(equinox and epoch 1950) is

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

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.

ACKNOWLEDGMENTS

The author is indebted to the U. S. Naval Observatory, Astronomy and Astrophysics Division, Washington, D. C., for 42 h of measuring time on their automatic machine. He also acknowledges the continued support from the National Science Foundation.

REFERENCES

Aitken, R. G. 1914, *Publ. Lick Obs.* **12**, 72.
Biesbroeck, G. van 1947, *Astron. J.* **53**, 23.
Binnendijk, L. 1948, *ibid.* **54**, 21.
Lippincott, S. L. 1958, *ibid.* **63**, 314.
Makemson, M. 1958, *ibid.* **63**, 41.
Miller, J. A. 1919, *Publ. Sproul Obs.* **4**, 64.
Mitchell, S. A., Alden, H. L., Reuyl, D., Anderson, C. M., Osvalds, V. 1960, *Publ. McCormick Obs.* **14**, parts I, II.
Reuyl, D. 1931, thesis, Utrecht University.
——. 1941, *Publ. Astron. Soc. Pacific* **53**, 336.
Straka, W. C. 1971, *Astrophys. J.* **165**, 109.
Upgren, A. R., and Mesrobian, W. S. 1971, *Astron. J.* **76**, 78.

THE ASTRONOMICAL JOURNAL VOLUME 77, NUMBER 2 MARCH 1972

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

SARAH LEE LIPPINCOTT
Sproul Observatory, Swarthmore College, Swarthmore, Pennsylvania
(Received 23 December 1971)

Measurements of photographs taken with the Sproul 24-inch refractor between 1937 and 1970 on Groombridge 34 A and B yield $\pi_{abs} = +0''.283 \pm 0''.005$ (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 $\pi_{abs} = +0''.092 \pm 0''.005$. Relative positions B−A are given.

I. MATERIAL AND MEASURES

GROOMBRIDGE 34 A,B ($0^{h}12^{m}.7$, +43° 27′: 1900) $m_V = 8.07$, 11.04; sp M1e V, M6e V (Gliese 1969), separation 33″ (1971), and ADS 9090 A,B ($13^{h}58^{m}.5$, +46° 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 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. Feierman. 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:

$$X = c_x + \mu_x t + \pi P_\alpha$$
$$Y = c_y + \mu_y t + \pi P_\delta,$$

TABLE I. Reference stars.

Star	No.	Diameter	m_{pv}	γ_x	Sp.	Standard frame x_s	y_s	$D_{\pi 1}$	ΔD	$D_{\pi 2}$	$D_{\pi 3}$
		mm				mm	mm				
BD+43° 37	1	0.090	11.0		F5	−66.68	+5.79	+0.402	−0.001666	+0.383	+0.304
	2	0.138	10.2		M2	+27.45	+27.84	0.123	+0.001394	0.151	0.151
BD+43° 52	3	0.133	10.2		K0	+39.23	−33.63	0.475	+0.000272	0.466	0.541
				mm							
BD+43° 48	π_3	0.141	10.1	−0.0017	A2	+5.16	−12.12				
Grb. 34A	π_1	0.224	8.07	+0.0007	M1	−4.49	−10.27				
Grb. 34B	π_2	0.088	11.04	+0.0013	M6	−3.07	−9.27		$[x_s^2]=67$, $[y_s^2]=19$ cm^2		
BD+46° 1919	1	0.128	10.8		...	−34.70	−48.97	+0.405	−0.000295		
BD+47° 2110	2	0.123	10.9		...	−5.04	+56.35	0.248	−0.000224		
	3	0.114	11.0		...	+39.74	−7.38	0.347	+0.000519		
ADS 9090A	π_1	0.113	(11.0)*	0.0000	M3e	−1.54	−8.56				
ADS 9090B	π_2	0.104	(11.2)*	0.0000	M3e	−1.49	−8.38		$[x_s^2]=28$, $[y_s^2]=56$ cm^2		

* Sector reduction of 1.2 mag.

where the symbols have the usual meanings; t is referred to 1950.00. The positions X between 1937 and 1941.822 contain the corrections for color equation γ_x, which are given in Table I (Lippincott 1957). Combined least-squares solutions for parallax were made for each component and are given in Table II, together with the differences in the parallaxes found from the separate solutions in x and in y.

The large probable error of unit weight for Grb 34 A is in part due to the large diameter of the images on the plate compared to those of B and of the reference stars. The size of the reference frame measured by $[x_s^2]$ and $[y_s^2]$ given in Table I is reflected in the larger size of the p.e. 1_x for all three measured central stars (Lippincott 1971). Normal points computed from the nightly residuals from the least-squares solutions are given in Table III. No γ_x was used for ADS 9090 since the spectra, or colors of the reference stars, were not available. The positive residuals in the first normal point for both components are probably indicative of the need for applying a color correction.

The reduction to absolute parallax (Heintz 1955) for Grb 34 is $+0.''003$ based on an average magnitude of the reference system. Adopting a straight mean value for the A and B components we find the Sproul $\pi_{\rm abs}=+0.''283\pm0.''005$ (p.e.). The average of the parallax determinations from the McCormick, Yale, and Dearborn Observatories, using the Yale precepts was combined with the Sproul value in the ratio of 1 to 2 to yield $+0.''281\pm0.''004$, which is adopted for further use.

The reduction to absolute parallax for ADS 9090 is $+0.''004$, based on the average magnitude 10.9 of the reference system. The difference between the relative parallax value for A and B seems large but there is no obvious explanation. The straight average for the parallax of A and B yields $\pi_{\rm abs}=+0.''092\pm0.''005$ for the Sproul value. The Yale Catalogue value, which includes determinations from McCormick, Yerkes, Mt. Wilson, and Van Vleck, is $+0.''081\pm0.''006$. For further use a value of $+0.''087\pm0.''005$ for the absolute parallax of ADS 9090 is adotpted.

III. ORBITAL MOTION

Grb 34. Visual observations of Grb 34 A,B were started in 1860; by 1969 the position angle had changed 8° and the separation $3.''6$. This represents very little change in position for orbital analysis but suggests the possibility of a tentative study, which supersedes an earlier one by Hopmann (1958) when less material was available.

Dr. Laurence W. Fredrick kindly loaned us the parallax plates on Grb 34 from the McCormick Observatory. The author measured the relative positions of A and B on 21 McCormick plates between 1923–29 and eight plates in 1964–65. Orientation was made via the trail plate (adjusted to the equator of 2000) in 1929 for the 1923–29 series; the 1964–65 plates were oriented by means of the reference-star positions determined by the Sproul trail plate in 1969. The orientation may possibly be off as much as $\pm0.^\circ1$ on any one plate.

TABLE II. Parallax and proper-motion solutions.

	μ_x	μ_y	$\pi_{\overline{xy}}$	π_{x-y}	p.e. 1	p.e. 1_x	p.e. 1_y
Grb 34 A	$+2.''8908\pm0.''0005$	$+0.''4193\pm0.''0005$	$+0.''273\pm0.''008$	$+0.''012\pm0.''016$	$\pm0.''068$	$\pm0.''071$	$\pm0.''065$
Grb 34 B	+2.8807± 3	+0.3552± 3	+0.286± 5	+0.004± 10	47	38	42
BD+43° 48	+0.008 ± 3	−0.0036± 2	−0.005± 4	−0.001± 8	34	41	27
ADS 9090 A	+0.5876± 4	−0.0430± 4	+0.095± 5	+0.016± 12	34	36	32
ADS 9090 B	+0.5979± 4	−0.0373± 4	+0.082± 6	+0.022± 13	37	37	37

Normal points were formed and are given in Table IV. Normal points of (B−A) formed from the Sproul measurements also appear in Table IV. All other measurements, made available by the U.S.N.O. from the Double Star Catalogue of Observations, were averaged into normal points, converted into $\Delta\alpha \cos\delta$, and $\Delta\delta$, and are given in Table IV. All of the above measurements have been reduced to the equator of 2000. Weights in the second column were assigned with respect to number of observations and method of observation.

From the normal points described above (omitting the observations in 1931.90 and 1937.58, which are both systematically discordant in position angle) a tentative orbit was found by a method appropriate for such a small arc of the orbit. The eccentricity was adopted as 0.00 and a least-squares solution was made from the following equations of condition,

$$X = C_x + \dot{X}t + (\ddot{X}/2)t^2,$$

and a similar equation in the y coordinate. Here X and Y refer to the relative positions $\Delta\alpha \cos\delta$ and $\Delta\delta$ in the sense B−A. The time t is counted from 1940.00.

The Period P was determined from the following relations

$$-(\ddot{X}/X) = \mu^2$$
$$-(\ddot{Y}/Y) = \mu^2,$$

where μ is the mean annual motion in radians.

On the basis of the two determinations of μ^2 a Period of 2600 years was adopted. The following relations

$$\rho^2 = X^2 + Y^2$$
$$\mu^2\rho^2 + \dot{X}^2 + \dot{Y}^2 = \mu^2 a^2 (1 + \cos^2 i)$$

yield

$$a = 41''.15$$
$$i = 61^\circ.4.$$

The 1940 positions for X and Y and the relation

$$X = \Delta\alpha \cos\delta = a \sin\Omega \cos M + a \cos\Omega \sin M \cos i$$
$$Y = \Delta\delta = a \cos\Omega \cos M - a \sin\Omega \sin M \cos i$$

yield

$$T = 1745; \quad \Omega = 45^\circ.3.$$

From the above orbital elements, computed values for the dates of the normal points yield the residuals

TABLE III. Normal-point residuals for parallax solution.

			Unit 0.0001 mm					
			Grb 34 A		Grb 34 B		BD +43°48	
Epoch	$\sum p$	n	v_x	v_y	v_x	v_y	v_x	v_y
1939.11	15	8	−14	−25	−8	−1	−12	−5
41.69	15	7	−28	−4	−19	−7	−7	0
53.41	36	13	+23	+10	+20	+5	+10	0
62.46	28	10	+18	+14	+6	+1	+11	+6
64.51	20	7	+3	+6	−3	−4	−3	+4
65.85	14	5	−4	+13	+2	0	+8	+2
68.35	21	7	−21	−8	−9	+6	−14	+1
69.85	36	13	−7	−12	−6	−4	−4	−6
			ADS 9090 A		ADS 9090 B			
1939.82	6	6	+24	−10	+11	−8		
43.65	5	3	−13	+13	−3	+3		
54.09	10	4	−13	−1	−8	+6		
60.29	18	7	−12	−2	−11	0		
65.52	30	13	+13	+5	+16	−2		
68.25	33	12	−1	−2	−8	−1		
69.20	12	5	−7	−3	+1	+6		

TABLE IV. Grb 34 A,B: Normal points of observations and residuals.

t	wt	Observer	$\Delta\alpha \cos\delta$ (Equator 2000)	$\Delta\delta$ (Equator 2000)	O−C $\Delta\alpha \cos\delta$	O−C $\Delta\delta$
1860.18	1	OΣ 1	31″.94	24″.16	+0″.02	+0″.16
68.50	1	OΣ 2	31.67	23.89	−0.35	+0.33
75.41	1	OΣ 2	31.98	23.37	−0.11	+0.17
82.67	1	OΣ 3	32.11	22.84	−0.05	+0.04
1905.88	2	HNR (pg)	32.26	21.56	−0.05	+0.07
07.49	1	β 5	32.37	21.45	+0.05	+0.05
08.85	2	Th2 Hzg 5 (pg)	32.39	21.12	+0.07	−0.20
18.18	1	Frk 4 VvS 1	32.60	21.58	+0.25	+0.81
25.79	10	Kpr 20 (pg)	32.40	20.24	+0.044	−0.075
31.90	1	Bz 4	32.89	19.68	+0.54	−0.26
37.58	1	Bz 2	32.52	19.08	+0.17	−0.52
37.68	5	LeidenO 11 (pg)	32.41	19.59	+0.061	−0.001
37.80	2	Hzg 1	32.43	19.61	+0.08	+0.03
52.71	5	LowellO (pg)	32.308	18.661	+0.008	+0.010
58.65	2	B 2	32.22	18.38	−0.05	+0.10
64.73	10	WashO (pg)	32.186	17.937	−0.044	+0.054
Sproul		No. of exp. on parallax plates				
1939.11	5	46	32.451	19.574	+0.104	+0.071
41.69	5	63	32.430	19.359	+0.090	+0.017
51.65	5	120	32.292	18.693	−0.013	−0.026
57.41	5	52	32.279	18.396	+0.003	+0.043
62.46	5	124	32.179	18.006	−0.067	−0.022
65.06	5	152	32.174	17.843	−0.053	−0.018
68.35	5	83	32.166	17.679	−0.037	+0.032
69.85	5	172	32.126	17.572	−0.067	+0.022
McCormick						
1925.15	5	24	32.432	20.336	+0.076	−0.018
26.90	2	12	32.464	20.190	+0.107	−0.058
29.85	1	2	32.513	20.062	+0.156	−0.008
65.58	2	20	32.240	17.741	+0.015	−0.087

TABLE V. Elements and ephemeris for Grb 34.

$P = 2600$ yr $\quad e = 0.00 \quad i = 61^\circ.4 \quad \omega = 0.00$
$T = 1745 \quad a = 41''.15 \quad \Omega = 45^\circ.3$

t	$\Delta\alpha \cos\delta$ (Equator 2000)	$\Delta\delta$ (Equator 2000)
1970	32″.19	17″.54
75	32.15	17.21
80	32.10	16.88
85	32.05	16.55
90	32.00	16.22
95	31.94	15.88
2000	31.87	15.54

TABLE VI. ADS 9090. Photographic normal points of ADS 9090 (B−A).

t	$\Delta\alpha \cos\delta$	$\Delta\delta$	ρ	θ	No. exp.
	mm	mm			
1939.82	+0.0450	+0.1712	3″.340	14°.73	22
43.65	498	0.1713	3.366	16.21	26
54.09	541	0.1763	3.480	17.06	55
60.29	577	0.1776	3.524	18.00	83
65.52	606	0.1782	3.552	18.81	104
68.25	+0.0611	+0.1800	3.587	18.75	130
69.20	630	0.1812	3.620	19.17	50

O−C given in the last two columns of Table IV. The average residual of the eight Sproul normal points, for which wt=40, is −0″.005 in x and +0″.015 in y, while the average McCormick residual, with wt=10, is +0″.078 in x and −0″.046 in y. Any further discussion of the orbital elements without a considerably larger arc would be fruitless. Table V gives the elements and ephemeris to 2000.

With the adoption of $P=2600$ years and $a=41''.15=146$ A.U., the sum of masses, $\sum \mathfrak{M}=0.46\odot$. Grb 34 A is suspected of being a spectroscopic binary because of an observed range in the radial velocity of 26 km/sec. However, the observations are insufficient to determine the orbital motion of the subsystem.

Grb 34 A has a Mt. Wilson spectral classification of M2.5 and M4.5e for the B component, which is a known flare star. Curiously the only flare found so far appeared on the Mt. Wilson plate taken in 1946 for spectral classification. In those days one was not so conscious of M-dwarf flares so that the star was classified as a subdwarf; the spectra of subdwarfs and flares look much alike on low-dispersion spectrograms (Joy 1971). The absolute visual magnitudes are 10.3 and 13.3, both slightly faint for their spectral classification.

ADS 9090. The positions $\Delta\alpha \cos\delta$, $\Delta\delta$ in the sense B−A, formed into normal points, are given in Table VI in millimeters, together with the corresponding positions ρ and θ, all referred to the equator year 2000. The number of exposures are given in the last column; in general there are four exposures per plate. The ρ determinations are smaller by about 0″.02 compared to other photographic measurements made over the time interval of the Sproul observations; the position angles are in good agreement. Very little curvature exists, and an attempt at an orbit determination would be very premature.

ACKNOWLEDGMENTS

The author wishes to thank Wulff D. Heintz for his suggestions and advice on the method of handling the provisional orbital analysis of Grb 34. The aid of the National Science Foundation is cheerfully acknowledged.

REFERENCES

Gliese, W. 1969, *Catalogue of Nearby Stars, Edition 1969* (Veröff, Astron. Resh. Inst. Nr. 22).

Heintz, W. D. 1955, *Astrophys. Nachr.* **282**, 221.

Hopmann, J. 1958, *Mitt. Universitäts-Sternwarte Wien*, Band **9**, 153.

Joy, A. 1971, private communication.

Lippincott, S. L. 1957, *Astron. J.* **62**, 55.

——. 1971, *Publ. Leander McCormick Observatory*, XVI, 59.