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Parallax and orbital motion of the astrometric binary BD+6° 398

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Plates taken with the McCormick 26-in. refractor of the astrometric binary BD + 6° 398 from 1915 to 1974 have been analyzed for parallax, proper motion, and orbital motion. An orbital period of 60 yr satisfies the observations; the mass of the unseen companion is on the order of 0.12 solar masses. The data suggests a large Δm.

INTRODUCTION

THE astrometric binary BD +6°398 (=HR753A =HD 16160; 2^h36^m, +6°54′: 2000) previously has been reported on by Lippincott (1973). She found the dynamical elements, $P=50\overset{y}{.}0$, $T=1940.0$, $e=0.6$, to be the most consistent with the Sproul data. Although the McCormick data is not as extensive as that of Sproul, our material covers a somewhat longer time interval. This system is of further interest owing to a common proper motion companion discovered by van Maanen (1938).

I. MATERIALS AND MEASURES

The present analysis is made from 269 exposures on 105 plates taken over 56 nights with the McCormick 26-in. refractor (1 mm=20″.75). All plates were measured by one of us (GEM) in X and Y on the observatory's Grant engine in the direct and reverse orientations with two settings per image. The parallax star was measured before and after the reference frame in both orientations and the unweighted mean of the two measurements was used. Weights were assigned to the individual images during final reduction according to the current McCormick procedure (Fredrick and Ianna 1973).

The reference frame consists of seven stars selected to have small proper motion and about the same photographic magnitude as the parallax star whose brightness was normally reduced with a rotating sector. Prior to the preliminary parallax reduction, relative proper motions were computed for the reference stars with respect to the equator of 2000. The measured positions of a plate were then corrected according to the time interval between it and the trail plate prior to plate constant reduction. This led to stronger plate constants and an increase in internal consistency for the provisional values of parallax and proper motion with only small changes in their values. Detailed information is presented for the reference frame in Table I.

The common proper motion companion (HR753B) generally has been obscured by the rotating sector but does appear on a pair of plates separated by an interval of 20.99 yr. We find an annual proper motion of 1″.817 in X and 1″.466 in Y which is in general agreement with the A component.

II. ORBITAL MOTION

Using provisional values for the parallax and proper motion and a radial velocity of 26.5 km sec^{-1} (Abt 1970) a correction for secular acceleration in the proper motion was calculated (van de Kamp 1967) of $-1\overset{''}{.}2\times10^{-5}$ yr^{-2} in X and $-9\overset{''}{.}9\times10^{-6}$ yr^{-2} in Y. Analysis for orbital motion was performed with a variety of combinations of the dynamical elements as suggested by the normal point residuals. The following values were adopted as giving the most consistent fit in both coordinates: $P=60\overset{y}{.}0$; $T=1937.0$; $e=0.45$. The final least-squares solution gives:

$$\mu_x=+1\overset{''}{.}8244\pm0\overset{''}{.}0002\text{(m.e.)};$$
$$\mu_y=+1\overset{''}{.}4628\pm0\overset{''}{.}0002;$$
$$\pi_x=+0\overset{''}{.}118\pm0\overset{''}{.}004;$$
$$\pi_y=+0\overset{''}{.}125\pm0\overset{''}{.}011;$$
$$\pi_{xy}=+0\overset{''}{.}119\pm0\overset{''}{.}004;$$
$$(B)=-0\overset{''}{.}135\pm0\overset{''}{.}007,\quad (A)=-0\overset{''}{.}011\pm0\overset{''}{.}006;$$
$$(G)=-0\overset{''}{.}181\pm0\overset{''}{.}012,\quad (F)=+0\overset{''}{.}150\pm0\overset{''}{.}011;$$
$$\alpha=0\overset{''}{.}257\pm0.012\text{(m.e.)};$$
$$\text{m.e.l}_x=0\overset{''}{.}063;\quad \text{m.e.l}_y=0\overset{''}{.}056.$$

Solutions without the correction for secular acceleration yield no change in the parallax and proper motion and only small changes in the modified Thiele–Innes constants. However with the correction there is a small

TABLE I. Reference frame (equator of 2000, epoch of 1971.926).

No.	m_v[a]	$B-V$[a]	x_T (mm)	y_T (mm)	μ_x ($\times10^{-3}$″/yr)	μ_y ($\times10^{-3}$″/yr)
1	10.35	+0.46	−14.342	−39.248	− 2.9	− 4.5
2	9.78	+0.51	−46.731	+ 2.154	+ 2.2	0.0
3	9.86	+0.29	−66.408	+18.507	+18.3	+ 6.5
4	11.11	+0.65	−45.680	+30.802	+ 5.2	+12.5
5	10.26	+1.37	+21.646	+54.323	− 6.2	−12.3
6	11.67	+0.74	+21.139	+41.406	+14.3	− 1.1
7	9.81	+1.38	+58.976	+25.487	+ 2.3	+ 4.2
π	5.83[bc]	+0.97[b]	− 2.792	− 5.180		

[a] Photometry by PAI; visiting Astronomer at Kitt Peak National Observatory which is operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.
[b] Johnson (1965).
[c] Reduced to ~10.0 by rotating sector.

improvement in internal consistency of the solutions and a small reduction in the residuals at both ends of the normal points. The modified Thiele–Innes constants for the companion are the same except for change in scale and sign. Information for the normal points is given in Table II. The displacement curves and the photocentric orbit are plotted in Fig. 1.

From the mean magnitude and color of the reference stars we find the reduction to absolute parallax to be 0″.006 (Vyssotsky and Williams 1948); then the absolute parallax of +6°398 is +0″.125±0″.004(m.e.). The current Sproul parallax is +0″.130±0″.003 (p.e.), based on 434 plates over 34 yr. The Yale Catalogue (Jenkins 1952) gives a combined value from Allegheny, Yale, and a previous McCormick determination of +0″.147±0″.005 (p.e.), based on short series of 19, 20, and 22 plates, respectively. The present McCormick value supersedes the earlier one. The unweighted mean parallax between Sproul and McCormick of 0″.128 ±0″.004 (m.e.) is adopted for further use.

The absolute magnitude of BD +6°398 is 6.37 and its spectral type is K3 V (Culver 1974). Adopting a bolometric correction of −0.35 mag (Harris 1963) a mass of 0.72 $M_\odot$ (Harris *et al.* 1963) is expected for BD +6°398. Assuming no contribution of light on the photographic plate from the companion, we take as the semimajor axis for the primary 2.01 AU. With our period of 60 yr a direct calculation (Gatewood and Eichhorn 1973) gives a semimajor axis for the companion of 12.39 AU. This implies a mass for the companion of 0.12 $M_\odot$, and, assuming a normal main-sequence star, its spectral class would be about M7 V. A m_v of ∼14.5 would then be expected using Johnson's (1965) bolometric correction of −3.6 mag.

TABLE II. Computed orbital effect and residuals.

⟨epoch⟩	nights	Orbital effect ⟨x⟩	Orbital effect ⟨y⟩	Residuals ⟨ν_x⟩	Residuals ⟨ν_y⟩
		(unit=0.0001 mm)			
1915.850	6	+128	−32	11	0
1916.794	6	+129	−37	− 8	− 2
1917.809	7	+130	−41	8	12
1922.838	1	+124	−57	−20	10
1928.945	2	+ 85	−61	−25	−15
1930.065	1	+ 72	−58	−10	12
1935.840	2	− 17	−17	−21	−20
1936.673	3	− 31	− 7	9	1
1937.722	1	− 46	+ 6	− 7	− 7
1934.003	2	− 60	+21	−15	0
1939.881	3	− 66	+30	24	10
1941.006	2	− 71	+41	2	0
1941.741	2	− 72	+46	10	11
1953.872	1	− 1	+59	2	−25
1967.931	2	+ 99	+ 3	− 7	− 9
1968.733	4	+103	− 1	−21	1
1969.840	2	+109	− 6	− 5	− 1
1970.821	3	+113	−10	− 5	− 5
1971.879	3	+117	−15	6	1
1973.853	3	+124	−24	35	12

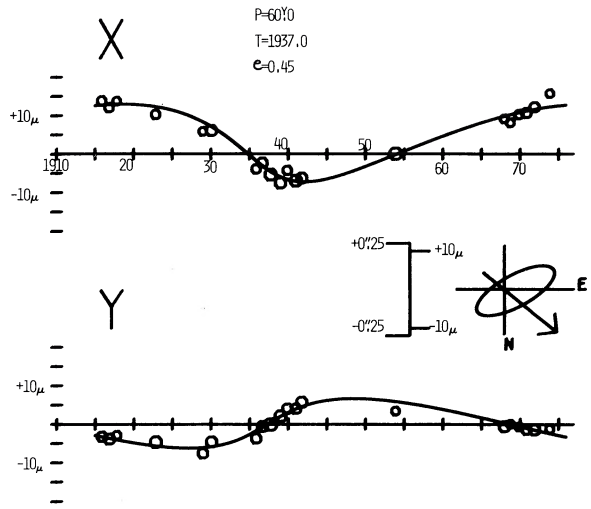

FIG. 1. Displacement curves of the orbital effect in right ascension and declination for BD +6°398 with proper motion and parallax removed. The symbols represent the residuals given in Table II. Their sizes are proportional to their mean weight. The insert shows the photocentric orbit. The arrow indicates the direction of the proper motion for the system.

The separation at this time, from McCormick data, is likely to be 1″.8, but BD +6°398 does not appear to be double on nights of good seeing through the McCormick telescope indicating a large Δm. BD +6°398 is being continued on the McCormick observing program for a more accurate determination of its orbit, and for a parallax for the proper motion companion.

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