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RELATIVE RADIAL VELOCITIES OF VISUAL BINARY COMPONENTS OBSERVED ON THE 6 M TELESCOPE (BTA) II. ADS 10759 AND ADS 12815

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ABSTRACT. *Relative radial velocity of components of wide double stars with a high accuracy (up to ±0.2 km/s) is needed to determine the orbits by the method of apparent motion parameters (AMP-method). This value was obtained for two bright visual binaries of the Pulkovo program (ADS 10759 = φ Dra and ADS 12815=16 Cyg) on the 6 m telescope (dispersion 9 A/mm, λλ 3900-5000 A) using special observational techniques. At the same time individual radial velocities of the components of these stars were determined.*

Для определения орбит широких двойных звезд методом параметров видимого движения (ПВД) необходима относительная лучевая скорость компонент с высокой точностью (до ±0.2 км/с.). Эта величина получена для двух ярких визуально-двойных звезд Пулковской программы (ADS 10759 и ADS 12815) с использованием специальной методики наблюдений на 6-метровом телескопе (дисп. 9 Å/мм, λλ 3900-5000 Å). Попутно отределены индивидуальные лучевые скорости этих звезд.

INTRODUCTION

This paper is a continuation of investigations published by Romanenko (1988). Since the processing of spectral data of visual binaries of the Pulkovo program obtained with the 6 m telescope has been continued. The apparent motion parameters of

the orbit of ADS 7251 and ADS 12169 (Romanenko, 1990) with a relative radial velocity presented by Romanenko (1988) were calculated. A conclusion on the constancy of relative velocities of both components of ADS 7251 made by Romanenko (1988) was confirmed by Morby and Griffin (1987). Note basic points of our investigations.

In 1960 A.N. Deitch and A.A. Kiselev (MAO AS USSR) had proposed the program of complex investigations of visual binaries in the vicinity of the Sun. The closest aim of this program was the detection of close binaries with a notable orbital movement, then accumulation of dense, uniform series of relative positions of components for determination of parallaxes, orbits, and masses of these stars. The main results of this work are given in the Catalogue of 200 Visual Binaries (Kiselev et al., 1988).

The method of apparent motion parameters, elaborated by Kiselev and Kiyaeva (1980) allows to obtain the orbits of wide binaries with periods of the order of 1000 years from short arc observations. To use the method of AMP the high precision data is needed: the uniform series of photographic positions, trigonometric parallax and relative radial velocity of the components determined at the moment close to the mean moment of astrophysical observations (see Kiselev et al., 1987; Romanenko, 1990).

For coordination of accuracies of all the data used the error of relative radial velocity must not exceed ±0.1-0.2 km/s. In connection with the fact that catalogues compiled by Wilson (1953), Abt (1973), etc. contain no radial velocities of required accuracy, we performed spectral observations of visual binaries of the Pulkovo program through 1982-1987 on the 6-m telescope (BTA SAO). For observations with the chamber 2 of the Main Stellar Spectrograph (dispersion 9 A/mm) we selected the brightest (up to $7^{m}.5$) stars of our program, whose components differ in brightness, no greater than one magnitude; in spectral class, no more than two spectral subclasses, and in most cases they coincide in these parameters.

Special observational techniques suggested by E.L. Chentsov were used. The spectra of both components of the star under investigation are exposed onto one plate tightly to each other and symmetrically about the centre of the slit image. The relative radial velocity was determined from pairs of spectral lines, individual radial velocities of the components were computed using usual methods i.e., with respect to the comparison spectrum. The measurements were carried out with the oscilloscopic spectrocomparator of SAO and were processed with the help of the author's program on the EC 1036 of the Main Astrophysical Observatory of Russian Academy of Sciences.

1. VISUAL BINARIES ADS 10759 AND ADS 12815

The goal of this research is to obtain a high precision relative radial velocity of the components of two visual binaries. ADS 10759 (ϕ Dra) and ADS 12815 (16 Cyg) are bright systems located close to the Sun, which have a rich astrometric history, as well as high precision series of positional observations on the 26" refrac-

tor of the Main Astrophysical Observatory for 10 and 30 years, respectively. Any information on these stars is valuable for investigations of the vicinity of the Sun. Furthermore, the components of 16 Cyg are sunlike.

The stars under investigations are characterized by the data listed in Table 1. Here ρ is the distance between the components in arcsec; r - the distance from the Sun in parsecs; m - the magnitude of the components; Sp - the spectral class; V_r and V sini - the radial velocity and the velocity of axial rotation (in km/s) from the Bright Star Catalogue (Hoffleit, 1982); P - the supposed period in years.

Table 1.

ADS	Dist		m	Sp	V_r	V sini	P
10759	ρ=30″	A	4.59	F5Y	-10 var?	14	80000
(ϕ Dra)	r=22pc	B	5.82	F5Y	-10 var?	≤25	
12815	ρ=39″	A	5.96	G2Y	-26 var	2	20000
(16 Cyg)	r=25pc	B	6.20	G3Y	-27 var	3	

Comparing the parameters of stars listed one can note that axial rotation velocities of the components of ϕ Dra are considerably greater than those of 16 Cyg, therefore larger errors can be expected when determining radial velocities of the components of ϕ Dra. It should also be noted, that radial velocity variability of B component of ADS 10759 is mentioned in the New Catalogue of double stars by Aitken (1932), and radial velocity variability of both components of investigated stars is suspected (ϕ Dra) or stated (16 Cyg) in the Bright Star Catalogue (Hoffleit, 1982). However, such data was found neither in the Seventh Catalogue of the orbital elements of spectroscopic binary systems (Batten et al., 1978) nor in papers of other authors.

2. PROCESSING RESULTS

Five spectrograms with exposures: 2-6 min for A and 8-12 min for B components obtained for ADS 10759 are measured by E.O. Sazonova. For ADS 12815 four spectrograms with exposures 10-15 min for A and 15-20 for B are measured by the author, the latter (No. 120) being measured with a visual gauge IZA-2 in Pulkovo. All spectrograms were obtained on Kodak plates IIaO, the slitwidth was 0.45 mm, the spectrum height - 0.6 mm. An iron hollow-cathode lamp, filled with neon, argon, and xenon mixture (1982), with argon (1986), neon (1987) was used as a comparison spectrum source. Laboratory wavelengths were taken from (Striganov et al., 1966; Norlen, 1983; Crosswhite, 1975). The star lines were identified with the help of Tables from (Swensson, 1946), and

(Peierce and Breckinridge, 1973), respectively.

The results of radial velocities of the components of ADS 10759 depending on the wavelengths for each plate are presented in Fig. 1. Each point was obtained as a weighted mean in the interval 50 Å in which from 3 to 8 lines were measured. The straight lines correspond to the weighted mean values of $\overline{V_r A}$ and $\overline{V_r B}$. One can notice, that the presence of systematic changes in individual radial velocities does not make a considerable contribution to their difference. Fig.2 shows it as well, there are presented the results of one plate processing (No. 78): at the top - individual radial velocities of the components, at the bottom - their difference.

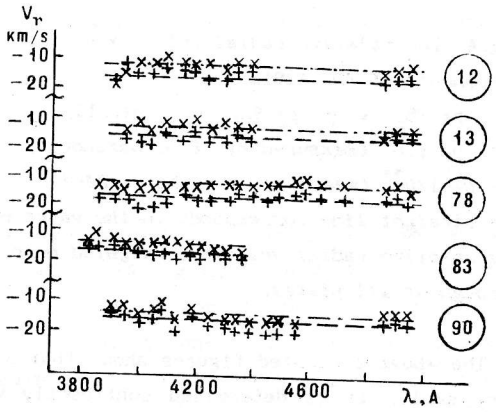

Fig.1. *Radial velocities of the components of ADS 10759.*
+ - values of the radial velocity of A component, weighted mean throughout the interval 50 Å;
x - the same for B component;
--- - the radial velocity of A component, mean-weighted throughout the whole plate;
-·-· - the same for B component.

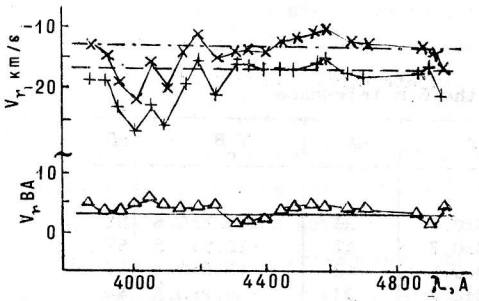

Fig.2. *Radial velocities of the components of ADS 10759 and their difference (pl.78).*
+ - values of radial velocity of A component, weighted mean throughout the interval 50 Å;
x - the same for B component;
Δ - the same for the difference $V_r BA = V_r B - V_r A$;
--- - the radial velocity of A component, weighted mean throughout the whole plate;
-.-. - the same for B component;
—— - the same for the difference of these velocities.

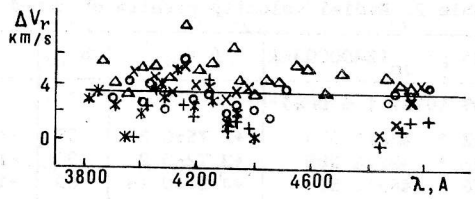

Fig.3. *The relative radial velocity of the components of ADS 10759. Different symbols denote the weighted mean values throughout the interval 50 Å of the relative radial velocity, determined from different plates:*
+ - pl. 12, x - pl. 13, Δ - pl. 78,
** - pl. 83, ∘ - pl. 90.*

Fig.3 presents the results of the relative radial velocity of the components of ADS 10759 from all 5 plates, marked by different symbols. Every point is also a weighted mean over the interval 50 Å. There are no systematic changes of ΔV_r along the spectrogram. Most points do not fall outside the limits ±2.5 km/s from the weighted mean value, indicated by the straight line.

Fig.4 shows ADS 12815 and is analogous with Fig. 3. Here one can see the best agreement between the plates. Disregard the IZA-2 (pl.No.120) measurements most points fall within ±1.3 km/s. No systematic variations along the spectrogram were found either.

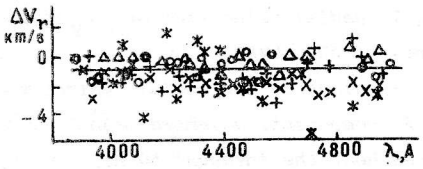

Fig.4. *The relative radial velocity of the components of ADS 12815.*
+ - pl.85, x - pl.92, Δ - pl.118,
∘ - pl.118° (measured by E.O. Sazonova),
** - pl.120°° (measured on the IZA-2).*
The straight line corresponds to the value of the relative radial velocity, weighted mean throughout all plates.

The above presented figures show that although the investigated value of ΔV_r is very small, it is determined confidently well from the measurements made with an oscilloscopic spectrocomparator. The main sources of systematic errors are considered by Romanenko (1988).

Table 2. Radial velocity results obtained at the 6 m telescope

No pl.	JD(2400000+)	ΔV_r	n	V_rA	nA	V_rB	nB
ADS 10759 (ϕ Dra)							
12 *	45214.373	+2.75±0.26	37	-15.5±0.7	36	-11.2±0.6	51
13 *	45214.388	+3.72±0.29	36	-16.3±0.7	47	-12.5±0.5	57
78 *	46516.509	+4.56±0.18	60	-17.9±0.4	62	-13.5±0.4	63
83 *	46638.262	+2.65±0.27	32	-16.8±0.7	34	-14.2±0.6	44
90 *	46639.387	+3.04+0.20	48	-16.6+0.5	48	-14.2+0.5	55
5	Cp.838.	+3.43±0.43	48	-16.9±0.4	45	-13.3±0.5	54
ADS 12815 (16 Cyg)							
85	46638.320	-1.41±0.13	83	-30.4±0.2	35	-31.9±0.2	35
92	46638.340	-1.53±0.10	86	-29.8±0.3	34	-31.2±0.3	34
118	46961.312	-0.40±0.08	78	-29.9±0.3	24	-30.1±0.2	24
118 *	46961.312	-0.87±0.18	39	-29.2±0.3	29	-30.2±0.2	31
120**	47043.452	-1.15±0.61	26	-29.9±1.4	26	-31.9±1.3	26
5	Cp.838.	-0.94±0.26	62	-29.9±0.2	30	-31.1±0.4	30

Note: * - measurements by E.O. Sazonova;
**- measurements made with the IZA-2.

Table 2 presents the results of relative (ΔV_r) and individual ($V_r A$ and $V_r B$) radial velocities of investigated star components. Values *n*, *nA* and *nB* correspond to the number of measured lines. The internal errors of one plate of all three values measured with the spectrocomparator for ADS 10759 appeared to be two times greater than for ADS 12815, as it was expected. The IZA-2 measurements which have considerably greater internal errors than those made with the spectrocomparator were included into the final result with low weight and affected neither the velocity values nor their errors. The errors of individual radial velocities for all four stars, both internal I and external E, have one and the same order and do not satisfy the known variability criterion E/I>2 (see, e.g., Abt and Levy, 1967). Therefore, our observations do not show any variability of radial velocities of the components of ϕ Dra and 16 Cyg.

3. DATA COMPARISON

Now let us refer to the catalogue data and observational results of other authors. They are tabulated for ϕ Dra in Table 3 and for 16 Cyg in Table 4. When there was a great number of observations only the extreme values and the mean values of radial velocities are presented. *N* is the number of observations if it is known. Apparently observational results obtained at the beginning of this century are not suitable for our problem.

Table 5 presents a more wide comparison of our results and those obtained simultaneously and independently by Tokovinin using the Measurer for stellar radial velocity (Tokovinin, 1987; 1990), and by Duquennoy et al. (1991), and Duquennoy and Mayor (1991) using the "Koravel" device. Here $V_r A$ and $V_r B$ are the radial velocities of the components, I and E are the internal and external errors of these values, N - the number of observations, difference ($V_r B - V_r A$) and its errors obtained from the results of the above mentioned authors.

It is known, that contemporary observations are carried out following the IAU recommendations: to observe the stars - standards of radial velocities in order to allow for instrumental errors. From the common with "Koravel" stars we can obtain the error for the standard system of radial velocities. For four stars under investigation this error appeared to be +2.75±0.19 km/s. The last line of Table 5 gives the corrected value of radial velocity for each star. However, the error of the zero point does not noticeably contribute to the value of relative radial velocity that we need.

The obtained by the suggested method relative radial velocities or more correct the differences of their individual radial velocities of the components of ADS 12815 (ΔV_r=-0.94±0.26 km/s) and ADS 10759 (ΔV_r = +3.43±0.43 km/s) have the accuracies of the same order as those obtained by other authors. A good agreement of the results

obtained by Tokovinin and Duquennoy-Mayor is well explained by the fact that they used the devices constructed by similar techniques (cross-correlation). We explain the difference (within the errors) in our determinations and those presented by the above mentioned authors by difference in observational and processing techniques.

Table.3. ADS 10759

Reference	V_r A	N	Note	V_r B	N	Note
Aitken, 1973	-10.3	-	----	var	-	K=28 km/s
Abt, 1973	- 9.6	1		-11.4	1	
(Observations	-12.8	1		- 8.0	1	
1918-1919)	- 6.3	1		-15.1	1	
				-14.5	1	
Wilson, 1953	-10.3	9	Lick			
	- 9.6	3	MtWilson	-11.4	4	Mt Wilson
	-14.4	1	Victoria	- 9.8	2	Victoria
	-10.3	13		-10.2	6	
Abt & Levy, 1976	-13.3	1	min			
	- 9.6	1	max			
(observations 1968-1972)	-10.9	19	const			
Romanenko, 1992	-17.9	1	min	-14.2	1	min
(Observations	-15.5	1	max	-11.2	1	max
1982-1986)	-16.9	5	const	-13.3	5	const
Duquennoy et al., 1991; Duquennoy, Mayor, 1991, (Observations 1983-89)	-14.8	1	min	-11.5	1	min
	-12.7	1	max	-10.4	1	max
	-13.7	16	const	-10.9	9	const

Table.4. ADS 12815

Reference	V_r A	N	Note	V_r B	N	Note
Abt, 1973 (Observations 1910-1916)	-27.2	1	1910	-21.2	1	1910
	-30.3	1		-50.2	1	
	+ 1.0	1		-23.1	1	
	-28.5	1	1913	-26.6	1	1913
	-27.0	1		-27.3	1	
	-23.4	1		-30.2	1	1916
Wilson, 1953	-26.3	3	MtWilson	-28.0	3	MtWilson
	-26.2	2	Victoria	-29.1	3	Victoria
	-25.6	5		-27.8	6	
Mayer, 1986	-27.1	-	------	-27.9	-	------
Tokovinin, 1987, 1990	-28.7	1	min	-28.8	1	min
	-26.9	1	max	-27.8	1	max
(Obs. 1986-90)	-27.7	9	const	-28.2	9	const
Romanenko, 1992 (Obs. 1986-1987)	-30.6	1	min	-31.9	1	min
	-29.2	1	max	-30.1	1	max
	-29.9	5	const	-31.1	5	const
Duquennoy et al., 1991; Duquennoy, Mayor, 1991, (Obs. 1978-89)	-27.7	1	min	-28.5	1	min
	-27.0	1	max	-27.3	1	max
	-27.4	11	const	-28.1	13	const

Table 5

References	Observations	$V_r A$	I	E	N	$V_r B$	I	E	N	$V_r B - V_r A$	I	E
ADS 12815												
Tokovinin, 1991	1986-1990	-27.73	.11	.19	9	-28.22	.11	.09	9	-0.49	.16	.21
Duquennoy--Mayor, 1991	1978-1989	-27.42	.08	.27	11	-28.08	.08	.29	13	-0.66	.11	.40
Romanenko, 1992	1986-1987	-29.93	.50	.22	4	-31.05	.46	.40	4	-1.12	.68	.46
		-27.18*				-28.30*				-0.94**	.22	.26
ADS 10759												
Duquennoy--Mayor, 1991	1983-1989	-13.70	.10	.42	16	-10.93	.12	.36	9	+2.77	.16	.55
Romanenko, 1992	1982-1986	-16.88	.61	.42	5	-13.28	.54	.50	5	+3.60	.81	.65
		-14.13*				-10.53*				+3.43**	.24	.43

Notes: * - correction is +2.75 km/s;

** - the value of ΔV_r

Finally we can draw the following conclusions:

1. The possibility to determine the relative radial velocity of visual binaries ADS 10759 and ADS 12815 using the observational techniques described was investigated.
2. ΔV_r was obtained which agrees well with the results of other authors with an accuracy of ±0.3÷0.4 km/s that is not limiting.
3. Radial velocities of the components of both stars are shown by our observations to be constant.

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REFERENCES

Abt H.A.: 1973, *Astrophys. J. Suppl. Ser.*, **26**, No. 234, 365.

Abt H.A., Levy S.G.: 1976, *Astroph. J. Suppl. Ser.*, **30**, No.3, 273.

Aitken R.G.: 1932, in: *New General Catalogue of Double Stars within 120° of the*

North Pole., Washington, Publ. Carnegie inst., 1488.

Batten A.H., Fletcher J.M., Man P.J.: 1978, *The Seventh Catalogue of the Orbital Elements of Spectroscopic Binary Systems*, Publ. Astroph. Obs. Victoria, **15**, 121.

Duquennoy A., Mayor M.: 1991, *Astron. Astrophys.*, **88**, No.2, 281.

Duquennoy A., Mayor M.: 1991, *Astron. Astrophys.*, **248**, No.2, 485.

Grosswhite H.M.: 1975, *Journal of Research of the National Bureau of Standards A. Physics and Chemistry*, **79** A, No. 1, 17.

Hoffleit D.: 1982, in: *The Bright Star Catalogue*, Yale University Obs., New Haven, 369.

Kiselev A.A., Kiyaeva O.B.: 1980, *Astron.J.*, **57**, 1227.

Kiselev A.A., Kiyaeva O.B., Chentsov E.L.: 1987, *Modern Astronomy*, L.: GAO AS USSR, 100.

Kiselev A.A., Kalinichenko O.A. et al.: 1988, in: *Catalogue of Relative Positions and Movements of 200 Visual Binaries Based on Pulkovo Observations with the 26" Telescope in 1960-1986*, M.: Nauka, 39.

Morby C.L., Griffin R.F.: 1987, *Astrophys. J.*, **317**, 343.

Neckel H.: 1986, *Astron. and Astroph.*, **167**, 1, 97.

Norlen G.: 1983, *Physica Scripta*, **8**, No.6, 255.

Peierce A.K., Breckinridge J.B.: 1974, *The Kitt Peak Table of Photographic Solar Spectrum Wavelengths*, Kitt Peak Nat. Obs., Contribution, No. 559, addendum.

Romanenko L.G.: 1988, *Astrofiz. Issled. (Izv. SAO)*, **27**, 60.

Romanenko L.G.: 1990, *Astron. Geodes. Issled.*, Sverdlovsk, 92.

Striganov A.R., Sventitzkij N.S.: 1966, in: *Tables of Spectral Lines*, M.: Nauka.

Swensson J.W.: 1944, *Astrophys. J.*, **103**, No.2, 207.

Tokovinin A.A.: 1987, *Astron. Zh.*, **64**, 196.

Tokovinin A.A.: 1990, in: *Catalogue of measurements of stellar radial velocities*, M.: Moscow Univ. Press, 4.

Wilson R.E.: 1953, in: *General Catalogue of Stellar Radial Velocities*, Mount Wilson Obs., Washington, 344.