MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXVIII. SUPPLEMENTARY NUMBER. No. 9

On the Parallax and Proper Motion of the Double Star Krueger 60 (*Burnham, Gen. Cat.*, 11761). By E. E. Barnard. (Plate 14.)

The History of Krueger 60.

Professor Krueger, in his catalogue of the Astronomische Gesellschaft, covering the zone $+55^\circ$ to $+65^\circ$, noted with the meridian instrument many stars which were double. He made a rough estimate of the quadrant and distances of these stars and of their magnitudes.

In 1890 Professor Burnham measured 67 stars from Krueger's list with the 12-inch and 36-inch telescopes of the Lick Observatory (*Pub. L.O.*, vol. ii.). The star No. 60 was among those measured. Krueger's note on this object is :—

"Dupl. 12″ pr. com. 9·3."

In measuring the principal star, Professor Burnham found that it was a wide and unequal double.

1890·788	Pos.	178°·8	Dist.	2″·32 (1 n)	9m·0 –	12m	A B
		56·3		26·82 (1 n)		9·2	A C

Of these A C is the Krueger pair.

No other measures were made of these stars until 1898, when Dr. Eric Doolittle remeasured them with the 18-inch Brashear telescope of the Flower Observatory (*A.J.*, vol. xxi. p. 47).

Doolittle's measures showed that the pair A B had a strong proper motion (0″·93 in the direction 247°·9). His measures are—

	°	″	m	m	
1898·446	140·66	3·19	9·1	– 10·5	A B } 5 n.
	58·71	34·39		9·4	A C }

Subsequent measures fully confirmed these results.

In *A.J.*, vol. xxi. p. 64, I have given measures of these stars which are in accord with the motion derived by Doolittle. (In the

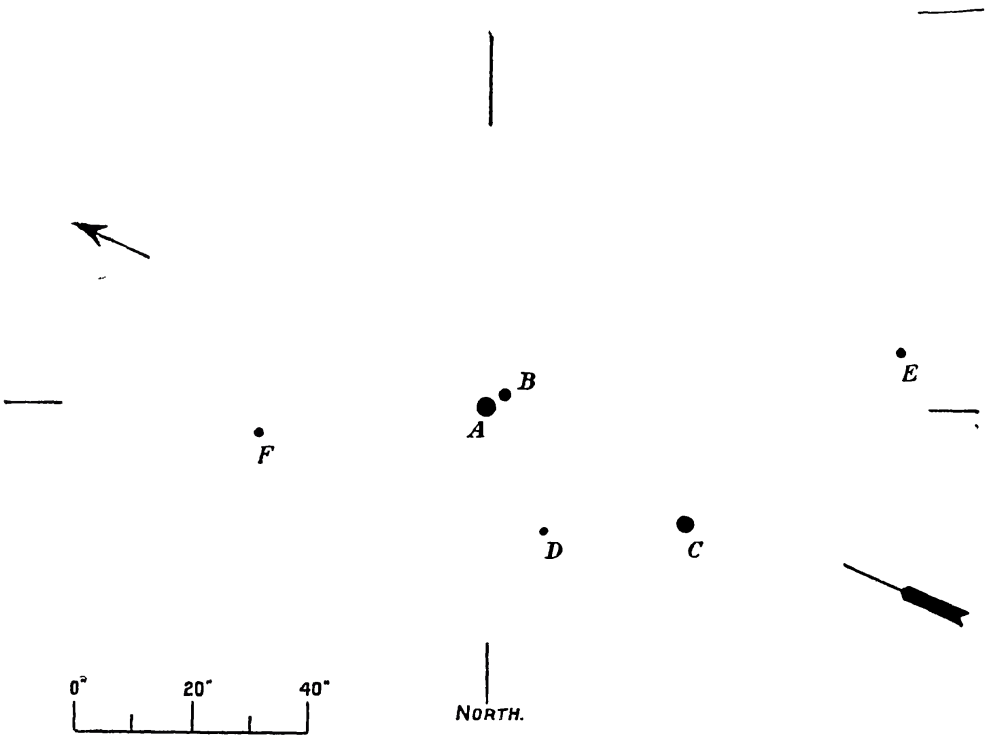


FIG. 1.

measures of A B in that paper there is a misprint of 2″·23 for 3″·23.) In *A.J.*, vol. xxiii.* pp. 169–172, I have given more observations, with a diagram showing the probable orbital motion of A B. A few years' measures soon showed that this was really a physical pair in rather rapid orbital motion. I also called attention to the probable proximity of these stars to our solar system. Acting on this last idea, I began in 1900 a series of measures, with the 40-inch telescope, of A and C for the parallax of A.

* On p. 171 in that paper, the motion in right ascension should be – 0ˢ·107 instead of – 1ˢ·606, and on p. 172 the seconds in the right ascension should be 32ˢ·00 instead of 32ˢ·69. In that paper I derived the proper motion 0″·951 in the direction 246°·3.

In the *Astrophysical Journal*, vol. xx. p. 128, for Sept. 1904, Dr. Schlesinger published his results of the parallax of A derived from photographs made with the 40-inch telescope. Dr. Schlesinger found a parallax of about $\frac{1}{4}''$, verifying the prediction of its nearness to us. I will give, later on, his final values for the parallax.

Additional measures are given by Professor Burnham in *Publications of the Yerkes Observatory*, vol. ii., 1903, p. 67.

This is briefly the history of this remarkable stellar system.

In May of 1903 I measured the position of A with respect to Helsingfors-Gotha A.G.C. 13177. From the measures the place of A is

$$1903{\cdot}0\ \alpha = \quad 22^{h}\ 24^{m}\ 32^{s}{\cdot}09$$
$$\delta = +57^{\circ}\ 12'\ 38''{\cdot}5$$

Proper motion $-0^{s}{\cdot}107 - 0''{\cdot}382$.

The star is Helsingfors-Gotha A.G.C. 13170.

Determination of the Parallax of A.

The present paper gives an investigation of the parallax of the star A from the visual micrometer measures made with the 40-inch telescope.

The micrometer screw and the tube of the 40-inch are both of steel. I have found from about ten years' experimental measures in the Pleiades (which are soon to be published) that the focus of the 40-inch glass shortens from summer to winter by an extreme change of $\frac{3}{4}$ inch. In the meantime the steel tube shortens $\frac{1}{2}$ inch. The temperature change in the micrometer screw will correct $\frac{1}{2}$ inch of the total change of the focus of the object-glass. There remains uncorrected, therefore, $\frac{1}{4}$ inch of the extreme focal change. The exact amount of this uncorrected change, from the measures of the Pleiades referred to above, is 0·0032 inch (0·081 mm.) for each degree of temperature. This would cause an extreme error in the measures of Krueger 60 for temperature of not quite $0''{\cdot}01$, and in the main it would not be appreciable. I have, therefore, not thought it necessary to correct the observations for temperature changes. I have not felt sure that the correction would be real. The corrections for aberration, being insensible, have been omitted.

All of the calculations for the parallax of this star were made, under my supervision, by my niece, Miss Mary Ross Calvert, who, through the courtesy of Mr. Andrew Carnegie, is at present my assistant. They have been carefully checked throughout, and seem to be free from errors. The observations, corrected for refraction, were first freed from proper motion. The parallax factors were then computed by Bessel's formulæ, as given in Chauvenet, vol. i. p. 695, fifth edition, where the parallax factor is

$$Rm \cos (\odot - M),$$

in which R and ⊙ are the distance and longitude of the Sun; m and M being derived from the formulæ

$$m \cos M = \sin \alpha \sin P + \cos \alpha \sin \delta \cos P$$
$$m \sin M = (-\cos \alpha \sin P + \sin \alpha \sin \delta \cos P) \cos \omega - \cos \delta \cos P \sin \omega^*$$

where P is the position-angle of the stars, α and δ the right ascension and declination, and ω the obliquity of the ecliptic.

The formula

$$n + ax + by + cp = 0$$

was used for the equations of condition. In all, there were seventy-six equations of condition. From these the normal equations were derived in the usual manner. The normal equations were solved by the ordinary methods of elimination. As a check, they were also solved by Chauvenet's "second method of computing the weights of unknown quantities" (Chauvenet, vol ii., art. 35, p. 516), from which the weights were also derived. From these last, the probable errors were computed by the formulæ.

Probable error of parallax

$$= \frac{P}{\sqrt{wp}}$$

where wp is the weight of the parallax and

$$P = \pm 0{\cdot}6745 \sqrt{\frac{\Sigma v^2}{n-3}},$$

v being the residuals derived by substituting the known values of x, y, and p in the equations of condition. Similarly for the probable errors of x and y, using for them the same value of P.

This method of determining the probable errors was kindly communicated to me by Dr. Schlesinger.

The proper motion used in these calculations was derived by me from a comparison with Professor Burnham's measures of A C in 1890 and my measures in the last of 1905. This value was $0''{\cdot}968$ in the direction $246°{\cdot}49$.

The corrections for motion, to the observed distances, were computed by the formulæ given on page 696, vol. i., of Chauvenet's *Theoretical and Practical Astronomy*.

In Table I. are given the observations and their reduction to 1901·0, the last column being the residuals from the mean of the corrected distances. Table II. contains the equations of condition.

* We have found that this last term is incorrectly given in Bessel's original paper, *A.N.* 366, pp. 83–84, as $-\sin \delta \cos P \sin \omega$.

The same error occurs in the second of the formulæ for determining the parallax from the position-angle on the same page of *A.N.*, 366, the last term of which should also be $-\cos \delta \cos P \cos \omega$.

TABLE I.

Reductions to 1901·0.

			Pos. Ang.	Dist.	Cor'n for motion.	1901·0.	Resid. from mean.
			°	″	″	″	″
1900·937	Dec.	8	59·27	36·88	+0·061	36·941	−0·423
·940		9	59·52	36·67	+0·058	36·728	−0·210
·945		11	59·25	36·69	+0·053	36·743	−0·225
·948		12	59·16	36·66	+0·050	36·710	−0·192
1901·729	Sept.	23	59·65	37·18	−0·700	36·480	+0·038
·731		24	59·84	37·20	−0·702	36·498	+0·020
·748		30	59·86	37·30	−0·719	36·581	−0·063
·751	Oct.	1	59·52	37·15	−0·722	36·428	+0·090
·783		13	59·63	37·43	−0·752	36·678	−0·160
·805		21	59·48	37·36	−0·774	36·586	−0·068
·827		29	59·49	37·34	−0·795	36·545	−0·027
1902·744	Sept.	29	59·64	38·29	−1·676	36·614	−0·096
·764	Oct.	6	59·69	38·10	−1·695	36·405	+0 113
·766		7	59·64	38·32	−1·697	36·623	−0·105
·786		14	59·60	38·50	−1·716	36·784	−0·266
1903·380	May	19	59·55	38·61	−2·287	36·323	+0·195
·396		25	59·57	38·69	−2·302	36·388	+0·130
·418	June	2	58·89	38·84	−2·323	36·517	+0·001
·437		9	59·18	38·76	−2·342	36·418	+0·100
·454		15	59·35	38·71	−2·358	36·352	+0·166
·473		22	59·59	38·74	−2·376	36·364	+0·154
·492		29	59·57	38·74	−2·394	36·346	+0·172
·495		30	59·22	38·71	−2·397	36·313	+0·205
·511	July	6	59·54	38·84	−2·413	36·427	+0·091
·514		7	59·70	38·71	−2·416	36·294	+0·224
·530		13	59·67	38·73	−2·431	36·299	+0·219
·533		14	59·50	38·78	−2·434	36·346	+0·172
·549		20	59·50	38·88	−2·449	36·431	+0·087
·552		21	59·72	38·76	−2·452	36·308	+0·021
·569	July	27	59·35	38·70	−2·468	36·232	+0·286
·590	Aug.	4	59·57	38·72	−2·489	36·231	+0·287
·607		10	59·33	38·86	−2·505	36·355	+0·163
·626		17	59·61	38·88	−2·523	36·357	+0·161
·645		24	59·84	39·02	−2·541	36·479	+0·039
·664		31	59·60	39·07	−2·560	36·510	+0·008
·667	Sept.	1	59·72	39·20	−2·563	36·637	−0·119
·725		22	59·81	39·31	−2·618	36·692	−0·174

TABLE I.—*Reductions to* 1901·0—continued.

			Pos. Ang.	Dist.	Cor'n for motion.	1901·0.	Resid. from mean.
			°	″	″	″	″
1903·741	Sept.	28	60·02	39·20	−2·634	36·566	−0·048
·757	Oct.	5	59·66	39·37	−2·649	36·721	−0·203
·782		13	59·74	39·37	−2·673	36·697	−0·179
·799		19	59·99	39·45	−2·689	36·761	−0·243
·818		26	59·50	39·38	−2·708	36·672	−0·154
·821		27	59·71	39·48	−2·711	36·769	−0·251
·827	Nov.	2	59·53	39·41	−2·726	36·684	−0·166
·897		24	59·45	39·66	−2·784	36·876	−0·358
·974	Dec.	22	59·40	39·61	−2·858	36·752	−0·234
1904·007	Jan	3	59·05	39·76	−2·889	36·871	−0·353
·335	May	2	59·02	39·73	−3·205	36·525	−0·007
·338		3	59·03	39·48	−3·207	36·273	+0·245
·374		16	58·73	39·50	−3·242	36·258	+0·260
·393		23	59·17	39·55	−3·260	36·290	+0·228
·434	June	7	59·16	39·78	−3·300	36·480	+0·038
·502	July	2	58·91	39·62	−3·365	36·255	+0·263
·521		9	59·34	39·62	−3·383	36·237	+0·281
·527		11	59·27	39·73	−3·389	36·341	+0·177
·560		23	59·47	39·80	−3·421	36·379	+0·139
·570		27	59·41	39·78	−3·430	36·350	+0·168
·584	Aug.	1	59·74	39·74	−3·444	36·296	+0·222
·598		6	59·51	39·69	−3·457	36·233	+0·285
·603		8	59·64	39·76	−3·462	36·298	+0·220
·623		15	59·30	39·85	−3·481	36·369	+0·149
·642		22	59·60	40·04	−3·499	36·541	−0·023
·655		27	59·69	40·08	−3·512	36·568	−0·050
·661		29	59·77	39·95	−3·518	36·432	+0·086
·675	Sept.	3	59·29	40·03	−3·531	36·499	+0·019
·680		5	59·57	40·12	−3·536	36·584	−0·066
·732		24	59·79	40·10	−3·586	36·514	+0·004
·751	Oct.	1	59·43	40·22	−3·604	36·616	−0·098
·790		15	59·87	40·25	−3·642	36·608	−0·090
·795		17	59·68	40·19	−3·647	36·543	−0·025
·828		29	59·59	40·25	−3·678	36·572	−0·054
·833		31	59·62	40 40	−3·683	36·717	−0·199
·866	Nov.	12	59·26	40·53	−3·715	36·815	−0·297
1904·905		26	59·33	40·56	−3·752	36·808	−0·290
1905·904	Nov.	26	59 70	41·46	−4·605	36·855	−0·337
·910		28	59·55	41·38	−4·611	36·769	−0·251

TABLE II.

Equations of Condition.

For x.

1900 Dec.	8.	$-0.423 + x - 0.063y + 0.939p = 0$
	9.	$-0.210 + x - 0.060y + 0.944p = 0$
	11.	$-0.225 + x - 0.055y + 0.951p = 0$
	12.	$-0.192 + x - 0.052y + 0.966p = 0$
1901 Sept.	23.	$+0.038 + x + 0.729y - 0.032p = 0$
	24.	$+0.020 + x + 0.731y - 0.011p = 0$
	30.	$-0.063 + x + 0.748y + 0.091p = 0$
Oct.	1.	$+0.090 + x + 0.751y + 0.102p = 0$
	13.	$-0.160 + x + 0.783y + 0.303p = 0$
	21.	$-0.068 + x + 0.805y + 0.427p = 0$
	29.	$-0.027 + x + 0.827y + 0.545p = 0$
1902 Sept.	29.	$-0.096 + x + 1.744y + 0.068p = 0$
Oct.	6.	$+0.113 + x + 1.764y + 0.184p = 0$
	7.	$-0.105 + x + 1.766y + 0.201p = 0$
	14.	$-0.266 + x + 1.786y + 0.314p = 0$
1903 May	19.	$+0.195 + x + 2.380y - 0.826p = 0$
	25.	$+0.130 + x + 2.396y - 0.884p = 0$
June	2.	$+0.001 + x + 2.418y - 0.936p = 0$
	9.	$+0.100 + x + 2.437y - 0.986p = 0$
	15.	$+0.166 + x + 2.454y - 0.997p = 0$
	22.	$+0.154 + x + 2.473y - 1.006p = 0$
	29.	$+0.172 + x + 2.492y - 1.002p = 0$
	30.	$+0.205 + x + 2.495y - 1.010p = 0$
July	6.	$+0.091 + x + 2.511y - 0.990p = 0$
	7.	$+0.224 + x + 2.514y - 0.983p = 0$
	13.	$+0.219 + x + 2.530y - 0.952p = 0$
	14.	$+0.172 + x + 2.533y - 0.952p = 0$
	20.	$+0.087 + x + 2.549y - 0.914p = 0$
	21.	$+0.210 + x + 2.552y - 0.902p = 0$
	27.	$+0.286 + x + 2.569y - 0.858p = 0$
Aug.	4.	$+0.287 + x + 2.590y - 0.775p = 0$
	10.	$+0.163 + x + 2.607y - 0.712p = 0$
	17.	$+0.161 + x + 2.626y - 0.620p = 0$
	24.	$+0.039 + x + 2.645y - 0.519p = 0$
	31.	$+0.008 + x + 2.664y - 0.417p = 0$
Sept.	1.	$-0.119 + x + 2.667y - 0.400p = 0$
	22.	$-0.174 + x + 2.725y - 0.055p = 0$
	28.	$-0.048 + x + 2.741y + 0.050p = 0$

TABLE II.—*Equations of Condition—For* x—continued.

1903 Oct.	5.	$-0.203 + x + 2.757\,y + 0.164\,p = 0$
	13.	$-0.179 + x + 2.782\,y + 0.295\,p = 0$
	19.	$-0.243 + x + 2.799\,y + 0.394\,p = 0$
	26.	$-0.154 + x + 2.818\,y + 0.495\,p = 0$
	27.	$-0.251 + x + 2.821\,y + 0.510\,p = 0$
Nov.	2.	$-0.166 + x + 2.837\,y + 0.595\,p = 0$
	24.	$-0.358 + x + 2.897\,y + 0.839\,p = 0$
Dec.	22.	$-0.234 + x + 2.974\,y + 0.977\,p = 0$
1904 Jan.	3.	$-0.353 + x + 3.007\,y + 0.960\,p = 0$
May	2.	$-0.007 + x + 3.335\,y - 0.638\,p = 0$
	3.	$+0.245 + x + 3.338\,y - 0.651\,p = 0$
	16.	$+0.260 + x + 3.374\,y - 0.801\,p = 0$
	23.	$+0.228 + x + 3.393\,y - 0.879\,p = 0$
June	7.	$+0.038 + x + 3.434\,y - 0.980\,p = 0$
July	2.	$+0.263 + x + 3.502\,y - 1.003\,p = 0$
	9.	$+0.281 + x + 3.521\,y - 0.973\,p = 0$
	11.	$+0.177 + x + 3.527\,y - 0.967\,p = 0$
	23.	$+0.139 + x + 3.560\,y - 0.886\,p = 0$
	27.	$+0.168 + x + 3.570\,y - 0.855\,p = 0$
Aug.	1.	$+0.222 + x + 3.584\,y - 0.799\,p = 0$
	6.	$+0.285 + x + 3.598\,y - 0.747\,p = 0$
	8.	$+0.220 + x + 3.603\,y - 0.723\,p = 0$
	15.	$+0.149 + x + 3.623\,y - 0.640\,p = 0$
	22.	$-0.023 + x + 3.642\,y - 0.511\,p = 0$
	27.	$-0.050 + x + 3.655\,y - 0.467\,p = 0$
	29.	$+0.086 + x + 3.661\,y - 0.434\,p = 0$
Sept.	3.	$+0.019 + x + 3.675\,y - 0.364\,p = 0$
	5.	$-0.066 + x + 3.680\,y - 0.326\,p = 0$
	24.	$+0.004 + x + 3.732\,y - 0.007\,p = 0$
Oct.	1.	$-0.098 + x + 3.751\,y + 0.105\,p = 0$
	15.	$-0.090 + x + 3.790\,y + 0.342\,p = 0$
	17.	$-0.025 + x + 3.795\,y + 0.373\,p = 0$
	29.	$-0.054 + x + 3.828\,y + 0.548\,p = 0$
	31.	$-0.199 + x + 3.833\,y + 0.578\,p = 0$
Nov.	12.	$-0.297 + x + 3.866\,y + 0.726\,p = 0$
	26.	$-0.290 + x + 3.905\,y + 0.862\,p = 0$
1905 Nov.	26.	$-0.337 + x + 4.904\,y + 0.863\,p = 0$
	28.	$-0.251 + x + 4.910\,y + 0.875\,p = 0$
		$+0.011 + 76x + 204.053y - 14.804\,p = 0$

Corresponding equations were deduced for y and p, the resulting normal equations being

$$+0{\cdot}0110 + 76{\cdot}000\,x + 204{\cdot}0530\,y - 14{\cdot}8040\,p = 0$$
$$+2{\cdot}2742 + 204{\cdot}053\,x + 642{\cdot}2801\,y - 52{\cdot}9454\,p = 0$$
$$-8{\cdot}5866 - 14{\cdot}804\,x - 52{\cdot}9454\,y + 38{\cdot}0005\,p = 0$$

The solution of these gives the following values :—

$$p = +0''{\cdot}249 \pm 0''{\cdot}0105$$
$$y = +0{\cdot}011 \pm 0{\cdot}0063$$
$$x = +0{\cdot}020 \pm 0{\cdot}0182.$$

The value of the parallax of the star A is, therefore,

$$\pi = +0''{\cdot}249 \pm 0''{\cdot}0105.$$

This gives a distance of over 830,000 times that of the Sun. Light, therefore, requires 13·1 years to come from Krueger 60.

Dr. Schlesinger has kindly supplied me with his final value for the parallax of this star. He determined the parallax by photography (during his connection with the Yerkes Observatory) from both right ascension and declination. These were from 19 plates taken with the 40-inch telescope from 1903 to 1906. Three separate images were impressed on each plate. His results are—

$$\text{From R.A. } \pi = +0''{\cdot}257 \pm 0''{\cdot}007$$
$$\text{,, Decl. } \pi = +0{\cdot}238 \pm 0{\cdot}011.$$

It will be seen that the mean of these,

$$\pi = +0''{\cdot}248,$$

is essentially identical with my value.

The results with the same instrument, by visual and photographic methods respectively, in the one case by position-angle and distance, and in the other by right ascension and declination, should inspire confidence in both methods.

Irregularity in the Proper Motion of A.

At present the stars A and B are moving almost directly away from C. This latter star, therefore, is a good one from which to determine the motion.

If B has a considerable mass ratio to A, a large irregularity in the proper motion of either star must occur because of the large apparent distance between the two. If their masses should be nearly equal, this deviation from uniformity of motion in either star may amount to as much as 1″·5. This last mass ratio is not

improbable, in view of the investigations of Mr. Lewis of the Greenwich Observatory who found * that in some cases the apparently smaller star of a binary is really the more massive of the two. It is important, therefore, frequently to measure the position of A with reference to C and other stars in the field. By this means, in the course of time, its mass will become accurately known. For this reason I have kept the star on my observing list, and have made frequent measures of it and the stars mentioned. Of my own work there are now some seven or eight years' observations. Of course, for various reasons, where it is possible, it is best to use the measures of one individual.

The known history of these stars perhaps covers too short an interval for the observations to show any very decided irregularity in the motion of A. To see if there was any such change, the measures were freed from parallax, and means of four or five taken. These were plotted on a large scale. A thread was then tightly stretched over the measures and carefully adjusted to give the best representation. This straight line does not represent the observations with entire satisfaction. The best average, however, was obtained, and the deviations read off. These differences are given in connection with the mean measures. The ends of the thread would represent the positions 1900·943, distance 36″·49, and 1908·302, distance 43″·53.

As these measures may be of interest to others, they are given below. The first column after the dates is the measured distance corrected for refraction, the next column gives the correction for parallax, while the last is the distance affected only by motion. The means of these and their deviation from the straight line are also given.

Distances (A C) *corrected for parallax.*

			Obs. dist.	Cor'n for pllx.	True dist.	
1900	Dec.	8	36″·88	−0″·23	36″·65	
		9	36·67	−0·23	36·44	
		11	36·69	−0·24	36·45	
		12	36·66	−0·24	36·42	
1900·943					36·49	− 0″·01
1901	Sept.	23	37·18	+0·01	37·19	
		24	37·20	0·00	37·20	
		30	37·30	−0·02	37·28	
	Oct	1	37·15	−0·03	37·12	
1901·740					37·20	− 0·04
1901	Oct.	13	37·43	−0·08	37·35	
		21	37·36	−0·11	37·25	
		29	37·34	−0·14	37·20	
1901·792					37·27	− 0·02

* *Memoirs R.A.S.*, vol. lvi. p. xxi.

Distances (A C) *corrected for parallax*—continued.

		Obs. dist.	Cor'n for pllx.	True dist.	
1902	Sept. 29	38″·29	−0″·02	38″·27	
	Oct. 6	38·10	−0·04	38·06	
	7	38·32	−0·05	38·27	
	14	38·50	−0·08	38·42	
1902·764				38·25	+ 0″·01
1903	May 19	38·61	+0·21	38·82	
	25	38·69	+0·22	38·91	
	June 2	38·84	+0·23	39·07	
	9	38·76	+0·25	39·01	
1903·407				38·95	+ 0·10
1903	June 15	38·71	+0·25	38·96	
	22	38·74	+0·25	38·99	
	29	38·74	+0·25	38·99	
	30	38·71	+0·25	38·96	
1903·480				38·97	+ 0·05
1903	July 6	38·84	+0·25	39·09	
	7	38·71	+0·24	38·95	
	13	38·73	+0·24	38·97	
	14	38·78	+0·24	39·02	
1903·524				39·01	+ 0·04
1903	July 20	38·88	+0·23	39·11	
	21	38·76	+0·22	38·98	
	27	38·70	+0·21	38·91	
	Aug. 4	38·72	+0·19	38·91	
1903·568				38·98	0·00
1903	Aug. 10	38·86	+0·18	39·04	
	17	38·88	+0.15	39·03	
	24	39·02	+0·13	39·15	
	31	39·07	+0·10	39·17	
1903·637				39·10	+ 0·03
1903	Sept. 1	39·20	+0·10	39·30	
	22	39·31	+0·01	39·32	
	28	39·20	−0·01	39·19	
	Oct. 5	39·37	−0·04	39·33	
1903·725				39·29	+ 0·14

Distances (A C) *corrected for parallax*—continued.

			Obs. dist.	Cor'n for pllx.	True dist.	
			"	"	"	
1903	Oct.	13	39·37	−0·07	39·30	
		19	39·45	−0·10	39·35	
		26	39·38	−0·12	39·26	
		27	39·48	−0·13	39·35	
1903·804					39·31	+ 0·09
1903	Nov.	2	39·41	−0·15	39·26	
		24	39·66	−0·21	39·45	
	Dec.	22	39·61	−0·25	39·36	
1904	Jan.	3	39·76	−0·24	39·52	
1903·927					39·40	+ 0·06
1904	May	2	39·73	+0·16	39·89	
		3	39·48	+0·16	39·64	
		16	39·50	+0·20	39·70	
		23	39·55	+0·22	39·77	
1904·360					39·75	0·00
1904	June	7	39·78	+0·24	40·02	
	July	2	39·62	+0·25	39·87	
		9	39·62	+0·24	39·86	
		11	39·73	+0·24	39·97	
1904·497					39·93	+ 0·04
1904	July	23	39·80	+0·22	40·02	
		27	39·78	+0·21	39·99	
	Aug.	1	39·74	+0·20	39·94	
		6	39·69	+0·19	39·88	
1904·579					39·96	0·00
1904	Aug.	8	39·76	+0·18	39·94	
		15	39·85	+0·16	40·01	
		22	40·04	+0·12	40·16	
		27	40·08	+0·12	40·20	
1904·631					40·08	+ 0·04
1904	Aug.	29	39·95	+0·11	40·06	
	Sept.	3	40·03	+0·09	40 12	
		5	40·12	+0·08	40·20	
		24	40·10	0·00	40·10	
1904·686					40·12	+0·06

Distances (A C) *corrected for parallax*—continued.

		Obs. dist.	Cor'n for pllx.	True dist.	
1904 Oct. 1		40″·22	−0″·03	40″·19	
15		40·25	−0·08	40·17	
17		40·19	−0·09	40·10	
29		40·25	−0·14	40·11	
1904·790				40·14	0″·00
1904 Oct. 31		40·40	−0·14	40·26	
Nov. 12		40·53	−0·18	40·35	
26		40·56	−0·21	40·35	
1904·869				40·32	+ 0·09
1905 Nov. 26		41·46	−0·21	41·25	
28		41·38	−0·22	41·16	
1905·907				41·21	− 0·03
1906 June 28		41·45	+0·25	41·70	
July 7		41·51	+0·24	41·75	
10		41·54	+0·24	41·78	
24		41·76	+0·22	41·98	
1906·523				41·80	− 0·03
1906 July 29		41·68	+0·21	41·89	
Aug. 11		41·72	+0·17	41·89	
14		41·63	+0·16	41·79	
1906·602				41·86	− 0·20
1907·289 Apr. 16		42·52	+0·10	42·62	+ 0·10
1907 July 2		42·73	+0·25	42·98	
12		42·57	+0·24	42·81	
28		42·63	+0·21	42·84	
30		42·64	+0·21	42·85	
1907·544				42·87	+ 0·04
1907 Aug. 6		42·77	+0·19	42·96	
8		42·62	+0·18	42·80	
11		42·53	+0·17	42·70	
13		42·78	+0·17	42·95	
20		42·68	+0·14	42·82	
1907·612				42·85	− 0·01
1907·749 Oct. 1		42·91	−0·03	42·88	− 0·11
1908 Apr. 19		43″·40	+0″·12	43″·52	
21		43·25	+0·12	43·37	
1908·302				43·44	− 0·08

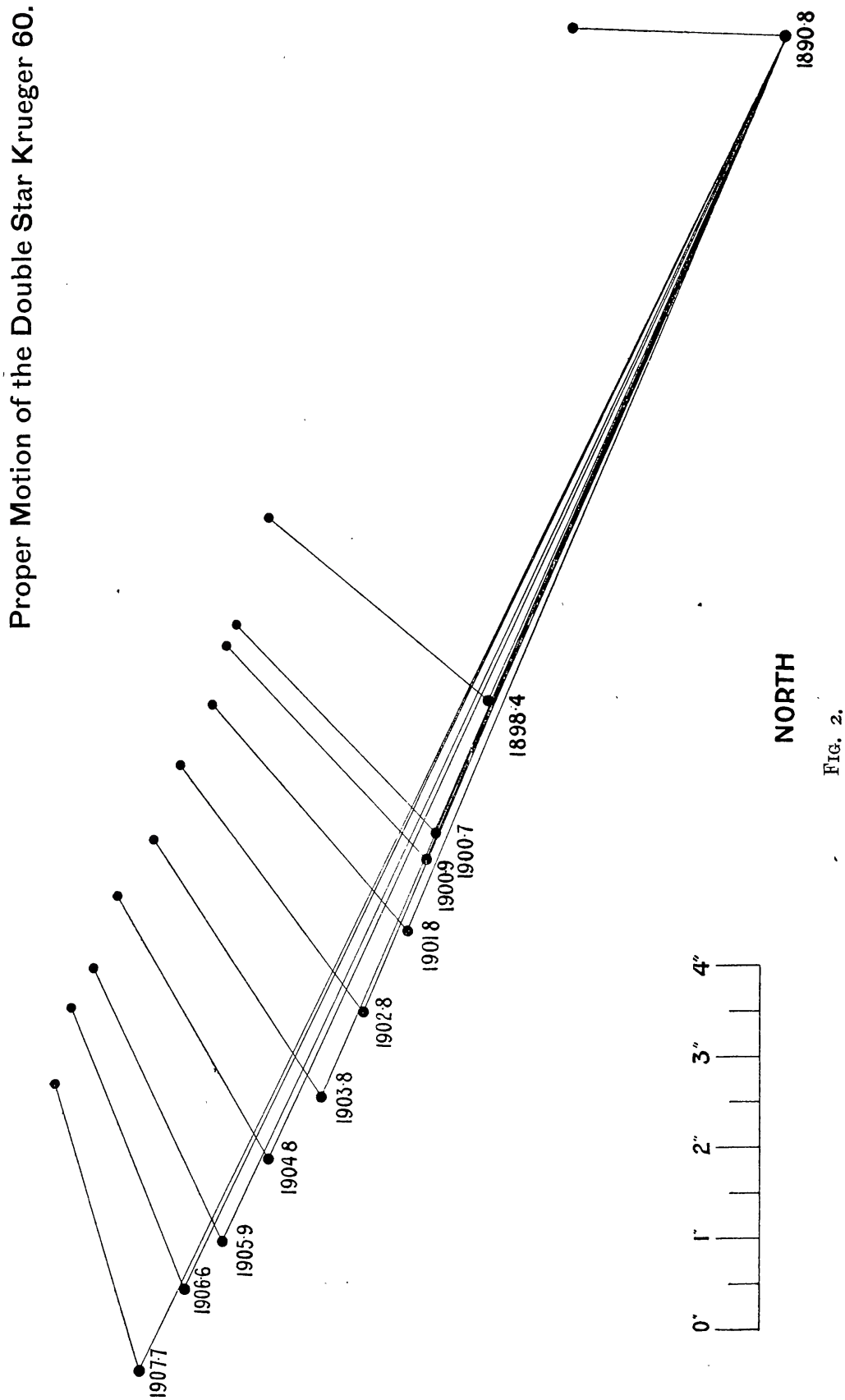


FIG. 2.

This investigation led me to notice that the direction of motion of A was regularly diminishing with the increase of time when derived from a comparison with the measures of 1890·8. The motion was also slightly increasing. To find out the cause of this change I plotted the observations for each year (fig. 2), correcting the distances for parallax, and selecting the positions so that there would be but little parallactic change in the angles. No correction for precession has been applied to the position-angles. The extreme change due to this last cause would be 0°·07. The result shows that between the epochs 1890·8 to 1901·8 and 1901·8 to 1907·7 there has been a total change of some 8° or 9° in the direction of motion. If we take the interval 1901·8–1907·7 the direction of motion is 239°, while the previous values were about 247°. A simple inspection of the diagram will show the change. It is evident, therefore, that the motion of A is not rectilinear. This change is undoubtedly due to the orbital motion of A about the centre of gravity of the system. It is therefore not possible to give a value of its proper motion that will be constant for any considerable interval of time.

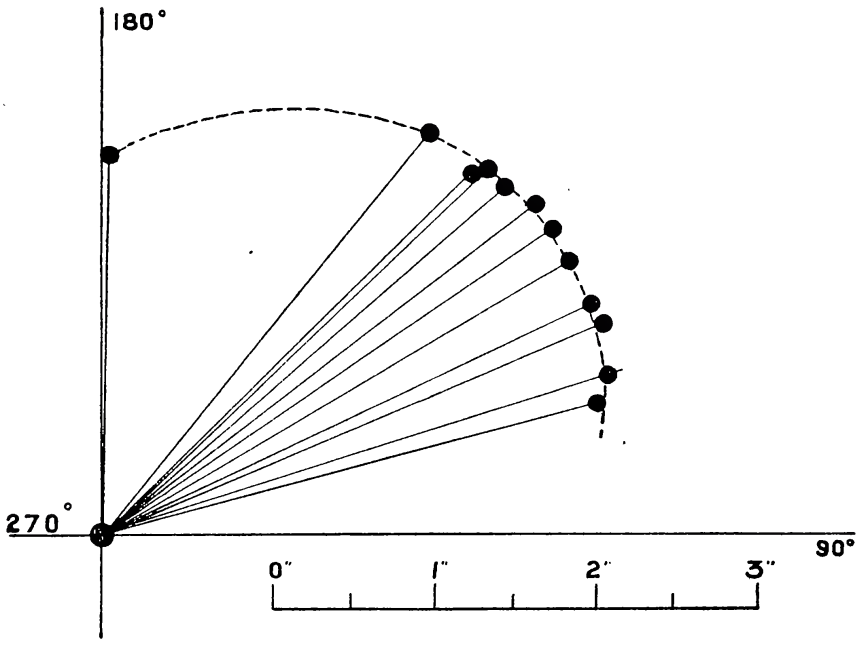
The following measures were used in constructing the diagram. The distances A C are corrected for parallax.

A C.

	°	″	Observer.
1890·788	56·30	26·73	Burnham.
1898·446	58·71	34·64	Doolittle.
1900·737	59·19	36·18	,,
1900·943	59·30	36·49	Barnard.
1901·766	59·62	37·23	,,
1902·764	59·64	38·25	,,
1903·765	59·77	39·30	,,
1904·782	59·55	40·19	,,
1905·907	59·63	41·21	,,
1906·602	59·54	41·86	,,
1907·680	59·57	42·87	,,

A B.

	°	″	Observer.
1890·788	178·80	2·32	Burnham.
1898·446	140·66	3·19	Doolittle.
1900·737	134·02	3·18	,,
1900·943	133·14	3·25	Barnard.
1901·767	130·67	3·28	,,
1902·765	127·05	3·36	,,
1903·761	123·89	3·35	,,
1904·791	120·30	3·33	,,
1905·907	115·34	3·31	,,
1906·601	112·27	3·34	,,
1907·676	107·00	3·27	,,



Orbital Motion of Krueger 60.

FIG. 3.

The Micrometer Measures.

I have collected here for this paper all my published and unpublished measures of these stars, so that my work on the subject up to the present may be presented as completely as possible. All the distances have been corrected for refraction.

The diagram (fig. 1) will show the relative positions of these various stars.

The measures follow.

Measures of Krueger 60 and Comparison Stars.

		A B.			
		°	"	mag.	mag.
1900·937 Dec.	8	132·06	3·30	9·2	10·5
·940	9	133·19	3·25		
·945	11	133·59	3·24		
·948	12	133·71	3·23		
1900·943		133·14	3·25	9·2	10·5

A B—*continued.*

				mag.	mag.
1901·729	Sept. 23	130°·05	3″·37		
·731	24	129·11	3·39	9·5	10·5
·748	30	131·50	3·37		
·751	Oct. 1	131·65	3·25		
·783	13	129·69	3·31		
·805	21	130·59	3·26	9·2	10·5
·827	29	130·59	3·22		
1901·768		130·45	3·31	9·3	10·5

1902·744	Sept. 29	127·25	3·33
·764	Oct. 6	128·17	3·43
·766	7	126·73	3·35
·785	14	126·06	3·35
1902·765		127·05	3·37

1903·380	May 19	122·36	3·32
·418	June 2	122·34	3·42
·437	9	123·85	3·40
·454	15	123·49	3·37
·473	22	123·47	3·33
·492	29	124·90	3·36
·495	30	125·96	3·26
·511	July 6	121·31	3·51
·514	7	123·18	3·30
·645	Aug. 24	124·52	3·45
·664	31	122·91	3·35
·667	Sept. 1	121·98	3·37
·725	22	124·54	3·27
·741	28	123·54	3·45
·818	Oct. 26	123·60	3·33
1903·562		123·46	3·37

A B—*continued.*

			°	″	mag.	mag.
1904·335	May	2	119·44	3·35		
·338		3	119·46	3·35		
·373		16	119·92	3·40		
·393		23	118·51	3·43		
·434	June	7	118·82	3·37		
·502	July	2	121·45	3·43		
·521		9	121·28	3·35		
·527		11	120·68	3·31		
·560		23	119·94	3·39		
·570		27	117·99	3·35		
·584	Aug.	1	120·47	3·43		
·598		6	119·24	3·48		
·642		22	120·96	3·42		
·655		27	119·47	3·37		
·675	Sept.	3	119·50	3·41		
·751	Oct.	1	118·98	3·31		
·795		17	121·07	3·28		
·828		29	120·84	3·39		
·905	Nov.	26	117·46	3·33		
1904·578			119·76	3·38		
1905·904	Nov.	26	116·04	3·30		
·910		28	114·64	3·31		
1905·907			115·34	3·31		
1906·490	June	28	113·63	3·28		
·515	July	7	112·44	3·28		
·523		10	109·72	3·34		
·561		24	112·57	3·33		
·575		29	112·71	3·31		
·610	Aug.	11	112·31	3·33		
·619		14	111·78	3·38		
1906·556			112·17	3·32		

A B—*continued.*

				mag.	mag.
1907·289	Apr. 16	108°·06	3″·14		
·500	July 2	108·09	3·26		
·528	12	106·31	3·29		
·571	28	106·59	3·28		
·577	30	107·83	3·23		
·596	Aug. 6	106·06	3·42		
·601	8	107·92	3·28		
·610	11	106·93	3·38		
·615	13	107·47	3·20		
·634	20	107·13	3·17		
·706	Sept. 15	105·34	3·37		
·749	Oct. 1	108·06	3·36		
1907·581		107·15	3·28		
1908·300	Apr. 19	105·65	2·97		
·338	May 3	105·19	3·30		
·376	17	103·99	3·21		
·382	19	104·63	3·23		
·390	22	104·18	3·26		
·401	26	102·70	3·13		
1908·373		104·39	3·18		

A C

In this table all the previous measures of A C—those used in the determination of the parallax—have been omitted, because they are given in Table I.

				mag.	mag.
1906·490	June 28	59°·01	41″·45		
·515	July 7	59·23	41·49		
·523	10	59·23	41·54		
·561	24	59·71	41·76		
·575	29	59·55	41·68		
·610	Aug. 11	59·60	41·72		9·5
·619	14	59·48	41·63		
1906·556		59·40	41·61		9·5

A C—*continued.*

				mag.	mag.
1907·289	Apr. 16	59°18	42″52		
·500	July 2	59·34	42·73		
·528	12	59·55	42·57		
·571	28	59·40	42·63		
·577	30	59·19	42·64		
·596	Aug. 6	59·44	42·77		
·601	8	59·59	42·62		
·610	11	59·14	42·53		
·615	13	59·50	42·78		
·634	20	59·55	42·68		
·749	Oct. 1	59·71	42·91		
1907·570		59·42	42·67		
1908·300	Apr. 19	59·32	43·41		
·305	21	58·99	43·25		
·338	May 3	58·76	43·51		
·357	10	59·15	43·72		
·376	17	58·98	43·32		
·382	19	59·24	43·52		
·390	22	58·98	43·57		
·401	26	59·19	43·54		
1908·356		59·08	43·48		

A D.

1900·945	Dec. 11	21°25	21″26	15
·948	12	20·86	21·34	15·5
1900·947		21·05	21·30	15·3
1901·783	Oct. 13	23·56	21·54	15
·786	14	21·58	21·85	
·805	21	23·04	21·72	15·3
·827	29	23·07	21·78	
1901·800		22·81	21·72	15·1
1903·511	July 6	24·68	22·75	
·514	7	24·09	22·83	15
1903·512		24·39	22·79	15
1908·415	May 31	29·25	26·69	
·467	June 19	29·51	26·99	
·472	21	29·48	26·93	
1908·451		29·41	26·87	

A E.

				mag.	mag.
1900·937	Dec. 8	98°·85	68″·03		12·5
·940	9	99·06	67·79		13·5
·945	11	99·00	67·76		13·5
1900·941		98·97	67·86		13·2
1901·729	Sept. 23	98·93	68·20		12
·731	24	99·14	68·49		12·5
·748	30	99·06	68·64		
·751	Oct. 1	98·92	68·22		
·783	13	99·01	68·32		
·805	21	98·91	68·39		11·3
·827	29	98·83	68·64		
1901·768		98·97	68·41		11·9
1903·437	June 9	97·89	69·17		13
·454	15	97·99	69·37		
·473	22	97·87	69·20		12
·495	30	97·96	69·42		
·511	July 6	98·07	69·47		
·514	7	97·78	69·51		
·530	13	98·26	69·38		
·533	14	98·18	69·44		
·549	20	98·09	69·55		
·569	27	98·01	69·47		
·607	Aug. 10	97·64	69·44		
·626	17	97·84	69·64		
·645	24	97·97	69·90		
·664	31	97·86	69·72		
·667	Sept. 1	97·93	69·71		
·725	22	98·02	70·12		
·741	28	97·90	69·89		12
·757	Oct. 5	97·86	69·93		
·782	13	97·59	70·11		
·799	19	97·80	70·26		13
·818	26	97·78	70·22		
·821	27	97·70	70·08		12·5
·837	Nov. 2	97·64	70·11		12
·897	24	97·56	70·26		12
·974	Dec. 22	97·41	70·22		12
1904·007	Jan. 3	97·49	70·47		12
1903·670		97·85	69·81		12·3

A E—*continued.*

			°	"	mag.	mag.
1904·335	May	2	97·14	70·10		12
·338		3	97·44	69·91		12
·527	July	11	97·42	70·38		12
·560		23	97·53	70·19		12
·570		27	97·43	70·13		13
·584	Aug.	1	97·64	70·21		13
·598		6	97·32	70·47		
·603		8	97·89	70·76		
·623		15	97·66	70·76		
·642		22	97·54	70·49		12
·655		27	97·50	70·61		13
·661		29	97·56	70·93		
·675	Sept.	3	97·44	70·61		12
·680		5	97·66	70·81		12·5
·751	Oct.	1	97·53	70·80		12·5
·790		15	97·54	71·00		12
·795		17	97·40	70·77		12
·828		29	97·48	70·97		12·5
·833		31	97·27	70·99		12·8
·866	Nov.	12	97·23	71·06		
·905		26	97·29	70·94		12
1904·653			97·47	70·61		12·3
1905·910	Nov.	28	96·87	71·97		
1906·610	Aug.	11	97·08	72·04		12·5
·619		14	96·61	72·20		12·5
1906·615			96·85	72·12		12·5
1907·596	Aug.	6	96·04	72·51		13
·601		8	95·96	72·66		
·610		11	95·70	72·80		
·615		13	96·29	72·80		
·634		20	95·93	72·59		
·667	Sept.	1	95·82	72·88		12·8
·706		15	96·24	72·89		
·749	Oct.	1	96·14	72·80		
1907·647			96·01	72·74		12·9

A E—*continued.*

				mag.	mag.
1908·415	May 31	95°·53	73″·05		
·417	June 1	95·39	73·00		
·428	5	95·47	73·10		
·467	19	95·41	73·14		
·472	21	95·50	73·08		
1908·440		95·46	73·07		

A F.

1901·729	Sept. 23	275°·36	39′·61		14
·731	24	274·78	39·53		14
·751	Oct. 1	275·20	39·61		
·784	13	275·33	39·52		15
·805	21	275·34	39·53		15
·827	29	275·53	39·57		
1901·771		275·26	39·56		14·5
1903·473	June 22	277·24	38·47		13
·492	29	277·59	...		13 clouds.
·495	30	276·84	38·46		12·7
·511	July 6	277·06	38·34		12
·514	7	277·09	38·51		
·533	14	276·52	38·37		
·549	20	276·34	38·50		
·626	Aug. 17	276·92	38·45		
·645	24	276·49	38·11		
·664	31	276·70	38·21		
·725	Sept. 22	276·74	38·16		
·741	28	276·87	37·80		15
·782	Oct. 13	277·06	38·15		
·799	19	277·14	38·07		14·5
·818	26	277·31	38·80		
·821	27	277·36	37·79		15·0
·897	Nov. 24	277·35	38·29		14·5
1903·652		276·98	38·28		13·7

A F—*continued.*

				mag.	mag.
1904·335	May 2	278°·20	37″·76		12·7
·393	23	277·89	38·05		12·5
·560	July 23	277·71	37·39		14
·570	27	277·64	37·62		
·584	Aug. 1	277·36	37·35		15
·598	6	277·01	37·90		
·655	27	277·74	37·15		14
·675	Sept. 3	277·67	37·40		15
·751	Oct. 1	277·84	37·15		14·5
·790	15	278·17	37·38		15
·795	17	277·64	36·83		14·5
·828	29	278·19	37·18		14·7
·833	31	277·87	37·34		14·5
·905	Nov. 26	278·16	36·99		14·5
1904·734		277·79	37·39		14·2

1907·667	Sept. 1	280·56	35·23		14·5
·706	15	280·76	34·47		
·749	Oct. 1	280·75	34·73		14·5
·782	13	281·05	34·67		14
1907·726		281·78	34·77		14·3

1908·415	May 31	281·80	34·94		
·417	June 1	282·06	35·16		
·428	5	282·13	35·15		
·467	19	281·58	34·63		
·472	21	281·40	34·78		
1908·440		281·94	34·93		

C E.

1903·552	July 21	129°·71	46″·19		
1907·634	Aug. 20	129·41	45·84		
·782	Oct. 13	129·88	45·98		13·7
1907·708		129·65	45·91		13·7

It will be seen from the measures that the distance A B is beginning to lessen, having attained a maximum about 1903 or 1904. The position-angle A C seems to have reached its greatest value about 1907 and is now slowly diminishing. Both changes are due to the orbital motion of A in the system A B.

The following estimates of the magnitude of C were made at the time of the observations which have been included in Table I.

	m
1900 Dec. 8	9·5
1901 Sept. 24	9·5
Oct. 21	9·7
1902 Sept. 29	9·9

At the observation of 1900 Dec. 9 the following note occurs:—"Both A and C are slightly yellowish."

Two small Double Stars near Krueger 60.

During these measures two small double stars were found and measured. Though they are not in any way connected with Krueger 60, their proximity to this star, and the general resemblance of one of them to A B, would seem to warrant their insertion here.

No. 1.

(1855·0 α 22^h 19^m 42^s·8, δ +57° 6′·3.)

		°	″	mag.	mag.
1901·731	Sept. 24	247·04	2·99	9·5	12
·805	Oct. 21	247·19	3·11	9	11
1901·768		247·11	3·05	9·3	11·5
1902·766	Oct. 7	247·23	2·67	9·5	11
1903·454	June 15	246·70	3·20	9·8	11
·473	22	248·79	3·09		
·511	July 6	247·62	3·04		
·514	7	246·68	3·25		
1903·488		247·45	3·14	9·8	11
1908·428	June 5	248·05	3·04		
·467	19	245·08	3·22	9·3	11·2
1908·447		246·57	3·13	9·3	11·2

No. 2.

(1903·0 α 22h 22m 52s·1, δ +57° 13′ 33″.)

				mag.	mag.
1902·744	Sept. 29	260°·15	1″·37	10	11
1903·454	June 15	262·50	1·41		
1907·749	Oct. 1	259·05	1·37		
1908·382	May 19	261·32	1·35	10	11
·401	26	260·95	1·45	9·6	10·5
·467	June 19	259·95	1·46		
1908·417		260·74	1·42	9·8	10·7

The Following Component of No. 2 and a Faint Star North.

				mag.	mag.
1908·382	May 19	340°·59	87″·67		12
·401	26	340·56	87·70		13·2
1908·391		340·57	87·69		12·6

Additional measures of some of the stars have been inserted since this paper was submitted to the R.A.S.

YERKES OBSERVATORY:
1908 *May* 18.

Postscript.

I am very glad to be able to add to this paper the value of the parallax of Krueger 60 determined by Dr. Henry Norris Russell from photographs with the Cambridge (England) refractor. Dr. Russell has kindly supplied me with his value since my paper was put in type.

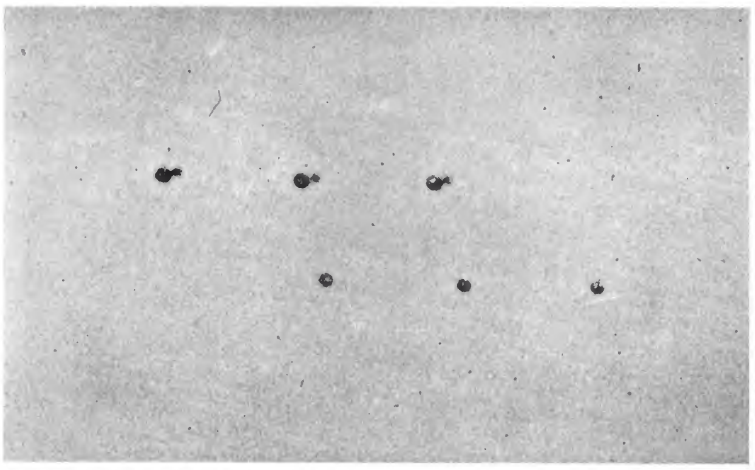
His result is:—

$$\pi = +0''\cdot258 \pm 0''\cdot013$$

from measures of $\Delta\alpha$. Nine comparison stars were used, and the probable error for a single plate was $\pm 0''\cdot026$.

The following, therefore, are all of the values of the parallax of this star known to me:—

Schlesinger = $+0''\cdot248 \pm 0''\cdot009$
Barnard = $+0\cdot249 \pm 0\cdot010$
Russell = $+0\cdot258 \pm 0\cdot013$



Photograph containing three exposures of the double star Krueger 60 A B and the comparison star C. Taken with the 40-inch refractor of the Yerkes Observatory, 1908 July 10 (enlarged). Exposures 10 minutes each. —E. E Barnard.