

STELLAR PARALLAX WORK AT THE McCORMICK OBSERVATORY

By S. A. MITCHELL

It has seemed advisable at the present time to publish the first measures of stellar parallaxes obtained by photography at the University of Virginia. It was generally conceded by the Clarks, while they were alive, that the 26-inch refractor was one of the best that they had ever made. Certainly the definition is excellent, with an almost utter absence of stray light.

Photographs were made with a yellow color-filter and Cramer isochromatic plates. The star images are small and clean-cut and lend themselves to accurate measurement, as the following results show. The plates, 5×7 inches, were measured on the Repsold measuring machine, which was kindly loaned by Columbia University. The methods of exposure, measurement, and reduction were substantially the same as those explained in this *Journal* by Schlesinger in Vols. 32, 33, and 34, and by Slocum and Mitchell in 38, 1, 1913.

70 Ophiuchi ($18^{\text{h}}0^{\text{m}}, +2^{\circ}31'$)

This system has a very large proper motion, $1''.13$ per year. It has a period of 88 years, and has completed one revolution since its discovery. This star was put on the parallax program because it was on the Yerkes program,[†] and because it was desirable to see how accurately measures could be made on such a pair. The components are of magnitudes 4.3 and 6.0, and the present distance about $4''$. As the scale of the photographs is $1 \text{ mm} = 20''.8$, the stars were separated by 0.2 mm. A rotating sector was used to cut down the brightness of the two stars. The sector was opened so that the fainter star was nearly of the same brightness as the comparison stars. This, of course, made the principal star brighter than would ordinarily be used for parallax determinations. The

[†]Slocum, *Astrophysical Journal*, 41, 237, 1915.

two stars were well separated when definition and guiding were both good.

The measures and calculations were carried out to 0.1 micron. The final values were turned into angle by multiplying by the value 1 mm = 20".8.

The details of the plates follow.

TABLE I
PLATES OF 70 OPHIUCHI

No.	Date	Hour Angle	Observers	Quality of Images
1.....	1914 May 2	+0 ^h .4	M	Good
6.....	May 9	-0.4	M	Fair-good
7.....	May 9	+0.2	M	Good
10.....	May 10	+0.3	M	Fair-good
13.....	May 11	-1.5	M	Fair-good
210.....	Sept. 9	+1.1	M	Fair
225.....	Sept. 13	+0.6	M, G	Poor
249.....	Sept. 15	+0.6	M	Fair-good
336.....	Sept. 28	+1.0	M	Fair
353.....	Sept. 30	+1.3	M	Fair-good
365.....	Oct. 1	+1.3	M, Ol	Fair
1119.....	1915 Mar. 27	-1.2	G	One good
1120.....	Mar. 27	-0.5	G	Good
1178.....	Apr. 11	0.0	A	Fair
1183.....	Apr. 12	-1.0	M	Fair
1203.....	Apr. 14	-0.9	A	Good
1213.....	Apr. 15	-0.9	M	Fair-good

M=S. A. Mitchell; Ol=Charles P. Olivier; A=Harold Alden; G=P. H. Graham.

COMPARISON STARS

No.	Diameter	X (Right Ascension)	Y (Declination)	Dependence
	mm	mm	mm	
1.....	0.12	-41.0	-23.2	+0.212
2.....	.12	-35.2	+35.0	.240
3.....	.10	+36.8	-29.5	.263
4.....	.13	+39.4	+17.7	+0.285
Principal star.....	.22	+ 3.7	+ 0.9	.....
Companion.....	0.12	+ 3.8	+ 0.7	.....

TABLE 2
REDUCTIONS FOR 70 OPHIUCHI, PRINCIPAL STAR

Plate	Solution (<i>m</i>)	Weight (<i>p</i>)	Parallax Factor (<i>P</i>)	Time in Days (<i>t</i>)	Residual (<i>v</i>)	$\sqrt{p \cdot v}$ in Arc
	mm				mm	
1.....	-0.0490	1.0	+0.752	-145	+0.0006	+0".01
6.....	-0.0486	0.9	+0.670	-138	-0.0003	-0.01
7.....	-0.0492	1.0	+0.670	-138	+0.0003	+0.01
10.....	-0.0500	0.9	+0.657	-137	+0.0010	+0.02
13.....	-0.0474	0.9	+0.644	-136	-0.0017	-0.03
216.....	-0.0578	0.6	-0.980	-15	-0.0017	-0.03
225.....	-0.0582	0.4	-0.990	-11	-0.0014	-0.02
240.....	-0.0582	0.9	-0.995	-9	-0.0014	-0.03
336.....	-0.0600	0.7	-0.998	+4	+0.0005	+0.01
353.....	-0.0600	0.9	-0.994	+6	+0.0005	+0.01
365.....	-0.0624	0.7	-0.992	+7	+0.0030	+0.05
1119.....	-0.0449	0.7	+0.992	+184	+0.0007	+0.01
1120.....	-0.0442	1.0	+0.992	+184	.0000	.00
1178.....	-0.0471	0.7	+0.942	+199	+0.0026	+0.04
1183.....	-0.0468	0.7	+0.929	+200	+0.0022	+0.04
1203.....	-0.0432	1.0	+0.917	+202	-0.0014	-0.03
1213.....	-0.0418	0.9	+0.908	+203	-0.0029	-0.06

The normal equations are:

$$\begin{aligned}
 13.9c + 3.155\mu + 3.7591\pi &= -0.7018 \\
 +28.2249\mu + 4.8637\pi &= -0.1104 \\
 +10.7958\pi &= -0.1184
 \end{aligned}$$

from which

$$\begin{aligned}
 c &= -0.05255 \\
 \mu &= +0.00075 = +0".0157 \\
 \pi &= +0.00699 = +0".145 \pm 0".007
 \end{aligned}$$

Probable error corresponding to unit weight ± 0.00105
 $= \pm 0".022.$

TABLE 3
REDUCTION FOR 70 OPHIUCHI, COMPANION

Plate	Solution (<i>m</i>)	Weight (<i>p</i>)	Parallax Factor (<i>P</i>)	Time in Days (<i>t</i>)	Residual (<i>v</i>)	$\sqrt{p \cdot v}$ in Arc
	mm				mm	
1.....	+0.0768	1.0	+0.752	-145	+0.0012	+0".02
6.....	+ .0808	0.9	+ .670	-138	- .0032	- .06
7.....	+ .0777	1.0	+ .670	-138	- .0001	.00
10.....	+ .0762	0.9	+ .657	-137	+ .0014	- .03
13.....	+ .0772	0.9	+ .644	-136	+ .0003	+ .01
216.....	+ .0678	0.6	- .980	- 15	+ .0014	+ .02
225.....	+ .0726	0.4	- .990	- 11	- .0034	- .04
249.....	+ .0682	0.9	- .995	- 9	+ .0011	+ .02
336.....	+ .0726	0.7	- .998	+ 4	- .0028	- .05
353.....	+ .0694	0.9	- .994	+ 6	+ .0005	+ .01
365.....	+ .0681	0.7	- .992	+ 7	+ .0018	+ .03
1119.....	+ .0896	0.7	+ .992	+184	+ .0027	+ .05
1120.....	+ .0928	1.0	+ .992	+184	- .0005	- .01
1178.....	+ .0935	0.7	+ .942	+199	- .0010	- .02
1183.....	+ .0919	0.7	+ .929	+200	+ .0005	+ .01
1203.....	+ .0934	1.0	+ .917	+202	- .0010	- .02
1213.....	+0.0925	0.9	+0.908	+203	-0.0001	0.00

The normal equations are:

$$\begin{aligned} 13.9 c + 3.155 \mu + 3.7591 \pi &= +1.1193 \\ +28.2249 \mu + 4.8637 \pi &= +0.3895 \\ +10.7958 \pi &= +0.3955 \end{aligned}$$

from which

$$\begin{aligned} c &= +0.07752 \\ \mu &= +0".00377 = +0".0782 \\ \pi &= +0.00794 = +0".165 \pm 0".007 \end{aligned}$$

Probable error corresponding to unit weight ± 0.00105
 $= \pm 0".022$.

The equations for 70 Ophiuchi might have been solved by allowing for the orbital motion. The above-described photographs, however, were all taken within a year, and in this interval of time it was assumed that the orbital motion was linear, or in other words, proportional to the time. Orbital motion is, therefore, included in the determination of μ , the proper motion in 100 days.

Other determinations of the parallax of this system are:

Authority	Method	Principal Star A	Center of Gravity $\frac{AB}{2}$
Krueger.....	Heliometer	.....	+0".156±0".010
Schur.....	Heliometer	.....	+ .286± .031
Jewdokimov.....	Meridian circle	.....	+ .279± .105
Flint.....	Meridian circle	0".19± 0".029	.....
Slocum.....	Photography	0".212±0".007	.....

Cygni 6 (19^h9^m, +49°37')

This is a system of the 61 Cygni class with nearly common proper motion of 0".65 per year in position angle 344°. The stars are of type K, and of magnitudes 6.6 and 6.8. The rotating sector was used. According to Adams and Kohlschütter,[†] these stars, though separated by nearly 10", undoubtedly form a physical system, since they have radial velocities of -41 and -39 km respectively. The values of the parallaxes below and their common proper motion confirm this notion.

TABLE I
PLATES OF CYGNI 6

Plate	Date	Hour Angle	Observers	Quality of Image
52.....	1914 May 30	-0 ^h 8	M	Fair-good
53.....	May 30	-0.3	M	Good
58.....	May 31	-1.1	M	Fair
59.....	May 31	-0.7	M	Good
212.....	Sept. 7	-0.2	M	Good
237.....	Sept. 14	-0.1	M, A	Good
278.....	Sept. 21	-0.5	M	Good
279.....	Sept. 21	0.0	M	Good
291.....	Sept. 22	-0.4	M	Fair-good
292.....	Sept. 22	0.0	M	Good
346.....	Sept. 29	-0.1	M	Good
1184.....	1915 Apr. 12	-1.3	M	Fair
1185.....	Apr. 12	-1.0	M	Good
1196.....	Apr. 13	-1.1	Ol	Good
1204.....	Apr. 14	-1.2	A	Good
1205.....	Apr. 14	-0.9	A	Good

[†] *Astrophysical Journal*, 39, 346, 1914.

COMPARISON STARS

No.	Diameter	X (Right Ascension)	Y (Declination)	Dependence
	mm	mm	mm	
1.....	0.15	-55.3	-27.8	+0.192
2.....	.20	-25.1	+41.2	+ .185
3.....	.10	+ 9.6	-32.7	+ .209
4.....	.10	+10.0	+32.6	+ .196
5.....	.21	+60.8	-13.3	+0.218
Parallax star, π_1.....	.18	+ 1.9	- 1.2	.....
Parallax star, π_2	0.16	+ 2.1	- 0.9	.....

TABLE 2

REDUCTION FOR CYGNI 6 (SEQ). BRIGHTER STAR

Plate	Solution (m)	Weight (p)	Parallax Factor (P)	Time in Days (t)	Residual (v)	$\sqrt{p \cdot v}$ in Arc
	mm				mm	
52.....	-0.0032	0.9	+0.608	-137	+0.0007	+0".01
53.....	- .0020	1.0	+ .608	-137	- .0005	- .01
58.....	- .0008	0.7	+ .595	-136	- .0017	- .03
59.....	- .0035	1.0	+ .595	-136	+ .0010	+ .02
212.....	- .0094	1.0	- .852	- 37	+ .0004	+ .01
237.....	- .0082	1.0	- .906	- 30	- .0012	- .02
278.....	- .0094	1.0	- .948	- 23	- .0003	- .01
279.....	- .0103	1.0	- .948	- 23	+ .0006	+ .01
291.....	- .0103	0.9	- .952	- 22	+ .0006	+ .01
292.....	- .0116	1.0	- .952	- 22	+ .0019	+ .04
346.....	- .0081	1.0	- .978	- 15	- .0019	- .04
1184.....	- .0080	0.7	+ .990	+180	- .0030	- .05
1185.....	- .0112	1.0	+ .990	+180	+ .0002	.00
1196.....	- .0116	1.0	+ .988	+181	+ .0006	+ .01
1204.....	- .0115	1.0	+ .986	+182	+ .0004	+ .01
1205.....	-0.0120	1.0	+0.986	+182	+0.0009	+0.02

The normal equations are:

$$\begin{aligned} 15.2 c + 1.897 \mu + 0.3689\pi &= -0.1271 \\ +22.5665 \mu + 7.0162\pi &= -0.0655 \\ +11.9135\pi &= +0.0053 \end{aligned}$$

from which

$$\begin{aligned} c &= -0.00805 \\ \mu &= -0.00299 = -0".0622 \\ \pi &= +0.00245 = +0".051 \pm 0".006 \end{aligned}$$

Probable error corresponding to unit weight ± 0.00086
 $= \pm 0".018$.

TABLE 3
REDUCTION FOR CYGNI 6 (PR). FAINTER STAR

Plate	Solution (<i>m</i>)	Weight (<i>p</i>)	Parallax Factor (<i>P</i>)	Time in Days (<i>t</i>)	Residual (<i>v</i>)	$\sqrt{p \cdot v}$ in Arc
	mm				mm	
52.....	+0.0541	0.9	+0.608	-137	+0.0018	+0".04
53.....	+ .0543	1.0	+ .608	-137	+ .0016	+ .03
58.....	+ .0588	0.7	+ .595	-136	- .0021	- .05
59.....	+ .0570	1.0	+ .595	-136	- .0012	- .02
212.....	+ .0508	1.0	- .852	- 37	- .0012	- .02
237.....	+ .0475	1.0	- .906	- 30	+ .0018	+ .04
278.....	+ .0499	1.0	- .948	- 23	- .0009	- .02
279.....	+ .0481	1.0	- .948	- 23	+ .0009	+ .02
291.....	+ .0482	0.9	- .952	- 22	+ .0007	+ .01
292.....	+ .0474	1.0	- .952	- 22	+ .0015	+ .03
346.....	+ .0513	1.0	+ .978	- 15	- .0027	- .06
1184.....	+ .0468	0.7	+ .990	+180	- .0020	- .04
1185.....	+ .0452	1.0	+ .990	+180	- .0004	- .01
1196.....	+ .0446	1.0	+ .988	+181	+ .0002	.00
1204.....	+ .0432	1.0	+ .986	+182	+ .0015	+ .03
1205.....	+0.0446	1.0	+0.986	+182	+0.0001	0.00

The normal equations are:

$$\begin{aligned} 15.2 c + 1.897 \mu + 0.3689\pi &= +0.7499 \\ +22.5665 \mu + 7.0162\pi &= +0.0230 \\ +11.9135\pi &= +0.0130 \end{aligned}$$

from which

$$\begin{aligned} c &= +0.04975 \\ \mu &= -0.00370 = -0".0770 \\ \pi &= +0.00173 = +0".036 \pm 0".007 \end{aligned}$$

Probable error corresponding to unit weight ± 0.00107
= $\pm 0".022$.

Various determinations of the parallax of this system have been as follows:

Authority	Method	Brighter Star A	Fainter Star B	Center of Gravity $\frac{AB}{2}$
Ball.....	Equatorial (dis- tance).....	+0".504±0".060	.....	.....
Ball.....	Equatorial (pos. ang.)	+0.383±0.13	.....	.....
Ball.....	Equatorial (dist. and pos. ang.)	+0.482±0.054	.....	.....
A. Hall.....	Equatorial ($\Delta\delta$)	-0.094±0.025	.....	.....
A. Hall.....	Equatorial ($\Delta\delta$)	-0.137±0.017	.....	.....
A. Hall.....	Equatorial ($\Delta\alpha$)	+0.023±0.009	.....	.....
Chase.....	Heliometer	.....	-0.027±0.039	.....
Kostinsky....	Photography	+0.040±0.03	+0.05±0.03	+0.04±0.02
Russell.....	Photography	-0.011±0.049	+0.075±0.063
Flint.....	Meridian circle	0.045±0.021
Jewdokimov..	Meridian circle	0.094±0.055

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LEANDER MCCORMICK OBSERVATORY
UNIVERSITY OF VIRGINIA
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