\, d\nu' (d\Omega'/4\pi) + \epsilon B(\nu_0, T_e),$$

where ϵ is a parameter which measures the probability per scattering that the photon is destroyed through collisional deexcitation, $B(\nu_0\ T_e)$ is Planck function at line center ν_0 for the local electron temperature T_e, and ϕ_ν is the normalized absorption profile. If $\epsilon = 1$, the LTE limit is recovered.

In the theory of line formation, one is usually more interested in the redistribution of the radiation in frequency, than in angle, because the effect of small shift in frequency during the scattering process enables a photon originating at the central part of a line to diffuse to the line wings, increasing its mean free path. Hence, a photon undergoing many succesive scatterings can travel very long distances in the atmosphere and can even freely escape through the boundary.

Because of that, very useful approximation is often made by introducing an angle–averaged redistribution function $R(\nu', \nu)\, d\nu'\, d\nu$.

From the mathematical point of view, transfer problem becomes much simpler, if one assumes that the emission and absorption processes in a given line are completely uncorrelated, and, thus, described by identical profiles ϕ_ν. This approximation reffered to as complete redistribution or complete non–coherence is valid if there is a great number of elastic (velocity changing) collisions during the scattering process.

In this case, the corresponding redistribution function is given as a product of two independent processes:

$$R(\nu', \nu) = \phi(\nu')\, \phi(\nu),$$

and the source function becomes frequency–independent:

$$S = (1 - \epsilon) \int \phi_\nu J_{\nu'} d\nu' + \epsilon B,$$

with:

$$J_{\nu'} = \frac{1}{4\pi} \int d\Omega' I(\nu', \vec{n}').$$

The complete redistribution approximation is widely used in the literature and the corresponding problem is well known as „the standard non–LTE problem". The most important results of the solution of this problem for two–level atoms can be found in a paper of Avrett and Hummer (1965).

3. KINETIC APPROACH

An approach to the problem different from that described above was introduced by Oxenius (1965), who explicitelly expressed frequency dependence of both the absorption and emission coefficients, ϕ_ν and ψ_ν, respectively, through their respective atomic (profile coefficients in a rest frame of atom) and kinetic (velocity distribution functions) contributions. In this so–called kinetic approach, non–excited and excited atoms are treated as two kinds of particles with the corresponding number densities n_1 and n_2 and velocity distribution functions $f_1(v)$ and $f_2(v)$. In Oxenius' notation:

$$\psi_\nu = \int d^3v f_2(v)\, \eta_\nu(\vec{n}, \vec{v}),$$

$$\phi_\nu = \int d^3v f_1(v)\, \alpha(\nu - \frac{\nu_0}{c} \vec{n}\,\vec{v}),$$

where α_ν and η_ν are atomic absorption and emission profiles, respectively.

No assumption about the form of the functions f_1 and f_2 is a priori made.

As typical atmospheric condition, one can assume that kinetic temperature is much lower than the one of the excitation, so that stimulated emission can be neglected and, consequently, the ground atomic level beeing „naturally" populated. As the processes, starting from that level, do not depend on the previous history of the atom, the atomic absorption profile is known, i.e., determined by all of the relevant line broadening mechanisms. For the same reason, the velocity distribution function of the non–excited atoms, $f_1(v)$, can be supposed to be Maxwellian.

Regarding the emission profile, the situation is, generally speaking, more complex. Because of the selectivity of the absorption process, the upper (excited) level is not „naturally'' populated. Both the atomic emission profile and velocity distribution function of the excited atoms depend on the radiation field and, therefore, have to be found by an iterative process of the solution of coupled set of radiative transfer and kinetic equations. The kinetic equation defines the distribution function of the excited atoms $F_2(\vec{r}, \vec{v}) = n_2(\vec{r}) f_2(\vec{r}, \vec{v})$ in the following way (Oxenius, 1979):

$$\vec{v}\, \nabla F_2 = \left(\frac{\partial F_2}{\partial t}\right)_{el} + \left(\frac{\partial F_2}{\partial t}\right)_{inel} + \left(\frac{\partial F_2}{\partial t}\right)_{rad}.$$

The left hand side of the above equation describes the streaming of the excited atoms due to non–LTE line transfer, while the terms of the right hand side represent the elastic, inelastic and radiative contributions to the excited level population, respectively. In the absence of streaming, this equation reduces to the statistical equilibrium equation.

This approach, by its generality, has many advantages. It includes „local" (if there is no streaming of the excited atoms) case as the limiting one and affords an explicit treatment of the velocity distribution functions of an atom in different levels. It was used in the first truly self–consistent non–LTE solution of the two–level atom transfer problem (taking into account the transport of excited atoms) described in the paper of Simonneau (1984) and in the series of papers of Borsenberger et al. (1986, 1987) and Atanacković et al. (1987).

4. ACTIVITY AND PLANS AT THE BELGRADE OBSERVATORY

The activity at the Belgrade Observatory concerning non–LTE theory and its applications is at its early stage. The line profile synthesis made in the frame of solar limb effect analysis (Vince, 1986) for NaI non–resonant lines, as well as the line synthesis for early–type stars (Kršljanin, 1986) are performed in LTE approximation.

On the other hand I myself had a chance to start my work in non–LTE theory during my seven months' advanced studies in 1985 at the Institut of Astrophysics in Paris, under the supervision of Dr. Eduardo Simonneau to whom I am greatly obliged for having initiated me in this domain. Results of that work, bearing on the effects of elastic collisions on local frequency redistribution, non–LTE line radiative transfer with transport of excited atoms in a diffuse approximation, as well as some applications of the theory to real stellar atmospheric conditions, form the subject of papers (Atanacković and Simonneau 1985, 1987a, 1987b) and of my M.S. thesis.

Our projections at the Belgrade Observatory envisages the research work on the methods for the solution of radiative transfer equation as well as the line profile synthesis using non–LTE radiative transfer.

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REFERENCES

Atanacković, O. and Simonneau, E. : 1985, *Collisions et rayonnement*, Orleans, P3.

Atanacković, O., Borsenberger, J., Oxenius, J. and Simonneau, E. 1987, *J.Q.S.R.T.* 38, 427.

Atanacković–Vukmanović, O. and Simonneau, E.: 1987a, *Bull. Obs. Astron. Belgrade,* **137**, 58.

Atanacković–Vukmanović, O. and Simonneau, E.: 1987b, *Bull. Obs. Astron. Belgrade,* **137**, 66.

Athay, R.: 1972, *Radiation Transport in Spectral Lines,* D. Reidel, Dordrecht and Boston.

Avrett, E.H. and Hummer, D.G.: 1965, *Monthly Notices RAS* **130**, 295.

Borsenberger, J., Oxenius, J. and Simonneau, E.: 1986, *J.Q.S.R.T.* **35**, 303.

Borsenberger, J., Oxenius, J. and Simonneau, E.: 1987, *J.Q.S.R.T.* **37**, 331.

Hubeny, I.: 1984, in *Progress in Stellar Spectral Line Formation Theory* (ed. by J.E. Beckman and L. Crivellari), NATO ASI Series, 27.

Hummer, D.G.: 1965, *Proceedings of the Second Harvard - Smithson. Conference on Stellar Atmospheres, SAO Spec. Rep.* **174**, 143.

Hummer, D.G. and Rybicki, G.: 1967, *Methods in Computational Physics* 7, 53.

Jefferies, J.T. and Thomas, R.N.: 1958, *Astrophys. J.* **127**, 667.

Kršljanin, V.: 1989, this volume.

Mihalas, D. and Athay, R.G.: 1973, *Ann. Rev. Astron. Astrophys.* **11**, 187.

Mihalas, D.: 1978, *Stellar atmospheres* 2nd.ed., W.H. Freeman, San Francisco.

Oxenius, J.: 1965, *J.Q.S.R.T.* **5**, 771.

Oxenius, J.: 1979, *Astron. Astrophys.* **76**, 312.

Simonneau, E.: 1984, in *Progress in Stellar Spectral Line Formation Theory* (ed. by J.E. Beckman and L. Crivellari), NATO ASI Series, 73.

Thomas, R.N.: 1957, *Astrophys. J.* **125**, 260.

Vince, I.: 1989, this volume.

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Professional paper

DIGITAL DESIGNATIONS OF CATALOGUES AND SURVEYS OF STAR POSITIONS

(Series 1)

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SUMMARY: Digital designations for first 60 catalogues and surveys of star positions are given. The designations contain 16 information groups with a total of 50 digits for observational catalogues and 10 groups with a total of 36 digits for other catalogues (derived, fundamental) and surveys.

INTRODUCTION

Following the suggestion which was given at IAU Colloquium No 48 „Modern Astrometry", Vienna 1978, (Teleki, Ševarlić 1978) we are giving a list of first 60 digital designations of catalogues which are all from „Bibliography of the Catalogues of Star Positions" (Ševarlić et al. 1978).

The designations contain 16 information groups of 50 digits for observational catalogues and 10 groups of 36 digits for other catalogues (derived, fundamental) and surveys of star positions. These 10 groups are identical with the first 10 groups of informations of the observational catalogues.

For practical reasons we will repeat the explanations for each individual digit although these were published earlier.

1. First four digits give the register number according to the number given in the mentioned Bibliography.
2. Fifth digit furnishes information on the type of catalogue:
   1 observational
   2 derived
   3 fundamental
   4 survey (list) of star positions (Durchmusterung)
3. Sixth digit is related to the type of stellar radiation:
   1 light
   2 radio
4. Next six digits, 7th to 12th, are reserved for the number of stars.
5. Two places, the 13th and 14th, are giving data on the type of coordinates:

   13th digit denotes:
   1 right ascension,
   2 correction to R.A.,
   3 longitude,
   4 correction to longitude,
   5 rectangular coordinate x.

   14th digit denotes:
   1 declination,
   2 correction to D,
   3 latitude,
   4 correction to latitude,
   5 rectangular coordinate y,
   6 polar distance, north,
   7 polar distance, south.

6. Digit places from 15th to 20th give the lower (first three digits) and the upper limits of declinations of catalogue stars. First two digits specify the declination in degrees (minutes and seconds are omitted), and the third indicates the celestial sphere: 0 indicates a southern declination and 1 indicates northern declination.
7. 21st place gives the optical and physical characteristics of the stars
   1 bright,
   2 faint,
   3 variable,
   4 double,
   5 quasars,
   6 point–like galaxies,
   7 bright and faint,
   8 bright galaxies,
   9 clusters and associations.

8. From the 22nd to 27th digital place information is related to the catalogue equinox given in tenths of the year units, reckoned from beginning of the New Era. The last digit of this group tells us whether catalogue positions are given for one equinox only (indicated by 1) or several (from 2 to 9). If more than one equinox is contained, the first five places give the latest one. The digit 0 in the sixth place of the group indicates a B C year.

9. Epoch is specified by the 28th to 33rd digits in the same way as equinox. For the observational catalogues this numeral denotes the mean epoch of observations.

10. Digit places 34th, 35th and 36th indicate the institution where the catalogue has been worked out. The list of the institutions with the corresponding number is given at the end of this paper. Catalogues and surveys not uniquely attached to any determinate establishment are given code number 999.

The next 6 groups of data appear only for the observational catalogues.

11. 37th and 38th digits provide information on the type of instrument by which observation has been made:

- 01 ancient type of instrument (mural quadrant, etc.),
- 02 meridian circle,
- 03 transit instrument (large),
- 04 transit instrument (small),
- 05 vertical circle,
- 06 horizontal meridian circle,
- 07 photographic vertical circle,
- 08 Danjon astrolabe,
- 09 zenith–telescope,
- 10 photographic zenith tube (PZT),
- 11 astrograph,
- 12 astrometric satellite tracker,
- 13 radio telescope,
- 14 radio interferometer (short base),
- 15 radio interferometer (long base),
- 16 Cassegrain telescope.

12. 39th digital place specifies techniques applied in the observations:

- 1 eye,
- 2 photographic plate,
- 3 photoelectric device,
- 4 television techniques.

13. 40th digit furnishes information on the circle on the celestial sphere along which observations have been performed:

- 1 meridian,
- 2 prime vertical,
- 3 almucantar.

14. 41st digit indicates the method of observations

- 1 differential,
- 2 quasi–absolute (orientation of the coordinate system, with reference to the planets and the Sun, or otherwise, is absent)
- 3 absolute.

15. The next six digits, from 42nd to 47th, provide information on the mean square error of a single observation: in the determination of R.A. (first 3 digits) in units of $0^s.001$ and in the determination of declination (last 3 digits) in units of $0''.01$.

16. Last three digits, from 48th to 50th, inform about the mean number of the observations of stars.

If an information group or digit place is marked by digit 0, the catalogue or survey does not have relevant information.

System of designation

Groups	Digit places
1. Register number	4
2. Type of catalogue	1
3. Type of stellar radiation	1
4. Number of stars	6
5. Star coordinates	2
6. Declination zone	6
7. Optical or physical characteristics	1
8. Catalogue equinox	6
9. Catalogue epoch	6
10. Institution	3
11. Type of instrument	2
12. Observational technics	1
13. Circle on celestial sphere	1
14. Observational method	1
15. Mean error of a single observation	6
16. Mean number of star observations	3
16 groups	50 places

DIGITAL DESIGNATIONS OF CATALOGUES AND SURVEYS OF STAR POSITIONS:

Alb_1 Schl – F. Schlesinger, C.J. Hudson, L.Jenkins, J. Barney. Catalogue of 1275 Stars. Re–observation by means of photography of Astronomische Gesellschaft stars between declinations +1° and +2°, reduced to 1875.0 without applying proper motions. Transactions of the Astron. Obs. of Yale Univ, 3, part 4, New Haven, 1926.

0656 1 1 001275 11 011021 7 187501 191479 023 11 2 1 1 011016 002

Yale 4(31) – F.Schlesinger, J.Barney. Catalogue of the positions and proper motions of 8359 stars. Reobservation by means of photography of the Astron. Gesellschaft Zone between declinations +50° and +55°. Trans. Yale Obs., 4, 1925 (Ref.: VJS, 61, 31, 1925)

0672 1 1 008359 11 501551 7 187501 191601 023 11 2 1 1 011016 002

$Hels_1$ Schl – F.Schlesinger. Catalogue of Positions and Proper Motions of 7727 Stars between +55° and +60°. Trans. of the Yale Obs., 7, 1930.

0700 1 1 007727 11 551601 7 187501 191661 023 11 2 1 1 010015 002

$Hels_1$ SchlApI – F.Schlesinger. Catalogue of Positions and Proper Motions of 7727 Stars between +55° and +60°. Trans. of the Yale Obs., 7, 1930, App I.

0701 1 1 000396 11 551601 2 187501 191661 023 11 2 1 1 010015 002

$Hels_1$ SchlAppII – F.Schlesinger. Catalogue of positions and Proper Motions of 7727 Stars between +55° and +60°. Trans. of the Yale Obs., 7, 1930, App II.

0702 1 1 000080 11 501551 7 187501 191661 023 11 2 1 1 010015 002

Yale5 – F.Schesinger, C.J. Hudson, L.Jenkins, J. Barney. Catalogue of 5833 Stars, –2° to +1°. Trans. of the Astr Obs. of Yale Univ. 5, 1926.

0718 1 1 005833 11 020011 7 187501 191449 923 11 2 1 1 011016 002

Yale 9 – F.Schlesinger, J.Berney. Catalogue of the Positions and Proper Motions of 10 358 Stars. – Re-observations by Photography of Astronomische Gesellshaft Zone between Declinations +25° and +30°, reduced to 1875. 0 without applying Proper Motions. Together with Photographic Magnitudes determined by means of the Thermoelectric Photometer by J.Schilt. Trans. of the Astron. Obs. of Yale University, New Haven, 9, 1933.

0742 1 1 010358 11 251301 7 187501 192929 023 11 2 1 1 009014 002

Yale 4(175) – Positions of 1070 Comp.Stars.Trans. of the Astron. Obs. Yale Univ. 4, 1925, p. 175.

1333 1 1 001070 11 501551 7 191701 191701 037 02 1 1 1 000000 002

Yale10 – F.Schlesinger, J.Barney, C.Gesler. Catalogue of 8703 stars +20° to +25°. Trans. of the Astron. Obs. of Yale University, New Haven, 1930. 10

1584 1 1 008703 11 201251 7 187501 192929 023 11 2 1 1 009014 002

AGK3 – O.Heckmann, W. Dieckvoss, H.Kox, A.Günther, E.Brosterhus. AGK 3. Star catalogue of positions and proper motions north of –2°5 declination, derived from photographic plates taken at Bergedorf and Bonn in the years 1928–1932 and 1956–1963. Hamburger Sternwarte, Hamburg–Bergedorf, 1975.

1622 2 1 183566 11 020901 7 195001 196083 018

$Bel_{50}1$ – S.N.Sadžakov, D.P.Šaletić. Catalogue of declinations of the latitude programme stars (KŠZ). Publ. Obs. Astron. Beograd, 17, 1972.

1656 1 1 004175 01 201651 1 195001 196951 001 02 1 1 1 000034 004

$Bel_{50}2$ – S.Sadžakov, D. Šaletić. Declinations and proper motions of the stars of the ILS on the basis of meridian catalogues from 1929–1972. Publ.Obs. Astron. Beograd, 21, 1975.

1657 2 1 000401 01 131621 7 195001 195001 001

$Bel_{50}3$ – D.Djurović. Corrections des ascensions droites de 245 etoiles du catalogue FK4. Bull.Obs.Astron. Beograd, 127, 1976, p.1 (Epoch 1966–68).

1658 1 1 000245 20 300701 7 000000 196802 001 04 1 1 1 020000 000

Bord$_{50}$Ph – I.M.Mazurier, G.Mangenot, Y.Requieme. A catalogue of 1649 stars observed in Bordeaux with a tracking photoelectric meridian micrometer. Astron. Astrophys., Suppl. Ser., 27, 1977, p. 467.

1673 1 1 001649 11 101621 7 195001 197559 035 02 3 1 1 009020 006

BucKSZ – F. Marcus. Bucharest KSZ catalogue of faint stars for 1950.0, declination zone −11° to +11°. Publ. House of the Rom. Acad., Bucharest, 1972.

1677 1 1 003939 11 110111 7 195001 000000 004 02 1 1 1 029049 004

CASF1 M.Sanchez. Astrolabe stars catalogues of San Fernando. Astron. Astrophys., Suppl. Ser. **25**, 1976, pp. 9–23.

1683 1 1 000190 11 081671 1 195001 197132 034 08 1 1 1 008016 100

CASF2 M.Sanchez. Astrolabe stars catalogues of San Fernando. Astron. Astrophys., Suppl. Ser., **25**, 1976, pp. 9–23.

1684 1 1 000226 11 081641 1 195001 197342 034 08 1 1 1 008016 100

CASF3 M.Sanchez. Astrolabe catalogue CASF3 of San Fernando. Astron. Astrophys., Suppl. Ser., **29**, 1977. p. 245.

1685 1 1 000218 11 081641 1 195001 197642 034 08 1 1 1 008016 100

Gol$_{50}$F – A.K. Korol'. Declinations of bright and faint fundamental stars in a uniform system, Akad. nauk. Ukr. SSR, Glavnaya Astron.Obs., Kiev. 1969.

1729 1 1 001792 01 310901 7 195001 195001 003 05 1 1 3 000032 006

Gol$_{50}$L – A.S.Charin. Katalog der Deklinationen von Sternen der Zenitteleskopprogramme im FK4–system für die Beobachtungsepoche und das Äquinoktium 1950.0. Verlag Akad. Wiss. Ukr.SSR. Glavnaya Astron.Obs., Kiev. 1963.

1730 1 1 002253 01 101801 7 195001 000000 003 05 1 1 1 000051 004

Gol2(3) – A.K.Korol, W.W.Konin. Katalog der Deklinationen von 67 Sternen im programm des Poltawaer Zenitteleskops. Izv. GAO Kiew 1958, 2, vyp. 2. p. 3.

1735 1 1 000067 01 271721 7 195001 195291 003 05 1 1 1 000024 005

KiewF1(3) – A.A.Gorynja. Katalog der Deklinationen von 585 am Meridiankreis des Astron. Obs. Kiew im System des FK3 beobachteten Sternen. Trudy Kievsk. Astron. Obs., **1**, 1956, p. 3. (Die Sterne liegen zwischen −20° Dekl. und dem Pol, und wurden von Febr. 1948 bis Apr. 1951 beobachtet).

1759 1 1 000585 01 200901 7 195001 000000 009 02 1 1 1 000053 005

MüCan$_{50}$Vert – F.Scheidler. Messungen fundamentaler Deklinationen auf beiden Hemisphären. Veröff. Sternwarte München, **4**, Nr 22. 1957, p. 211 (Observations at München in the mean epoch 1949 and at Canberra in 1955).

1834 1 1 000000 01 900901 0 195001 000000 005 05 1 1 3 000037 000

Par$_{50}$I – M.I.Levy. Catalogue de 3997 étoiles (Paris 50I) (On cards).

1873 1 1 003997 11 331351 0 195001 000000 016 02 1 1 1 000000 000

SantAC1N30 – F.Noël. Individual corrections Astrolabe–N30 for 449 southern stars. Astron. Astrophys., Suppl. Ser., 22, No 1, 1975, p. 63 (see catalogue No 2053).

1922 1 1 000449 22 620040 1 195001 197139 002 08 1 1 1 005008 000

SAO – Smithsonian Astrophysical Observatory Star Catalogue. Positions and proper motions of 258997 stars for the epoche and equinox of 1950.0. Washington, D.C.Smithsonian Institution, 1966.

1926 2 1 258997 11 800801 7 195001 195001 020

4, ToulR1 – R.Bonique, H.Dedieu. Positions et mouvements propres des étoiles de rapéie de la zone de Toulouse (Quatriéme catalogue révisé). Ann. Obs. Astron. Met. Toulouse, **30**, 1965, p 21.

1967 2 1 001702 11 041121 2 195001 190001 017

4.ToulR2 – R.Bonique, H.Dedieu. Positions et mouvements propres des étioles de repère de la zone de Toulouse (Quatriéme catalogie révisé). Ann. Obs. Astron. Met. Toulouse, **31**, 1965, p.9.

1968 2 1 001685 11 041121 2 195001 190001 017

UcSILG – P.Melchior, R. Dejaffe. Calcul des declinaisons et mouvements propres des étoiles du Service international des latitudes à partir des catalogues méridiens. Ann. Obs. Roy. Belg., Uccle, (3), **10**, fasc. 3, 1969.

1971 2 1 000404 01 130620 0 195001 195001 011

$Wr_{50}2$ – P. Rybka. Rektascensje 555 gwiazd fundamentalnogo katalogu slabych gwiazd w systemie FK3. Contr. Wroclaw Astr. Obs., **13**, 1956 (Ep. 1950–53).

1986 1 1 000555 10 150901 2 195001 000000 008 03 1 1 1 044000 005

Yale11 – F.Schleisnger, I.Barney. Catalogue of the positions and proper motions of 8101 stars. Re–observation by photography of the Astr. Geselschaft Zone between declinations -10^o and -14^o reduced to 1950.0 without applying proper motions. Trans. Astron. Obs. Yale Univ., 11, 1939.(Epoch 1933).

1989 1 1 008101 11 140100 7 195001 193351 023 11 2 1 1 008010 002

$Yale12_1$ – F.Schlesinger, I.Barney. Catalogue of the positions and proper motions of 8563 stars. Trans.Astron.Obs. Yale Univ. **12**, part 1, 1940.

1990 1 1 008563 11 180140 7 195001 193379 023 11 2 1 1 008010 002

$Yale12_2$ – F.Schleisnger, I.Barney. Catalogue of the positions and proper motions of 4553 stars. Trans.Astron.Obs.Yale Univ. **12**, part 2, 1940.

1991 1 1 004553 11 200180 7 195001 193389 023 11 2 1 1 008010 002

$Yale13_1$ – F.Schlesinger, I.Barney. Catalogue of the positions and proper motions of 4292 stars. Re–observations by photography of the Astr. Geselsch. Zone between declinations -20^o and -22^o, reduced to 1950.0 without applying proper motions. Trans. Astron. Obs. Yale Univ. **13**, part 1, 1943. (Epoch 1933).

1992 1 1 004292 11 220200 7 195001 193389 023 11 2 1 1 007010 002

$Yale13_2$ – F.Schlesinger, I.Baney. Catalogue of the positions and proper motions of 9455 stars. Re–observation by photography of the Cordoba Zone between declinations -27^o and -30^o, reduced to 1950.0 without applying proper motions. Trans. Astron. Obs. Yale Univ., **13**, part 2, 1943 (Epoch 1933).

1993 1 1 009455 11 300270 7 195001 193401 023 11 2 1 1 007010 002

Yale14 – F.Schlesinger, I.Barney. Catalogue of the positions and proper motions of 15110 stars. Re–observation by photography of the Cordoba Zone between declinations –22° and –27°, reduced to 1950.0 without applying proper motions. Trans. Astron. Obs. Yale Univ., **14**, 1943 (Epoch 1933).

1994 1 1 015110 11 270220 7 195001 193399 023 11 2 1 1 007010 002

Yale16 – I.Barney. Catalogue of the positions and proper motions of 8248 stars. Re–observation by photography of the Astr. Ges. Zone between declinations –6° and –10°, reduced to 1950.0 without applying proper motions. Trans. Astron, Obs. Yale Univ., **16**, 1943 (Epoch 1933).

1995 1 1 008248 11 100060 7 195001 193399 023 11 2 1 1 007010 002

Yale17 - I.Barney. Catalogue of the positions and proper motions of 8108 stars. Re–observation by photography of the Astr. Ges. Zone between declinations –2° and –6°, reduced to 1950.0 without applying proper motions. Trans. Astron.Obs. Yale Univ. **17**, 1945.

1996 1 1 008108 11 060020 7 195001 193399 023 11 2 1 1 007010 002

Yale18 – I Barney. Catalogue of the positions and proper motions of 9092 stars. Re–observation by photography of the Astr. Ges. Zone between declination +15° and +20°, reduced to 1950.0 without applying proper motions. Trans. Astron. Obs. Yale Univ., **18**, 1947.

1997 1 1 009092 11 151201 7 195001 194049 023 11 2 1 1 008012 002

Yale19 – I.Barney. Catalogue of the positions and proper motions of 8967 stars. Re–observation by photography of the AG Zone between declinations +10° and +15°, reduced to 1950.0 without applying proper motions. Trans. Astron. Obs.Yale Univ., **19**, 1948.

1998 1 1 008967 11 101151 7 195001 194049 023 11 2 1 1 008012 002

Yale20 – I.Barney. Catalogue of the positions and proper motions of 7996 stars. Re–observation by photography of the AG zone between declinations +1° and +5°, reduced to 1950.0 without applying proper motions. Trans. Astron. Obs.Yale Univ., **20**, 1949

1999 1 1 007996 11 011051 7 195001 193799 023 11 2 1 1 008012 002

Yale21 – I.Barney. Catalogue of the positions and proper motions of 5583 stars. Re–observation by photography of the AG Zone between declinations –2° and +1°, reduced to 1950.0 without applying proper motions. Trans. Astron. Obs. Yale Univ., **21**, 1950

2000 1 1 005583 11 020011 7 195001 193799 023 11 2 1 1 008012 002

Yale22_1 – I.Barney. Catalogue of the positions and proper motions of 9060 stars. Re-observation by photography of the Astr. Ges. Zone between declinations +5° and +9°, reduced to 1950.0 without applying proper motions. Trans. Astron. Obs. Yale Univ., **22**, part 1, 1950.

2001 1 1 009060 11 051091 7 195001 193799 023 11 2 1 1 008012 002

Yale22_2 – I.Barney. Catalogue of the positions and proper motions of 1904 stars. Re–observation by photography of the Astr. Ges. Zone between declinations +9° and +10°, reduced to 1950.0 without applying proper motions. Trans. Astron. Obs. Yale Univ., **22**, part 2, 1950.

2002 1 1 001904 11 091101 7 195001 194049 023 11 2 1 1 008012 002

Yale23A – I.Barney. Supplementary volume to the Yale Zone catalogues, –30° to + 30°. Section A: Zone catalogue, –6° to –10°. Suppl. to Vol. 16 Trans. Astron. Obs. Yale Univ., **23A**, 1951.

2003 1 1 001244 11 060100 2 195001 193399 023 11 2 1 1 007010 002

Yale23B – I.Barney. Supplementary volume to the Yale Zone catalogues –30° to +30°. Section B: Zone catalogue, –2° to –6°, Suppl. to Vol. 17. Trans. Astron. Obs. Yale Univ., **23B**, 1951.

2004 1 1 000651 11 060020 2 195001 193399 023 11 2 1 1 007010 002

Yale24 – I.Barney. Reviced catalogue of the positions and proper motions of 10358 stars. Contained in the Astr.Ges. Zone between declinations +25° and +30°, on the system of the FK3, and reduced without applying proper motions to the equinox 1950.0. Trans. Astr. Obs. Yale Univ., **24**, 1953.

2005 2 1 010358 11 251301 7 195001 192929 023

Yale25 – I.Barney. Revised catalogue of the positions and proper motions of 8703 stars. Contained in the Astr.Ges. zone between declinations +20° and +25° on the system of the FK3, and reduced without applying proper motions to the equinox 1950.0 Trans. Astron. Obs. Yale Univ., **25**., 1954.

2006 2 1 008703 11 201251 7 195001 192999 023

$Yale26_1$ – I.Barney, A.J.J. van Woerkom. Catalogue of the positions and proper motions of 1031 stars between declinations +85° and +90°, reduced without applying proper motions to the equinox 1950.0 Trans. Astron. Obs. Yale Univ., **26**, part 1, 1954.

2007 1 1 001031 11 851901 7 195001 195131 023 11 2 1 1 006008 004

2007 1 1 001031 55 851901 7 195001 195331 023 11 2 1 1 006008 004

$Yale26_2$ – I.Barney, D.Hoffleit, R.B.Jones. Catalogue of 8380 stars, between declinations +50° and +55°. Trans. Astron. Obs. Yale Univ., .**26**, part 2, 1959.

2008 1 1 008380 11 501551 7 195001 194749 023 11 2 1 1 006009 002

Yale27 – I.Barney, D.Hoffleit, R.B.Jones. Catalogue of 8164 stars, between declinations +55° and +60°. Trans. Astron. Obs. Yale Univ., 27, 1959.

2009 1 1 008164 11 551601 7 195001 194749 023 11 2 1 1 006009 002

Yale31 – P.K.Lü. Preliminary catalogue of the positions and proper motions of stars between declinations –70° and -90°, reduced to the equinox of 1950 without applying proper motions. Trans. Astron. Obs. Yale Univ. **31**, 1971.

2010 1 1 018702 11 900700 7 195001 195669 023 11 2 1 1 017026 010

SantAC1 – F.Noël, K.Czuia, P.Guerra. First astrolabe catalogue of Santiago. Astron. Astrophys., Suppl. Ser., **18**, 1974, p. 135 (325 FK4 and 215 FK4Sup stars; zone –5° to –62°; epoch 1967–71).

2053 1 1 000540 22 620050 1 197501 197130 002 08 1 1 1 005008 000

AAS12(277) – G.Goy. A new general O type stars catalogue. Astron. Astrophys., Suppl Ser., **12**, 1973, p. 277.

2060 4 1 000633 11 900901 7 190001 000000 033

AAS18(169) – H.Neckel. Photoelectric catalogue of 1030 M–type stars located along the galactic equator. Astron. Astrophys., Suppl. Ser., **18**, p. 169, 1974.

2061 1 1 001045 11 230671 7 190001 197129 018 16 3 0 0 000000 003

LaP138 – C.Jaschek, E.Hernandez, A.Sierra, A.Gerhardt. Catalogue of stars observed photoelectrically. Obs. Astron. Univ. Nac. La Plata, Argentina, Ser. Astron., **38**, 1972.

2065 4 1 025000 11 900901 7 190001 000000 022

PASP80(342) – A.R.Upgren. R.Grossenbacher. Positions and color indices of twenty–six carbon stars. Publ. ASP, **80** 1968, p. 342.

2067 1 1 000026 11 311351 7 190001 000000 014 11 2 0 1 000000 002

4ToulII – R. Bouigue, H.Dedie. Positions et mouvements propres des étoiles de repère de la zone de Toulouse (Quatrième catalogue révisé) II. Ann.Obs.Astron.Toulouse, **32**, 1968, p.7 (AR 8–12h standard stars of Toulouse).

2069 2 1 001772 11 041121 2 195001 190001 017

AAS26(219)Bes – V. Maitre. Mean positions and proper motions of 355 stars in the declination zone +33° to +36° Astron. Astrophys., Suppl. Ser, **26**, 1976, p 219.

2074 2 1 000355 11 331361 1 195001 195199 015

The List will be continued in the following issues of Bulletin.

List of institution digits used in this paper:

001 Astronomical Observatory, Belgrade, Yugoslavia.
002 Observatorio astronomico nacional Cerro Calan, Santiago de Chile, Chile.
003 Main Astronomical Observatory Golosejevo, Kiev, USSR.
004 Astronomical Observatory, Bucharest, Romania.
005 Sternwarte Munchen and Observatory Canberra, Australia.
006 Sternwarte Munhen, FRG.
007 Observatory Canberra, Australia.
008 Astronomical Observatory, Wroclaw, Poland.
009 University Astronomical Observatory, Kiev, USSR.
010 Main Astronomical Observatory, Pulkovo, Leningrad, USSR.

011 Observatoire Royal de Belgique, Bruxelles, Belgium.
012 Engelgardt Astronomical Observatory, Kazan, USSR.
013 University Astronomical Observatory, Odessa, USSR.
014 Van Vleck Observatory, Wesleyan University, USA.
015 Observatoire de Besancon, France.
016 Observatoire de Paris, France.
017 Observatoire Astronomique et Meteorologique, Toulouse, France.
018 Hamburger Sternwarte, Hamburg–Bargedorf, FRG.
019 University of Minnesota, USA.
020 Smithsonian Astrophysical Observatory, USA.

021 Sternberg State Astronomical Institute, Moscow, USSR.
022 Astronomical Observatory La Plata, Argentina.
023 Yale University Observatory, USA.
024 Texas University, USA.

025 Carnegie Institution Washington, USA.
026 Northwestern University, Evaston, USA.
027 Academy Kiado, Budapest, Hungary.
028 Astronomical Department, University Michigan, USA.
029 Radio Astrophysical Observatory, Latvia, USSR.
030 Centre de Physique Theorique, CNRS, Marseille, France.

031 Astronomical Institute, University Basel, Switzerland.
032 Observatoire Alcor, Sevilla, Spain.
033 Observatoire de Geneve, Switzerland.
034 Observatory Marina, San Fernando, Spain.
035 Observatoire de l'Universite de Bordeaux, France.
036 Ostermundingen Switzerland.
037 Lick Observatory, USA.

REFERENCES:

Teleki, G., Ševarlić, B.: 1978, *Proc. IAU Coll. 48, Modern Astrometry*, 483, Vienna.

Ševarlić, B., Teleki, G., Szadeczky–Kardoss, G.: 1978, *Publ. Dept. Astron. Belgrade*, 7, 69.

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