

Astrometric Study of Four Binary Stars

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Orbits, parallaxes, and masses have been derived for the visual binaries ADS 8197, Wolf 424, 99 Her, and Kpr 112, as listed in Table II. The results are based on a total of more than 1000 Sproul astrometric plates measured by the author. The components of Wolf 424 appear to be the least massive visible stars currently known.

ADS 8197 = OΣ 235

THE revised elements are based on the normal places of Table I, and are accurately known by now. The previous orbit, computed in 1912 by Aitken (published 1914), held for a long time but its period was too short.

The plates obtained with the 24-inch Sproul refractor (scale 18".87 per millimeter) consist of two series, in 1914–16 and 1968–71 (after and before periastron, respectively) while the apastron arc is covered only by some scattered plates. The reference stars are AC 62°21333, BD+62°1186, and +61°1248, with the dependences 0.167, 0.403, and 0.430, respectively. The

first and third have annual proper motions of 0".03, relative to fainter stars in the field. Allowing for this, the corrected annual proper motion of ADS 8197 becomes +0".021 in α and $-0".076$ in δ . A rotating sector reducing the brightness by 4.8 mag was used since 1970 while all earlier plates have a poorer compensation (3.5 to 4.5 mag), making the binary brighter than all of the reference stars. The blended images of the binary are partly elongated. The present parallax supercedes the previous Sproul result (Miller 1919), and agrees closely with the McCormick value. Yet it may be somewhat too large, the dynamical parallax being 0".034. The result in Table II, for this and the other stars, represents the combined solution from α and δ , and the

TABLE I. Visual observations of ADS 8197.

t	θ_{2000}	ρ	n		O—C	
1844.53	289°8	0".58	4	Mä OΣ 2	+1.4	—0".02
50.31	320.9	0.55	8	OΣ	+0.5	—0.06
57.47	351.6	0.58	5	OΣ	—4.7	—0.10
62.42	13.6	0.71	4	OΣ	—2.1	—0.05
69.70	38.1	0.89	7	Dem 4,1 OΣ 3	+1.1	—0.01
78.17	56.0	1.05	14	Dem 6 OΣ H/ 3 WSS 2	+0.4	+0.04
81.77	64.1	1.11	16	En 6 Dob 4,2 β Big Sb 2	+1.5	+0.09
88.59	74.0	1.11	16	H/ 5 Sp Tarr 4 OΣ 2 Maw 1	—2.3	+0.14
92.30	85.4	0.92	24	Big 8 Com 4 Maw HΣ 3 β Lv Jones 2	+0.4	+0.04
96.30	96.8	0.78	24	Com 13 Doo 4,2 Dob 3,0 See 2 Brown Renz 1	—0.3	+0.04
1898.77	108.0	0.66	25	Hu 8,7 A 6 Com 4 Doo 3 Brown GrO 2	+0.3	+0.03
1901.57	126.8	0.50	13	Hu Com 5 GrO 3	+0.8	+0.01
03.51	144.9	0.40	10	VB 5 Dob 3 Com 2	—1.3	0.00
05.60	184.4	0.33	7	A 3 GrO 2 Lohse Lau 1	+7.1	—0.02
08.90	225.7	0.36	20	Dob 8 Doo 5 VB 4 Storey 2	—0.5	—0.05
12.38	255.2	0.51	18	VB 8 GrO 5 A 3 NeuJ 2	—2.4	—0.02
14.99	276.3	0.54	21	Rabe 11 VB 6 Com 4	+1.8	—0.04
18.56	293.0	0.55	24	Com 11 VB 7 Barn 3 GrO Bern Chand 1	—1.9	—0.05
22.94	321.2	0.58	26	B 10 Przy 5 VB Magg 3 A BabO 2 Lv 1	+2.1	—0.03
27.72	345.0	0.61	24	GrO 5 GΣ Rabe 4 Fat Kom 3 Berm Bon 2 Fox 1	+0.9	—0.03
32.00	2.4	0.71	16	Kom 10 Bz 4 Bon 2	—0.9	+0.01
36.91	20.3	0.77	28	Rabe 13 Duruy 7,4 GrO 5 Bz 3	—0.8	—0.02
38.92	25.3	0.81	30	Rabe 13 Phil Schmei Duruy 4 Bz 3 Fox 2	—2.1	—0.02
41.40	30.9	0.84	29	Rabe 25 Bz 4	—3.2	—0.04
45.16	41.7	0.94	24	Rabe 13 Bz Mlr 4 Eggen 3	—1.5	0.00
49.55	52.7	0.98	25	Rabe 13 Bz 4 VB 3 Mark Fokker 2 Dubois 1	+0.1	—0.02
51.82	56.1	1.08	23	Rabe 16 Bz 5 Mlr 2	—1.0	+0.07
53.60	60.4	1.06	24	Rabe 15 Mlr 5 Dju 3 Pretre 1	—0.2	+0.04
55.90	64.8	1.06	37	Rabe 18 Wor 8 Bz BabO 4 Mlr 3	—0.2	+0.04
57.70	70.0	1.01	30	BabO 10 Rabe 7 C 3 Wor Bru 2	+1.4	0.00
59.46	71.8	1.01	26	GrO 9 BabO 6 Wor hz 4 C 3	—0.3	+0.02
62.20	77.6	0.95	33	GrO 10 B 8 Wor 7 Bz Hold 4	—0.4	0.00
65.04	85.1	0.88	20	hz 7 Wor 6 Bz Soulie 3 BabO 1	+0.4	—0.01
1968.83	96.3	0.71	8	hz Walk 4	+0.4	—0.05

TABLE II. Orbits, parallaxes, masses, and probable errors.

Star	ADS 8197	Wolf 424	99 Her	Kpr 112
α and δ (1950)	11 ^h 29 ^m 5 +61°22'	12 ^h 30 ^m 9 +09°18'	18 ^h 05 ^m 1 +30°33'	22 ^h 30 ^m 8 +53°32'
Visual magnitudes, spectrum	5.8-7.1 F6V	13.2-13.2 M5Ve	5.1-8.4 F7V	10.7-10.8 M0V
Elements: n	4.9403	22.222	6.4516	7.0588
T	1981.50	1961.6	1941.8	1970.3
e	0.398	0.28	0.74	0.59
ω	130°7	20°	300°6	310°0
i	47.7	103	32.0	43.0
Ω (2000)	81.0	151	218.7 asc	110.8
annual precession	+0.0015	-0.0008	-0.0065	-0.0035
a''	0".813	0".76	1".00	0".504
P (yr)	72.87	16.2	55.8	51.0
Measured annual motion R.A.	+0".0344±0".0003	-1".7356±0".0002	-0".0838±0".0002	+1".3615±0".0002
Dec.	-0.0755 0.0002	+0.2105 0.0002	+0.0938 0.0002	+0.1053 0.0002
Relative parallax	+0".0388±0".0037	+0".2396±0".0038	+0".0609±0".0033	+0".0388±0".0022
Absolute Sproul parallax	+0.043 0.004	+0.242 0.004	+0.064 0.003	+0.042 0.002
Combined with other results, adopted parallax	+0.043 0.004	+0.234 0.003	+0.060 0.003	+0.042 0.002
Photocentric semi-axis major $a(f-\beta)$	+0".179 ±0".008	-0".007 ±0".005	+0".353 ±0".004	+0".014 ±0".003
$f-\beta$	0.220 0.010	-0.009 0.007	0.353 0.004	0.028 0.006
Fractional luminosity β (from Δm)	0.229	0.50	0.045	0.477
Fractional mass $f=B/(A+B)$	0.449 0.01	0.49 0.01	0.398 0.01	0.505 0.01
Mass A ($\odot$)	0.70 0.2	0.067 0.015	0.90 0.1	0.33 0.05
Mass B ($\odot$)	0.57 0.2	0.064 0.015	0.59 0.1	0.33 0.05
Number of nights; exposures measured	52; 484	140; 613	74; 736	102; 1335
Total night weight	102	189	157	246
Measuring machine	Ridell	Kasten	Ridell	USNO Strand
p.e. (unit weight) 1x	±0".0260	±0".0321	±0".0319	±0".0183
p.e. (unit weight) 1y	0.0294	0.0330	0.0296	0.0260

seasonal average residuals (observed minus computed) are listed in Table III.

WOLF 424 (REUYL)

The star was in 1938 recognized to have a large parallax, the same time as Reuyl noticed its duplicity

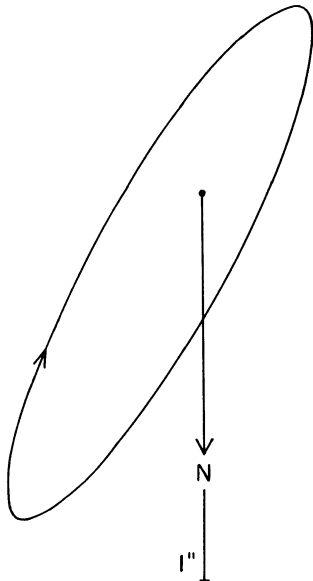


FIG. 1. The orbit of Wolf 424.

(elongation) on the first McCormick plate taken. Pre-discovery plates of Mount Wilson and Sproul confirmed the duplicity.

Owing to the faintness of the pair, the visual results are scanty and discordant, yet the orbit (Fig. 1) can be fairly well defined by adding the elongations of photographic images (Table IV). The Sproul material covers the years 1938-56 and 1963-71. L. W. Fredrick and P. A. Ianna kindly made available the McCormick series, mostly plates from 1938-42, and a few later ones up to 1954. As the McCormick plates had already been

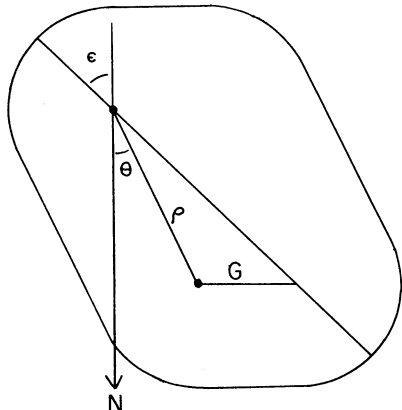


FIG. 2. Correction for guiding error.

TABLE III. Mean yearly residuals R_α, R_δ (unit 10^{-4} mm = $0''.00189$) and weights.

	ADS 8197			Wolf 424			99 Her			Kpr 112		
	R_α	R_δ	wt	R_α	R_δ	wt	R_α	R_δ	wt	R_α	R_δ	wt
1914	-5	-9	3									
15	-9	+1	8				-28	+4	4			
16	+32	0	3				-4	+5	8			
17							+6	+5	2			
29	-5	+10	1									
1937	+5	+24	3				-8	-1	3	-11	-10	6
38				-9	+21	4	-14	+19	1	-21	-9	3
39				+2	-7	6	0	-17	5	+17	-18	5
40				-2	+11	6	-3	-17	7	0	-29	1
41				+12	+4	7	-24	-1	6	+3	-13	3
1942				-2	0	9	+24	-9	3			
43							+16	-3	5	-12	+5	2
44				-34	-3	4	+6	-10	5	-5	+19	3
45				+3	-27	2	-1	-19	6			
46				+6	+23	2	-1	+3	9	-21	+17	4
1947				+2	+1	4	+19	+9	11	-13	+14	2
48				+5	-1	5				-7	+4	1
49	+9	-28	3							+15	+8	6
50				-6	+3	7				+8	+14	3
51				-12	+28	1				+16	0	3
1952				+29	-22	2				+19	-10	3
53				+14	-27	5	+29	+4	3	+9	+21	3
54	-20	-41	1	+19	+16	1	+37	+21	3	0	+14	3
55				-22	-21	2				+2	0	3
56				-2	+6	6	+19	+33	3	0	+12	3
1957	-30	+34	3				-7	-4	2	-8	-5	4
58	+2	+6	3							+7	-33	3
59							+8	+14	3	+5	-5	9
60							-20	+3	3	-4	-9	9
61										+5	+6	9
1962							+3	+16	3	+1	+7	15
63				+13	+6	9				-5	-2	7
64	+8	+14	3	+10	-10	7	+28	+22	3	+6	+17	9
65	+20	-13	3	+3	-8	13				-1	+15	10
66				-17	-16	11						
1967				-22	-18	7				-4	+7	15
68	-8	-10	8	+2	+7	19	-8	+13	8	+2	-4	21
69	+11	+7	6	+13	+4	17	-1	+9	9	-2	-5	34
70	0	+1	43	+4	+11	18	-6	-8	42	+1	-4	26
71	-1	-4	11	-15	+2	15				-4	-4	18

measured for parallax (Mitchell *et al.* 1960), they are not included in the present parallax solution but were measured for elongations only.

The elongations are affected by the guiding error, as Reuhl (1941) had already noted. It was allowed for by the model of Fig. 2: Let E be the measured elongation (length minus breadth of the image) in position angle ϵ (with $|\epsilon| < 90^\circ$). The amount G of guiding error (in angle 90°) was similarly measured on three reference stars, other stars in the field being either of too different brightness, or too far off center, and beginning to show coma. The image radius (depending on exposure) cancels out, and the true separation ρ and position angle θ are given by

$$\rho \cos \theta = E \cos \epsilon + G(\cos 2\epsilon + 1),$$

$$\rho \sin \theta = E \sin \epsilon + G(\sin 2\epsilon \mp 1),$$

where the double sign refers to ϵ in the first and fourth quadrant, respectively. These results are listed in Table IV. The overmeasurement of separations in blended images found by Reuhl (1931) probably does not apply to edge settings on pairs as close as this; on the contrary, the side bulging of the photographic image near the center where the two star disks overlap will possibly cause the elongation to appear somewhat too small. This effect was omitted, however, since an attempt to allow for it by assuming elliptical shapes or Cassini curves for the images did not significantly alter the result. The semi-axis major $a = 0''.76$ was determined as to approximately match the average visual separations, to leave the average of the photographic elongations slightly on the small side, and to explain the absence of elongation in certain years. The image contours are always curved, not flat sided, which also may

TABLE IV. Observations of Wolf 424.

<i>t</i>	θ_{2000}	ρ	<i>n</i>	O—C	
<i>Visual</i>					
1938.42	321°2	1".10	1 Kpr	−0°7	+0°30
41.48	249	0.3	2 Jef	−24	+0.09
52.29	325.0	0.80	2 VB	−5.1	−0.16
52.53	294.2	0.51	2 Wils	−35	−0.45
56.33	315.8	0.44	2 VB	+5.3	−0.06
60.30	169.3	0.8	2 Wor	+10.7	+0.28
1965.18	353.1	0.37	1 Wor	+6.8	−0.14
<i>Photographic (elongations)</i>					
1938.34	321.7	0.72	12n/14 exp.	−0.8	−0.09
39.18	316.1	0.81	20/24	−2.2	+0.13
40.16	311.4	0.73	15/27	+1.2	+0.24
41.18	300.3	0.29	8/13	+11.9	+0.01
42–45	round				
46.20	126.4	0.45	1/8	−8.5	+0.09
47–48	round				
50.13	335.6	0.70	2/7	−2.1	−0.07
52.37	326.3	0.69	1/5	−3.5	−0.26
53.21	323.8	0.68	4/11	−3.5	−0.26
54.15	316.7	0.73	2/6	−7.4	−0.13
55.38	338.7	0.73	1/8	+20.4	+0.05
56.17	316.9	0.43	3/13	+4.3	−0.09
63–65.1	round				
65.4	0±	0.2		+17	−0.4
66.1	round				(0.7)
66.29	343.5	0.56	1/2	+5.6	−0.20
67.18	329.2	0.72	2/8	−5.1	−0.16
68.20	326.9	0.73	10/40	−4.1	−0.22
69.16	328.6	0.77	8/42	+0.6	−0.18
70.32	324.5	0.84	9/42	+0.4	−0.02
1971.30	320.2	0.68	7/28	+0.4	−0.05

indicate that the separation never exceeds 1 sec arc. Combined images are flattened and notched if the separation exceeds the one-star disk radius, about 1'' under good seeing and exposure.

Notwithstanding the gap around 1960 (which is also not covered by Van Vleck or McCormick plates), a period close to 16 yr is clearly indicated, as was suggested by Lippincott (1958). Upgren (1971) favored a considerably longer period (from minute parallax residuals, not from elongations) but the Van Vleck series is far too discontinuous to permit any conclusion. A 32 years', zero-eccentricity solution fails as it makes the intervals of visible elongation too long.

The components apparently are of equal brightness (13^m2 visual). The maximum separation, placed here in the fourth quadrant, has been observed in three revolutions, viz. 1938–41, 1950–56, and 1966 to the present. Jeffers in 1941 witnessed the disappearance into the third quadrant, and the only data referring to the secondary maximum in the second quadrant are one plate in 1946 and Worley's difficult 1960 measurements. The elements represent the data as well as can be expected, and also the earlier Mt. Wilson plates (0^h95 in 1937.4, round in 1927.1, cf. Reuyl 1941). Jeffers' and van Biesbroeck's results are unpublished, and the pair was obviously too faint for Wilson's 18-inch refractor. Two discordances remain: At the 1941 disappearance, the McCormick plates show small but distinct elongations until mid-March while the

TABLE V. Visual observations of 99 Her.

<i>t</i>	θ_{2000}	ρ	<i>n</i>		O—C	
1859.63	346°2	1".71	2	Da	+0°3	+0°16
65.16	353.0	1.90	3	OΣ	−1.4	+0.38
76.95	19.0	1.14	5	β 3 OΣ 2	+0.6	+0.04
80.49	29.0	0.81	4	β	−3.4	−0.02
91.27	291.0	0.66	10	β	+8.8	−0.05
95.91	307.2	0.91	23	Bar 6 Com L 4 A See 3 Moul 2,0 Ho 1	+1.4	−0.10
1898.89	315.6	1.16	26	A 11 Com 4 β Doo GrO 3 Hu 2	+0.6	−0.01
1902.25	321.9	1.36	17	Com 9 A 6 GrO 2	−1.4	+0.06
05.20	326.2	1.44	24	Doo 7 VB 5 Com 4 A Lohse 3 β 2	−2.9	+0.04
09.77	335.9	1.50	30	VB 10 Com 8 Doo 6 A 3 J 2 Wtz 1	−1.2	0.00
12.93	342.0	1.53	18	Fox VB 4 Com V 3 A GrO 2	−0.1	−0.01
14.97	344.9	1.58	16	VB Com 7 A 2	−0.3	+0.03
18.33	349.5	1.59	24	Com 11 Lv Rabe 4 VB 3 A 2	−0.8	+0.04
21.95	357.5	1.53	26	BabO 14 B Przy 4 A Lv 2	+1.5	+0.02
23.92	359.3	1.54	26	BabO B 8 VB GrO 4 Gcb 2	0.0	+0.07
26.17	3.4	1.43	18	BabO 7 VB 5 B 4 Lv Plq 1	+0.1	+0.02
31.32	15.5	1.25	22	GΣ 9 Sim 6 VB 5 A 2	+1.1	+0.06
35.63	28.3	0.95	29	Bz 17 VB 11 Kpr 1	−0.8	+0.06
38.73	50.3	0.62	6	VB 4 Bz 2	−1.0	+0.06
40.56	105.8	0.35	1	VB	+16.1	+0.04
44.41	255.6	0.52	3	VB	+1.9	+0.04
46.01	272.4	0.68	4	VB	−0.9	+0.06
48.47	290.0	0.88	5	VB	−1.2	+0.07
51.07	301.3	0.93	12	Bz 8 FrBz Wils 2	−2.1	−0.04
55.11	315.2	1.12	22	Bz 9 Rabe 7 C Wor 3	−1.0	−0.06
57.04	322.6	1.24	23	Rabe Wor 8 B 7	+1.6	−0.02
59.22	326.4	1.36	26	Wor 11 BabO 8 B 5 Dju 2	+0.8	+0.02
61.73	329.8	1.40	21	B 8 Bz 6 hz 4 Wor 3	−0.7	−0.02
64.46	334.5	1.50	12	Wor Bz 6	−0.7	+0.02
1968.61	343.4	1.48	4	Wor	+1.5	−0.06

TABLE VI. Visual observations of Kpr 112.

<i>t</i>	θ_{2000}	ρ	<i>n</i>		O-C	
1934.6	225°6	0.55	1	Kpr	+4.7	+0.02
38.43	231.8	0.56	4	VB	-1.7	-0.04
42.18	243.3	0.59	4	VB	-0.3	-0.07
48.68	259.0	0.70	6	VB 5 Bz 1	+0.8	0.00
53.50	270.1	0.71	7	VB	+1.5	+0.02
58.04	280.7	0.66	9	B C VB 3	+1.2	+0.03
59.83	284.5	0.67	7	Wor 4 C 3	-0.2	+0.09
62.81	294.9	0.46	7	B 4 C 3	-0.8	-0.02
65.31	309.3	0.37	4	Wor	-1.0	0.00
66.87	327.2	0.24	2	Wor Walk 1	+0.5	-0.04
1971.80	108.7	0.21	3	hz	+0.3	-0.02

simultaneous Sproul images are perfectly round. The elongation is barely visible in 1965, and absent in early 1966 while it should have been conspicuous.

The previous Sproul parallax (Lippincott 1958) was based on the plates to 1956, as measured by C. Key. The material has more than doubled since. The author remeasured all plates on the same machine and continued to 1971. No significant difference was found (hz minus Key = $-0''.004$ in α and $+0''.001$ in δ) but the earlier measurements were given half-weight, owing to their larger scatter. The same three reference stars were used, though with slightly different dependences. The plates were taken without sector.

The present parallax supercedes previous Sproul values. The agreement from both coordinates is good: $0''.240 \pm 0''.004$ in α , and $0''.237 \pm 0''.009$ in δ . Yet most of the other parallaxes (Yale, Yerkes, Mt. Wilson, McCormick, Van Vleck) are smaller, averaging about $0''.22$.

The masses are practically equal, 6.5% of the solar mass each. (At face value of the photocentric motion, the star defined here as the primary would be the

slightly more massive one.) The major part of the uncertainty results from an estimated p.e. $\pm 0''.05$ of the semi-axis major. Thus, the components of Wolf 424 probably have the smallest masses known among visible stars, after the components of L 726-8 have lost that distinction, and they appear to lie below the theoretical stellar-mass limit found by several authors (cf. Straka 1971).

The star BD +9°2637 in the field has a 14th magnitude companion at 8'' separation which is optical.

99 HERCULIS (ADS 11077)

The present orbit is but a slight improvement over van Biesbroeck's elements (1949). The large magnitude difference causes systematic deviations in the separations ρ (Table V). Two later orbits by Makemson, Ames, and Pratt (Makemson 1958) are far less satisfactory.

The Sproul series chiefly consists of three strong groups (1915-18; 1937-47; 1968-70). The plates to 1947 had been measured by Binnendijk. All plates were remeasured on the Ridell machine; a reduction of $-0''.012$ in α and $-0''.019$ in δ was applied to all of Binnendijk's measurements, and the mean of both results adopted. The brightness of the star was reduced by 5 mag. Reference frame and dependences are the same as used by Binnendijk (1948).

The adopted parallax is a weighted mean with the Allegheny, Yerkes, and McCormick results.

$$\text{KUIPER 112} = \text{BD} + 53^\circ 2911 \text{ (ROSS 668)}$$

The orbit computation is provisional, depending largely on the 1971 observation after periastron passage, as shown by Table VI. The position of the star

TABLE VII. Ephemerides (equator of date).

	ADS 8197			Wolf 424		99 Her		Kpr 112	
1971.0	104°6	0°66		321°4	0°77	345°8	1°55	90°7	0°20
72	109.6	0.61		315.5	0.60	347.3	1.56	112.3	0.24
73	115.4	0.56		303.8	0.39	348.8	1.55	128.4	0.27
74	122.4	0.51		265.5	0.20	350.3	1.55	141.7	0.29
75	131.0	0.46		189.7	0.25	351.8	1.54	153.1	0.31
76	141.6	0.42		164.6	0.44	353.4	1.53	163.2	0.33
77	154.5	0.38		153.8	0.55	355.0	1.52	172.2	0.35
78	169.6	0.36		144.1	0.49	356.6	1.50	180.3	0.37
79	186.0	0.35		123.1	0.26	358.2	1.48	187.5	0.39
80	202.1	0.36		26.7	0.18	359.9	1.46	194.1	0.41
81	216.5	0.39		349.8	0.44	1.6	1.44	199.9	0.43
82	228.8	0.42		340.5	0.67	3.5	1.41	205.3	0.46
83	239.2	0.46		336.0	0.83	5.4	1.37	210.1	0.48
84	248.0	0.49		332.2	0.93	7.4	1.34	214.6	0.50
85	255.8	0.52		329.2	0.96	9.5	1.29	218.7	0.52
86	262.8	0.55		326.0	0.91	11.7	1.25	222.4	0.54
87	269.2	0.57		322.2	0.80	14.2	1.20	225.9	0.56
88	275.3	0.58		316.9	0.64	16.9	1.14	229.2	0.58
89	281.2	0.59		307.0	0.43	19.9	1.08	232.3	0.59
1990.0	286.9	0.60		278.1	0.23	23.3	1.00	235.2	0.61

(equinox and epoch 1950) is

$$\alpha = 22^{\text{h}}30^{\text{m}}49^{\text{s}}.3, \quad \delta = +53^{\circ}32'6''.$$

The proper motions given in the double-star and parallax catalogues are erroneous. The two distant companions measured by Abetti in 1912 are optical.

The Sproul plates extend continuously from 1937 to 1971, with a dense coverage of the last five years which turned out to be the periastron interval. No sector was used. Plate constants were computed from the three reference stars BD +52°3239, +53°2909, and 2916. Though many plates were taken at small parallax factors, and many are underexposed, a high parallax accuracy was obtained by the automated measuring. The average of four other parallax determinations agrees with the present result.

Orbit ephemerides are given in Table VII.

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Parallax and Orbital Motion of the Two Nearby Long-Period Visual Binaries Groombridge 34 and ADS 9090

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Measurements of photographs taken with the Sproul 24-inch refractor between 1937 and 1970 on Groombridge 34 A and B yield $\pi_{\text{abs}} = +0''.283 \pm 0''.005$ (p.e.). A provisional orbit was computed, including the Sproul B-A positions and those measured on plates from the McCormick Observatory in addition to all other available data. Measurements from plates taken with the Sproul refractor on ADS 9090 A and B over the interval 1938–1969 yield $\pi_{\text{abs}} = +0''.092 \pm 0''.005$. Relative positions B-A are given.

I. MATERIAL AND MEASURES

GROOMBRIDGE 34 A,B ($0^{\text{h}}12^{\text{m}}7^{\text{s}}$, $+43^{\circ}27'$: 1900) $m_V = 8.07, 11.04$; sp M1e V, M6e V (Gliese 1969), separation $33''$ (1971), and ADS 9090 A,B ($13^{\text{h}}58^{\text{m}}5^{\text{s}}$, $+46^{\circ}49'$: 1900) $m_V = 9.85, 9.95$, sp M3e, M3e (Gliese 1969), separation $3''.6$ (1971), have been photographed with the 24-inch Sproul refractor for over three decades.

For Grb 34 there are 812 exposures on 254 plates distributed over 40 nights between 1937 November 24 and 1970 January 4, with a total weight of 185. Measurements were also made on BD+43° 48, $m_V = 9.4$, close to the center of the plate, which served as a control star. For ADS 9090 there are 470 exposures on 70 plates distributed over 50 nights from 1935 April 25 to 1969 May 21 with a total weight of 114. A rotating sector was used between 1938 and 1943, and again between 1960 and 1969 to reduce the magnitude of ADS 9090 A and B to near equality with the reference stars.

Table I gives the standard frame and other pertinent data relating to the reference stars and the central

stars: the scale factor is $1 \text{ mm} = 18''.87$. The dependences are given for 1950 with their yearly changes, except for BD+43° 48 where no changes were necessary. The positions of the π stars refer to 1950. Grb 34 A,B was measured by Louise Mitchell on the Ridell measuring machine. The plates on ADS 9090 A,B between 1938 and 1959 were measured by F. Jerrold Josties, while the majority of the later plates were measured by Barry H. Feerman. Mitchell measured a few remaining plates along with some remeasurements to test for homogeneity. The remeasurements were averaged with the first measurements with no increase in weight. All measurements on ADS 9090 A,B were made on the St. Clair-Kasten machine.

II. SOLUTIONS FOR PARALLAX AND PROPER MOTION

The nightly means have been represented by the following equations of condition:

$$X = c_x + \mu_x t + \pi P_\alpha$$

$$Y = c_y + \mu_y t + \pi P_\delta,$$