1986SvA....30..359D

Speckle-interferometric measurements of binary stars on the BTA

V. N. Dudinov, S. G. Kuz'menkov, V. V. Konichek, V. S. Tsvetkova, V. S. Rylov, and V. N. Erokhin

Astronomical Observatory of Khar'kov State University; Special Astrophysical Observatory, USSR Academy of Sciences

(Submitted September 13, 1984)

Astron. Zh. **63**, 606–615 (May–June 1986)

We present the results of 42 measurements of the angular separations and position angles for 28 binary stars, made by the method of speckle interferometry on the 6-m BTA telescope. The ADS 11311 (φ Dra) system was measured for the first time by the method of speckle interferometry, while the ADS 11149 system was not identified earlier as a triple system in speckle-interferometric measurements. The procedure for acquiring and treating the initial material is presented in the paper. A comparison of these results with ephemerides and with the results of other observers shows the absence of systematic errors.

Speckle-interferometric observations on the 6-m BTA telescope were begun in 1977 by the combined efforst of colleagues of the Astronomical Observatory of Khar'kov State University (AO KhSU) and the Special Astrophyiscal Observatory (SAO), USSR Academy of Sciences. As is well known, the method of speckle interferometry allows one to extract information about the structure of the object at the diffraction limit of resolution of the telescope used. In the first stage, the observations were made without a brightness amplifier. The speckle images were recorded directly onto high-sensitivity Isopanchrome T-22 aerial-photography film using a Konvas 35-mm movie camera. Energy considerations led to the necessity of violating the condition $\Delta\lambda/\lambda \lesssim r_0 D$ in choosing the spectral interval $\Delta\lambda$ (Ref. 2), where r_0 is the coherence radius of the wave front disturbed by the atmosphere (Fried's parameter[3]) and D is the telescope diameter. The quantity $\Delta\lambda$ was chosen from considerations of compromise between the energy requirements and the necessity of assuring a sufficient signal-to-noise ratio at high spatial frequencies, and it reached 140 nm. Under such conditions, only the brightest objects, the stellar magnitude of which does not exceed $1^m.2$ with an image quality of 3", proved to be accessible to observations. In this stage we were able to determine the angular sizes of α Boo, α Tau, and α Ori, as well as to measrue the spectral binary α Aur repeatedly.[2,4]

Since March 1979, the observations have been made with a speckle camera incorporating an UM-92 brightness amplifier.[4] During the first observations, we measured three spectral binaries with the same visible spectrum, GC 25122 = χ Dra, ADS 14773 = δ Equ, and ADS 15281 = k Peg, and the close visual binary ADS 9757 = γ CrB. We note that the measurement errors given in Ref. 4 correspond to three rms deviations.

THE SPECKLE CAMERA

The speckle camera for the BTA, mounted at the Nasmyth focus, consists of a compensator for atmospheric dispersion, a block of light filters, a brightness amplifier, and a movie camera.

The compensator consists of a block of two prisms 70 mm in diameter. The first prism is made of F1 flint and has a refracting angle of 9°00' while the second is made of TK 14 heavy crown glass with a refracting angle of 9°01'. The compensator is mounted on the exit flange of the horizontal axis of the telescope. The direction toward the zenith at the Nasmyth focus rotates synchronously with the rotation of the exit flange as the zenth distance varies, so that the direction of the prisms' dispersion always coincides with the direction of atmospheric dispersion. The amount of compensation is varied by shifting a prism along a track inside the horizontal axis of the telescope. The compensator eliminates the influence of atmospheric dispersion with an accuracy exceeding the diffraction resolution of the telescope in the range of zenith distances of 15-60° in a spectral band of 40 nm.

The block of light filters consists of two disks, on one of which are located interference light filters with transmission maxima at 560, 600, and 650 nm and a half-width $\Delta\lambda$ = 40 nm. On the other disk there are narrow interference filters with $\Delta\lambda$ = 10-15 nm, designed for observations of red giants in the continuum (λ = 610 nm) and TiO absorption bands (λ = 590 and 623 nm). On the same disk there are neutral light filters and KS 17 and KS 19 light filters, yielding, in combination with the photocathode of the image converter, a transmission band $\Delta\lambda \approx$ 120-100 nm in the far-red region.

Up to 1981, the enhancement of speckle images in brightness was accomplished with a three-chamber UM-92 image converter with magnetic focusing of the electronic image. The photocathode is multislit with a maximum sensitivity at 480 nm and a long-wavelength limit at 850 nm. The amplification ratio is $\sim 10^3$ in brightness and the photographic resolution is ~ 10 mm^{-1}. The diameter of the working part of the photocathode is 15 mm. The luminescence output screen has green emission. To eliminate the influence of afterglow, which lasts for about 15 msec (to 10-fold decay), a mechanical gate with a variable obturator is located in front of the image converter, which makes it possible to acquire a set of exposures of from 3 to 30 msec. The rotation of the obturator is synchronized by the motor of the movie camera.

In 1981 a UMK-92 three-chamber image converter with a focusing system based on permanent magnets was installed. The amplification ratio is $\sim 10^5$, the visual resolution is 32^{-1} at the center of the field, and the diameter of the working part of the photocathode is 20 mm. The photocathode is multislit and the output screen has blue emission.

A six-power microscope objective with an aperture ratio of 0.20 is used to magnify the image on the photocathode of the image converter. The optics for transfer from the image converter screen to the film consists of RO2-2M and RO-109 objectives with focal lengths of 75 and 50 mm and aperture ratios of 1:2 and 1:1.2, respectively. The equivalent focal length of the entire system (telescope + speckle camera) is usually from 480 to 550 m. A Konvas 35-mm movie camera is mounted at the output of the speckle camera. Isopanchrome T-22 photographic film is used for recording. The film speed is 5 frames/sec. Series of 100-150 frames are usually taken in observations of binary stars and series of 250-300 frames for measuring angular diameters.

OBSERVATIONS AND COHERENT-OPTICS TREATMENT

In 1980, observations were made from May 30 to June 4 and from October 9 to 18 at twilight. The image quality on the nights of May 30-31 and May 31-June 1 was 2-3"; on the night of June 1-2 it was 3-4"; on June 4-5 it was 5-6" (observations were not made on June 2-3 and 3-4). The observations were made near full moon, which prevented the efficient use of observing time and reduced the capabilities of the recording apparatus with respect to limiting stellar magntiude. The observations in October were made at twilight: 9 (evening), 10-11, 13-14, 15 (morning), 17, and 19 (morning). The observations on October 17 and 19 were made with image quality of 3-4" and 5-6", respectively, while the others were made with image quality of 2-3".

The statistical treatment of the observational material, i.e., acquiring the power spectra of the speckle images, was done on the coherent-optics spectral analyzer of the AO KhGU.[5] The power spectrum of speckle images of a binary star can be represented by the expression

$$\langle|F(\nu_x,\nu_y)|^2\rangle = C\left\{1+\frac{2\beta}{1+\beta^2}\cos[2\pi l(\nu_x\cos\varphi+\nu_y\sin\varphi)]\right\} \times\langle|g(\nu_x,\nu_y)|^2\rangle\otimes|V(\nu_x,\nu_y)|^2, \qquad (1)$$

where C is a certain unessential constant, $\beta = 10^{-0.4\Delta m}$, Δm is the difference between the brightnesses of the components, ℓ is the distance between the components in a speckle image of the binary star, ϕ is the angle between the normal to the poles and the ν_x axis, connected with the position angle of the binary star, $g(\nu_x, \nu_y)$ is the optical transmission function (OTF) of the "telescope + atmosphere" system, $V(\nu_x, \nu_y)$ is the Fourier transform of the window function at the entrance to the spectral analyzer, and $\otimes$ denotes the convolution operation.

It has been shown (e.g., Ref. 6), and confirmed experimentally,[7] that at high spatial frequencies (more precisely, at $\nu=|\mathbf{v}|>r_0/\lambda$):

$$\langle|g(\nu_x,\nu_y)|^2\rangle\propto\left(\frac{r_0}{D}\right)^2 g_D(\nu_x,\nu_y), \qquad (2)$$

where $g_D(\nu_x, \nu_y)$ is the diffractional OTF of the telescope. And this circumstance enables us to make measurements of $\langle|F(\nu_x, \nu_y)|^2\rangle$ down to frequencies limited by diffraction on the telescope aperture.

Measurements of the power spectra on a two-coordinate microscope predetermined the two regimes of coherent-optics treatment of the speckle images. In the case of binary stars with $\Delta m < 2^m.5$, the power spectra were obtained with a spectrum analyzer, a diagram of which is given in Fig. 1. The spectrum analyzer consists of a planoconvex cuvette lens 80 mm in diameter, into which the diapositive containing the speckle images is drawn in an immersion liquid. Mikrat-200 film was used to obtain the diapositive copies. The construction of the cuvette makes it possible to obtain the mean square of the Fourier spectrum from a series of 300 frames. The small aperture ratio and minimum number of refracting surfaces almost fully eliminate aberrations and the coherent background in the exit plane of the spectrum analyzer. The power spectra are recorded on FP-1 photographic plates of the ORWO Co.

In the case of binary stars with components having a brightness difference $\Delta m \geq 2^m.5$, modulation in the spectrum is extremely low and the subsequent process of measurements becomes difficult. Moreover, the positions of the maxima and minima of the cosinusoidal function (1) are noticeable shifted under the action of $\langle|g(\nu_x, \nu_y)|^2\rangle$ for large Δm. In this case the maxima and minima are shifted in opposite directions (the former toward the center and the latter toward the periphery of the power spectrum), and the size of the shifts grows with an increase in ν. Calculations in accordance with (1) show that, e.g., for $\Delta m = 5^m$, modulation in the power spectrum exists only up to the frequency $\nu = 0.45\nu_D$, where $\nu_D = D/\lambda$ is the limiting frequency of the OTF of a telescope with a continuous round aperture.

Therefore, speckle images of binary stars with $\Delta m \geq 2^m.5$ were treated with a two-stage spectrum analyzer containing two frequency planes. In the first frequency plane a filter was placed with an assigned distribution of the transmission coefficient, with which the operation of dividing $\langle|F(\nu_x, \nu_y)|^2\rangle$ by $\langle|g(\nu_x, \nu_y)|^2\rangle$ was performed. The undistorted square of the Fourier spectrum was recorded in the second frequency plane. The function $\langle|g(\nu_x, \nu_y)|^2\rangle$ can be determined from the speckle images of a (standard) star not resolved by the given telescope. Using Eq. (2), however, we synthesized a $1/g_D(\nu_x, \nu_y)$ filter photographically, using a noncoherent optical correlator. Power spectra of standard stars were used as the control.

MEASUREMENT OF POWER SPECTRA

The power spectra of binary stars were measured on a UIM-21 universal measuring microscope. The measurement process was set up in such a way that information about the two parameters being sought, the band period $T = 1/\ell$ and the angle ϕ, was obtained directly after the treatment. The values of T and ϕ were estimated from the positions and orientations of the minima of the function (1) in the chosen coordinate system. The straight line

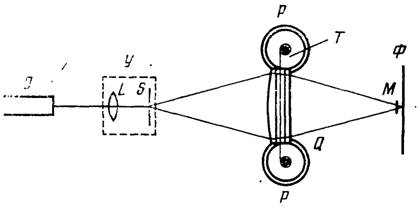

FIG. 1. Diagram of the coherent-optics spectrum analyzer. O) laser; U) Beam-attenuation unit; S) point diaphragm; Q) Fourier-transform cuvette lens P) film-winding mechanism; T) diapositive containing speckle images; F) spectral plane; M) filter mask.

TABLE I. Results of Measurements of Binary Stars

ADS or GC	Star	α, δ (1900,0)		Epoch 1980.0+	λ , nm	ρ	θ	Note
GC 3245	12 Per	02^{h}35^m,9	+39°46′	0,7744	600	0,042±0″,001	25,0±0°,5	1
GC 3664	γ Per	02 57,6	+53 07	0,7745	600	0,200±0,003	63,3±0·3	2
3841 Aa	α Aur	05 09,3	+45 54	0,7829	650	0,047±0,001	180,8±0,5	3
				0,7993	590, 610	0,043±0,001	157,7±0,3	
4229 AB	26 Aur	05 32,2	+30 26	0·7773	560	0.082±0,001	68,7±0,3	
4241 AB	σ Ori	05 33,7	−02 39	0·7773	600	0,261±0,003	158,6±0.2	
4265	126 Tau	05 35,5	+16 29	0·7773	560	0,340±0.002	236,6±0,3	
4617 AB	μ Ori	05 56,9	+09 39	0·7773	600	0,184±0·001	13,0±0,2	4
GC 8017	Rst 5225	06 10,7	+01 12	0,7828	560	0,230±0.004	203,0±0,3	
4890 Aa	75 Ori	06 11,6	+09 59	0,7828	560, 600	0,099±0,001	110,7±0,3	5
6185 AB	Stt 175	07 28·8	+31 11	0,7828	600	0,147±0,001	329,3±0·3	
GC 12434	10 UMa	08 54,2	+42 11	0,7993	600	0,737±0,006	18,8±0,2	6
7158	*k* UMa	08 56,8	+47 33	0.7883	560	0,292±0,002	284.9±0,2	
8804 AB	α Com	13 05.1	+18 03	0,4205	600	0.529±0.004	191,2±0,3	
GC 20795	β CrB	15 23,7	+29 27	0.4152	560	0,089±0,001	326.6±0.3	7
9688	ν^2 Boo	15 28,2	+41 14	0.4153	560	0.055±0,002	7,2±1,2	
9744 AB	ι Ser	15 37.1	+20 00	0,4153	560	0,213±0·002	67.7±0,3	
				0,4264	600	0,213±0,003	68.6±0.4	
9757	γ CrB	15 38.6	+26 37	0,4154	600	0.362±0.003	123,4±0.2	
GC 22296	σ Her	16 30.9	+42 39	0,4154	560	0.084±0,003	1.9±0,8	8
				0,4183	560	0,081±0,002	4,1±0.5	
10360 AB	*c* Her	17 04,5	+36 04	0.4182	560	0.098±0.001	78.4±0,4	
				0.4264	560	0,097±0.006	77.7±0,8	
11149 AB	B 2545	18 08,1	+33 25	0.4265	600	0,096±0,002	44,8±0.7	9
11149 AB, C	Ho 82					0.771±0,010	218,3±0.4	
	B 2545			0,7870	560	0,097±0·001	44,1±0.4	
	Ho 82					0,754±0,008	216,5±0.3	
11311	φ Dra	18 22,2	+71 17	0,7734	600	0.323±0.002	280,5±0,2	10
				0.7953	600	0,325±0,002	279,4±0,2	
GC 25122	χ Dra	18 22,9	+72 41	0,7734	650	0,137±0,002	225,2±0.4	11
				0,7953	650	0.139±0.001	225,2±0,4	
11468	A 1377	18 31,7	+52 16	0·4183	560	0.270±0.002	93.5±0,3	
				0,4265	560	0,272±0.003	94.9±0,4	
GC 27235	QS Aql	19 36,5	+13 35	0,7761	560	0.163±0.002	306,2±0.3	12
				0.7871	560	0.164±0,002	306.6±0.4	
12808 AB	χ Aql	19 37.9	+11 35	0,4157	560	0,453±0.005	77,1±0.2	13
				0.7871	560	0.454±0,005	74,7±0.3	
14073 AB	β Del	20 32,9	+14 15	0,4184	650	0.536±0.004	187,2±0.2	14
GC 28780 Aa	α Del	20 35,0	+15 34	0,4157	600	0,171±0,003	334,1±0,4	
				0,7843	600	0,153±0,002	325·0±0,3	
15032 Aa	β Cep	21 27,4	+70 07	0,4185	650	0,184±0,003	49.2±0.3	15
				0,7953	650	0,182±0,002	48,9±0.3	

Notes. 1. GC 3245 = HR 788 = 12 Per: a spectral binary with two visible spectra. Period of the system P = 331^d (obtained by Colacevich in 1941, Ref. 9). The speckle-interferometric observations of McAlister[10] made it possible, on the spectroscopic orbital elements obtained by Kolasevich, to ultimately determine the masses and luminosities of the components and the distance to the system.

2. GC 3664 = HR 915 = γ Per: a spectral binary with two spectra, P = 14^y.65 (Ref. 9). First resolved directly and measured in 1973 by Labeyrie et al.[11] by the method of speckle interferometry. McAlister,[12] using numerous speckle-interferometric observations and the elements of the spectroscopic orbit of Ref. 9, determined the fundamental astrophysical parameters of this system.

3. ADS 3841 Aa = α Aur: a well-known spectral binary with P = 104^d. McAlister constructed a new orbit for Capella[13] exclusively from interferometric observations made since 1920 (14 of the 56 observations used were speckle-interferometric). The new orbit is in fine agreement with a joint solution of Finsen,[14] yielding a smaller deviation from the observations, on the average. Our observations, made in two different filters (epoch of 1980.7993), yielded identical results.

4. ADS 4617 AB = A 2715 AB = μ Ori: a visual, astrometric, and spectral binary with P ≈ 18^y. Recent research by Fekel[15] shows that μ Ori is a quadruple system in which components A and B are spectral binaries.

5. ADS 4890 Aa = Fin 331 Aa = 75 Ori: a close visual binary with large variations of the relative (components B with respect to A) radial velocity.[16] Our measurements in two different filters yielded the following results: ρ = 0.098 ± 0''.001 and θ = 110.5 ± 0°.4 at 560 nm and ρ = 0.100 ± 0''.001 and θ = 110.8 ± 0°.4 at 600 nm.

6. GC 12434 = Kui 37 AB = 10 UMa: a spectral binary with one visible spectrum, P = 21^y.85 (Ref. 9). van Dessel[16] refers to the system as a binary with large variations of the relative radial velocity. Coureau[17] enters it in the list of stars for which the masses are reliably determined, although it is obvious, thanks to speckle-interferometric measurements, that this is not entirely so, and evidently the values of the masses will be refined in the near future.

7. GC = 20795 = HC 137909 = β CrB: a spectral binary with one visible spectrum, P = 10^y.5 (Ref. 9). First resolved by Labeyrie et al.[11] in 1973. A combined solution for the orbit proposed in Ref. 11 is in very poor agreement with observations.

8. GC 22296 = HR 6168 = σ Her: first resolved by Labeyrie et al.[11] in 1972. The difference between the brightnesses of its components is very large (by Labeyrie's estimates,[11] Δm = 3-4^m at 545 and 620nm). Our observations show that the band contrast is even higher (i.e., Δm is smaller) at 560 nm than at 600 nm (the power spectrum at 600 nm was not measured), and Δ m is in no way less than 3^m. Not resolved by McAlister at the epochs of 1976.2963 or 1976.2991 (Ref. 18). Orbit not yet constructed.

9. ADS 11149: a visual triple system – components AB are designated as B 2545, AB and C is designated as Ho 82 (Ref. 19). We first discovered and measured it as a triple system in speckle-interferometric measurements.[20] Our observations at the epoch of 1980.7870 were made with two exposures of 20 and 30 msec (per frame), and measuremetns of the power spectra gave ρ = 0.098 ± 0''.001, θ = 44.2 ± 0°.4 (B 2545); ρ = 0.750 ± 0''.012, θ = 216.5 ± 0°.5 (Ho 82) and ρ = 0.097 ± 0''.001, θ = 44.1 ± 0°.4 (B 2545); ρ = 0.756 ± 0''.010, θ = 216.5 ± 0°.3 (Ho 82), respectively.

10. ADS 11311 = Stt 353 = ϕDra: first measured by the method of speckle interferometry in the present work. The measurements pertain to the visual pair; component A is a spectral binary with one visible spectrum, P = 26^d.8 (Ref. 9).

11. GC 25122 = HD 170153 = χ Dra: a spectral binary with one visible spectrum and an astrometric binary, P = 280^d.531 (Ref. 9). Bonneau and Foy,[21] as well as McAlister,[22] using speckle-interferometric observations and the elements of the Crawford (1928) and Winter–Hansen (1942) spectroscopic orbits,[9] respectively, determined the fundamental astrophysical parameters of this system.

12. GC 27235 = Kui 93: a close visual binary, one of the components of which is an eclipsing variable (of the EA variability type, P = 2^d.5133).[23] No orbit.

13. ADS 12808 = Stt 380 AB = χ Aql: a star with a composite spectrum (F3 + A3), appearing in Hynek's list[24] as number 85. No orbit. Speckle-interferometric observations since 1976 show no appreciable orbital motion.

14. ADS 14073 AB = Bu 151 AB = β Del: a spectral binary with one visible spectrum, P = $26^{y}.6$ (Ref. 9). Van Dessel[16] assigns this system to binaries with suspected secondary radial-velocity variations (possibly due to the presence of a third component).

15. ADS 15032 Aa = Stt 2806 = β Cep: first resolved by Gezari et al.[25] in 1971 by the method of speckle interferometry. One of the components comprising this pair iis a well-known variable of the BC type with P = $0^{d}.1905$ (Ref. 23).

---

was given by the normal equation

$$\xi\cos\varphi+\eta\sin\varphi-p=0, \qquad (3)$$

where $\xi = \lambda_0 f_0 \nu_x$, $\eta = \lambda_0 f_0 \nu_y$, λ_0 is the wavelength of the laser emission, f_0 is the focal length of the spectrum analzyer, p is the distance from the straight line to the origin of coordinates, and ϕ is the angle between the normal to the straight line and the ξ axis, which we chose along the direction of motion of film in the speckle camera. Obviously, $p_1 = T/2$ for the first minimum, $p_2 = 3/2T$ for the second, etc. The straight line (3) was determined from the condition that the sum of the squares of the distances from the points (ξ_i, η_i) to the straight line being sought is minimal. The straight line thus determined is called the straight line orthogonal to the quadratic mean regression.[8] The requirement

$$\sum_{i=1}^{k}(d_i)^2=\sum_{i=1}^{k}(\xi_i\cos\varphi+\eta_i\sin\varphi-p)^2=\min, \qquad (4)$$

where d_i is the distance from the point (ξ_i, η_i) to the straight line, leads us to the method of least squares. We went by way of the linearization of (3) with respect to the parameter ϕ thus reducing the problem of finding the estimates of ϕ and p by the method of least squares to an iteration process. All the straight lines obtained through measurements of the entire power spectrum were then reached to one weighted-mean line passing through the first minimum. Finally, we determines the weighted-mean estimates of the parameters and their errors.

The formula for converting from T to the angular separation (in arc seconds) has the form

$$\rho=\frac{206265\lambda_0 f_0}{R_0 MT} \qquad (5)$$

where R_0 is the focal length of the telescope (Nasmyth focus) and M is the magnification of the speckle camera.

TABLE II. Comparison with Ephemerides

ADS or GC	Star	Epoch of 1980.0+	$(O-C)_\rho$	$(O-C)_\theta$	Author or orbit
GC 3245	12 Per	0.7744	−0″.005	−0°,4	McAlister, 1978 [10]
GC 3664	γ Per	0.7745	−0.015	+1.7	McAlister, 1982 [12]
3841 Aa	α Aur	0.7829	0.000	+2.1	Merrill, 1921, FW1 [26]
			0.000	−0.8	Finsen, 1975 [14]
			0.000	0.0	McAlister, 1981 [13]
		0.7993	+0.001	+2.0	Merrill, 1921, FW1 [26]
			+0.001	−1.1	Finsen, 1975 [14]
			+0.001	0.0	McAlister, 1981 [13]
4229 AB	26 Aur	0.7773	+0.005	+1.7	Baize, 1954. FW3 [26]
			+0.005	+5.6	Scardia, 1982 [27]
			+0.008	−3.8	Baize, 1954 [26], but dynamic elements of Starikova, 1977 28
4241 AB	σ Ori	0.7773	+0.032	+0.3	Heintz, 1973* [29]
4265	126 Tau	0.7773	+0.031	−6.5	Valbousquet 1980* [30]
4617 AB	μ Ori	0.7773	+0.101	−17.4	Alden, 1938 [26], but dynamic elements of Starikova, 1977 28
GC 8017	Rst 5225	0.7828	+0.041	−8.2	Heintz, 1974* [31]
			+0.035	−3.0	Starikova 1982* [32]
4890 Aa	75 Ori	0.7828	−0.029	−4.0	Starikova 1982* [32]
GC 12434	10 UMa	0 7993	+0.038	−1.0	Heintz, 1966 FW2* [26]
			+0.019	−0.2	Baize, 1967 [33]
			+0.030	−3.1	Starikova 1978* [34]
7158	*k* UMa	0.7883	+0.038	+2.4	Morel, 1969 FW3* [26]
			+0.030	+1.8	Starikova 1982* [32]
8804 AB	α Com	0.4205	+0.042	−0.1	Haffner, 1938 FW1* [26]
			+0.042	−0.2	Harting, 1950* [35]
9744 AB	ι Ser	0.4153	+0.003	−1.4	van den Bos, 1963, orbit I, FWA1 [26]
			+0.004	−1.6	van den Bos, 1963, orbit. II, FWA1 [26]
		0.4264	+0.003	−0.6	van den Bos, 1963, I, FWA1 [26]
			+0.004	−0.7	van den Bos, 1963, II, FWA1 [26]
9757	γ CrB	0.4154	−0.045	−1.6	Baize, 1952, FW2* [26]
10360 AB	*c* Her	0.4182	−0.017	+1.6	Cester, 1963, FWA2 [26]
		0.4264	−0.018	+1.1	Cester, 1963, FWA2 [26]
11311	φ Dra	0.7734	+0.096	+17.6	Olevic, 1975* [36]
		0.7953	+0.098	+16.5	Olevic, 1975* [36]
C 25122	χ Dra	0.7734	+0.004	−2.3	Bonneau, Foy, 1980 [21]
		0.7953	+0.002	−1.1	McAlister, 1980 [22]
			+0.002	−4.0	Bonneau, Foy, 1980 [21]
			+0.004	−2.4	McAlister, 1980 [22]
11468 AB	A 1377	0.4183	+0.013	−4.7	Baize, 1976 [37]
		0.4265	+0.015	−3.3	Baize, 1976 [37]
14073 AB	β Del	0.4184	−0.027	−1.2	Finsen, 1936 FW1* [26]
			−0.033	+0.3	Couteau, 1959 FW1* [26]
			−0.022	+0.2	Starikova 1976* [38]

The measured angle ϕ, with the given structural features of the "telescope + speckle camera" system, is connected with the position angle θ of the binary star by a linear algebraic equation, which includes the zenith distance of the object and its parallactic angle at the time of observation. We note that in this case the values of θ have an uncertainty of 180°, inevitable in speckle-interferometric measurements.

The final values of the errors in the measured parameters ρ and θ were calcualted from the well-known rules of transfer of errors in the conversion from p to ρ and from ϕ to θ. For the given means of measurement and estimation, the minimum rms error in estimating ρ is proportional to

$$\sigma_\rho \sim \frac{\sqrt{\rho}}{D}, \tag{6}$$

while the analogous error in estimating θ in degrees is

$$\sigma_\theta = 57.3 \frac{\sigma_\rho}{\rho}. \tag{7}$$

RESULTS OF MEASUREMENTS

The results of the measurements are presented in Table I. The first column contains the number of the star from the ADS or GC catalog; the second contains the name or designation of the star; the third contains the coordinates at the epoch of 1900.0; the fourth contains the epoch of the observations in fractions of a Bessel year, supplemented to 1980.0; the fifth contains the angular separation ρ of the components and its rms error; the sixth contains the position angle θ and its rms error; the seventh contains a note.

A comparison of the results for the same object obtained in different filters (ADS 3841, ADS 4890; see the notes to Table I) or with different exposures (ADS 11149; see the notes to Table I), as well as the results of observations separated by an interval of several days for objects having slow orbital motion (ADS 9744, ADS 11311, ADS 11468, and GC 27235), demonstrates their high stability. To the last of the four above-mentioned systems, we can add ADS 10360 = c Her, which has a period, evidently, of ~8 yr (Ref. 26), but for which the epochs of the observations were separated by only ~72 h.

For these five systems, observed at the respective epochs t_1 and t_2 for each star, we form the differences

$$x = (\rho_2 - \rho_1)/\bar{\rho}, \quad y = \theta_2 - \theta_1, \tag{8}$$

where $\bar{\rho} = (\rho_1 + \rho_2)/2$. We find the mean differences $\langle x \rangle$ and $\langle y \rangle$ and their rms errors $\sigma_{\langle x \rangle}$ and $\sigma_{\langle y \rangle}$. We have $\langle x \rangle = 0.0019$, $\langle y \rangle = 0^\circ.18$, $\sigma_{\langle x \rangle} = 0.0033$ and $\sigma_{\langle y \rangle} = 0^\circ.47$. The inequalities $\sigma_{\langle x \rangle} > \langle x \rangle$ and $\sigma_{\langle y \rangle} > \langle y \rangle$ indicate an absence of any systematic effects from observation to observation.

Using the estimates of the errors σ_ρ and σ_θ given in Table I, we find the values of $\langle \sigma x \rangle$ and $\langle \sigma y \rangle$. In doing this, we must exclude the measurement errors for c Her at the epoch of 1980.4264 as entirely atypical (because of the poor quality of the speckle images, the power spectrum had a low contrast and was measured with an MF-4 microphotometer). We have $\langle \sigma_x \rangle = 0.0144$ and $\langle \sigma_y \rangle = 0^\circ.47$. We find that $\langle \sigma_x \rangle \approx 4\sigma_{\langle x \rangle}$ and $\langle \sigma_y \rangle = \sigma_{\langle y \rangle}$. Thus, the errors given in Table I are quite realistic. The internal convergence of the results of the measurements is ~1% for the separations of the of the components and 0°.3 for the position angles.

Table I contains 42 measurements of 28 stars (four of these measurements pertain to the triple system ADS 11149), including: five measurements of four spectral binaries with two visible spectra (12 Per, α Aur, γ Per and μ Ori), five measurements of four spectral binaries with one visible spectrum (10 UMa, β CrB, χ Dra, and β Del), and two measuremetns of a star having a composite spectrum (χ Aql). The remaining measurements pertain to 19 close visual binaries, for seven of which the orbits have not yet been constructed, and two of these stars having variable components (QS Aql and β Cep).

The measured separations of the components lie in the range from 0".042 to 0".771, and 13 of the measurements were made with $\rho \leq 0''.1$. It must be noted that ADS 11311 (ϕ Dra) was measured by the method of speckle interferometry for the the first time, while the ADS 11149 system was not identified as a triple in earlier speckle-interferometric measurements: All the observers give results pertaining only to components A and B. The brightness difference between components AB and C is 4^m according to the IDS catalog,[19] while $m_C = 9^m.8$, which serves as an illustration of the sensitivity (penetrating power) and dynamic range of the light-gathering apparatus and treatment system.

COMPARISON WITH EPHEMERIDES AND RESULTS OF OTHER OBSERVERS

The ephemerides were calcualted for the binary stars for which the orbital elements are known. The results of the comparison with ephemerides are given in Table II. The first two columns in this table have the same meaning as those in Table I; in the third column is the epoch of the observation; in the fourth and fifth are the deviations $(O-O)_\rho$ and $(O-C)_\theta$ of the measured separations and position angles from the ephemerides; in the sixth column we give the author for the orbit and the year of the last observation of publication of an orbit.

The orbits taken from the catalog of Finsen and Worley[26] are marked by the letters FW with an indication of the quality of the orbit given in that catalog. The deviations from the ephemerides for those orbits yielding the least deviations from our measurements are netered in Table II. In a case when this choice among orbits was difficult to make for any star, the values of the deviations are given for all these orbits.

Orbits which yield ephemeris values deviating strongly from the measured values are marked by an asterisk. There were 16 of them out of the 32 figuring in Table II. For 10 of the stars, σ Ori, 126 Tau, μ Ori, Rst 5225, 75 Ori, k UMa, α Com, γ CrB, ϕ Dra, and β Del, the deviations are quite pronounded and demand a re-examination of the orbits existing for them. This conclusion is also supported by the observations of McAlister[39] and Tokovin.[40] Eliminating these stars from consideration, we analyzed the deviations for the remaining nine systems. It did not make sense to analyze the the June and October observations separately, since the sample is so small, while these observations were made under uniform conditions. In the given case we chose one orbit for each star, while for the long-period stars ADS 9744 and ADS 11468 we took the deviations averaged over two observations (for the mean epoch), since the observations are very close together and the corresponding deviations are almost the same. We found that $\langle\Delta\rho\rangle = -0.0006 \pm 0''.0033$ and $\langle\Delta\theta\rangle = -0.25 \pm 0^\circ.5$ or, for the position angles, $\langle\rho\Delta\theta\rangle = -0.002 \pm 0''.002$, where $\Delta\rho = (O-C)_\rho$ and $\Delta\theta = (O-C)_\theta$, for 12 observations. The rms values of the deviations from the ephemerides are $\sigma_{\Delta\rho} = 0''.0116$ and $\sigma_{\rho\Delta\theta} = 0''.006$. These results indicate that there are no systematic errors in our measurements.

A comparison with the results of other observers[39,40] obtained at epochs close to those of our observations shows that they agree well with each other, while the deviations from the ephemerides prove to be least for one and the same orbits.

Five of the systems from Table II (α Cm, γ CrB, c Her, A 1377, β Del) were observed by McAlister et al.[39] in the period from June 23 to 26, 1980. We designate the deviations of the ephemerides of our data by the index 1 and those for McAlister's data by the index 2. We find $\langle\Delta\rho_2 - \Delta\rho_1\rangle = -0.002 \pm 0''.002$ and $\langle\Delta\theta_2 - \Delta\theta_1\rangle = 0.7 \pm 0^\circ.7$, or, for θ, $\langle\rho_2\Delta\theta_2 - \rho_1\Delta\theta_1\rangle = 0.008 \pm 0''.004$. The fact that the average difference between the weighted deviations $\rho\Delta\theta$ is twice as great as its rms deviation hardly points to the presence of systematic differences in θ between our measurements in June 1980 and McAlister's measurements, since the sample is very small. Using the methods of the theory of hypothesis verification, it is easy to show that the mean difference $\rho\Delta\theta$ is not statistically significant for this sample. The rms values of the difference between the deviations from the ephemerides are $\sigma_{\Delta\rho_2-\Delta\rho_1} = 0''.005$ and $\sigma_{\rho_2\Delta\theta_2-\rho_1\Delta\theta_1} = 0''.008$.

Six of the systems from Table II (12 Per, γ Per, α Aur, 26 Aur, μ Ori and χ Dra) were observed by McAlister et al.[39] in the period from September 19 to 23, 1980. For the analysis of our October observations, we also drew upon McAlister's observations of February 26-28, 1980, of the two long-period binaries 126 Tau and k UMa. Thus, for eight observations we obtained $\langle\Delta\rho_2 - \Delta\rho_1\rangle = 0.001 \pm 0''.002$ and $\langle\Delta_{\theta 2} - \Delta\theta_1\rangle = 0.8 \pm 0^\circ.7$, or, for θ, $\langle\rho_2\Delta\theta_2 - \rho_1\Delta\theta_1\rangle = 0.002 \pm 0''.002$. The rms values fo the difference between the deviations are $\sigma_{\Delta\rho_2-\Delta\rho_1} = 0''.006$ and $\sigma_{\rho_2\Delta\theta_2-\rho_1\Delta\theta_1} = 0''.005$.

The results of this comparison indicate the absence of systematic differences between our measurements and the measurements of McAlister et al.

[1] A. Labeyrie, Astron. Astrophys. 6, 85 (1970).

[2] V. N. Dudinov, V. N. Erokhin, S. G. Kuz'menkov, et al., Dokl. Akad. Nauk Ukr. SSR, Ser. A. No. 7, 550 (1979).

[3] D. L. Fried, J. Opt. Soc. Am. 55, 1427 (1965).

[4] V. N. Dudinov, V. N. Erokhin, V. V. Konichek, et al., Astron. Tsirk., No. 1134, 4 (1980).

[5] V. N. Dudinov, V. S. Tsvetkova, V. A. Krishtal', et al., Vestn. Khar'kov. Univ., No. 160, 65 (1977).

[6] D. Korff, G. Dryden, and M. G. Miller, Opt. Commun. 5, 187 (1972).

[7] D. P. Karo and A. M. Schneiderman, J. Opt. Soc. Am. 66, 1252 (1976).

[8] H. Cramer, Mathematical Methods of Statistics, Princeton Univ. Press, Princeton (1971).

[9] A. N. Batten, J. M. Fletcher, and P. J. Mann, Publ. Dom. Astrophys. Obs. Victoria 15, 121 (1978).

[10] H. A. McAlister, Astrophys. J. 223, 526 (1978).

[11] A. Labeyrie, D. Bonneau, R. V. Stachnik, and D. Y. Gezari, Astrophys. J. 194, L147 (1974).

[12] H. A. McAlister, Astron. J. 87, 563 (1982).

[13] H. A. McAlister, Astron. J. 86, 795 (1981).

[14] W. S. Finsen, Int. Astron. Union Commun. 26, Circ. Inform., No. 66 (1975).

[15] F. C. Fekel, Publ. Astron. Soc. Pac. 92, 785 (1980).

[16] E. van Dessel, Commun. Obs. R. Belg., No. 103, 3 (1979).

[17] P. P. Couteau, Observations of Visual Double Stars [Russian translation], Mir, Moscow (1981).

[18] H. A. McAlister, Publ. Astron. Soc. Pac. 90, 288 (1978).

[19] H. M. Jeffers, W. H. van den Bos, and F. M. Greeby, Index Catalogue of Visual Double Stars, 1961.0, Publ. Lick, Obs., Vol. 21, in two parts (1963).

[20] V. N. Dudinov, V. V. Konichek, S. G. Kuz'menkov, et al., in: Proc. Int. Astron. Union Colloq., No. 67, 191 (1982).

[21] D. Bonneau and R. Foy, Astron. Astrophys. 86, 295 (1980).

[22] H. A. McAlister, Astron. J. 85, 1265 (1980).

[23] D. Proust, F. Ochsenbein, and B. R. Pettersen, Astron. Astrophys., Suppl. Ser. 44, 179 (1981).

[24] F. A. Hynek, Contrib. Perkins Obs., No. 10, 185 (1938).

[25] D. Y. Gezari, A. Labeyrie, and R. V. Stachnik, Astrophys. J. 173, L1 (1972).

[26] W. S. Finsen and C. E. Worley, Repub. Obs. Johannesburg, Circ. 7, 203 (1970).

[27] M. Scardia, Int. Astron. Union Commun. 26, Circ. Inf., No. 88 (1982).

[28] G. A. Starikova, Astron. Tsirk., No. 961, 7 (1977).

[29] W. D. Heintz, Int. Astron. Union Commun. 26, Circ. Inform., No. 60 (1973).

[30] A. Valbousquet, Int. Astron. Union Commun. 26, Circ. Inform., No. 82 (1980).

[31] W. D. Heintz, Int. Astron. Union Commun. 26, Circ. Inform., No. 63 (1974).

[32] G. A. Starikova, Pis'ma Astron. Zh. 8, 306 (1982) [Sov. Astron. Lett. 8, 166 (1982)].

[33] P. Baize, Int. Astron. Union Commun. 26, Circ. Inform., No. 42 (1967).

[34] G. A. Starikova, Pis'ma Astron. Zh. 4, 552 (1978) [Sov. Astron. Lett. 4, 296 (1978)].

[35] H. Harting, Astron. Nachr. 278, 264 (1950).

[36] D. Olevic, Publ. Obs. Astron. Beograd., No. 126, 49 (1975).

[37] P. Baize, Int. Astron. Union Commun. 26, Circ. Inform., No. 68 (1976).

[38] G. A. Starikova, Tr. Gos. Astron. Inst. 47, 96 (1976).

[39] H. A. McAlister, E. M. Hendry, W. J. Hartkopf, and B. G. Campbell, Astrophys. J., Suppl. Ser. 51, 309 (1983).

[40] A. A. Tokovinin, Pis'ma Astron. Zh. 8, 43 (1982) [Sov. Astron. Lett. 8, 22 (1982)].

Translated by Edward U. Oldham