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THE FINE GUIDANCE SENSOR ORBIT OF THE G4 BRIGHT GIANT HD 173764

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ABSTRACT

TRANS and POS mode observations of the G4 IIa star β Scuti (HD 173764) have been made with a *Hubble Space Telescope* (*HST*) Fine Guidance Sensor (FGS3). This spectroscopic binary with a period of 833 days and an eccentricity of 0.36 offered hope of resolving the secondary stellar component and inferring the orbital inclination, distance, and masses, thus contributing to comparisons with theory for rapid post–main-sequence evolution. From analysis of *IUE* observations and the total UV-optical energy distribution, the secondary has a spectral class of B9 and a difference in visual luminosity of ~3 mag. Isochrone fitting using this ΔV and temperatures from the spectral types yields ~26 mas for the anticipated projected separation at apastron. The TRANS mode data demonstrate duplicity in the signal but fail to provide reliable separations and position angles even near apastron. This separation is instead no more than 22 mas. However, the parallax is probably smaller, by a similar factor, than that expected from initial isochrone fitting, and β Sct is more luminous than originally estimated. Analysis of POS mode data reveals the orbital inclination and the orientation on the sky for a semimajor axis of only 5.7 ± 0.4 mas for the primary's orbit around the center of mass. The parallax from POS mode observations is quite small, only consistent with isochrones at the 2 σ level. From all of the evidence, the system lies at 210 ± 23 pc and the evolved G-type primary has $M_v \simeq -2.9$.

Key words: binaries: spectroscopic — stars: distances — stars: fundamental parameters — stars: late-type — supergiants

1. INTRODUCTION

We have obtained *Hubble Space Telescope* (*HST*) observations of the binary star β Scuti (HD 173764) under GO proposals 6495 (Cycle 6) and 7486 (Cycle 7) with FGS3 in TRANS/POS modes in order to resolve the secondary stellar component and determine both components' masses. Spectral classifications of the primary component include G4 IIa by Keenan & McNeil (1989) and G6 Ib by Ginestet et al. (1999); we adopt the former for now, although there are some other indications that a lower temperature than is typical for class G4 may be more appropriate. The secondary has a spectral class of B9, from *International Ultraviolet Explorer* (*IUE*) data, and a difference in visual luminosity of ~3 mag (Parsons & Ake 1998). Isochrone fitting (discussed in Parsons 2004 for some other systems) yields estimates of 4.6 and 2.6 $M_\odot$ for the G4 and B9 components, 180 pc for the distance, $M_v \simeq -2.5$ for the evolved primary, and $0''.020$ for the projected semimajor axis of the system from the spectroscopic period of 833 days.

Even with an eccentricity $e = 0.36$ such that apastron separation could be greater than the semimajor axis by a factor of ~1.3, this combination of separation and magnitude difference pushes the limits of *HST* astrometry; however, the system should be resolvable near apastron. Because G-type bright giants and supergiants are relatively rare, the primary's actual mass and luminosity are especially important for comparison with theory for rapid post–main-sequence evolution. Of several such spectroscopic binaries not yet resolved by speckle or other techniques, β Sct offered the best hope of resolution on a timescale comparable to *HST* observing cycles.

The HD 173764 components are sufficiently separated physically, at an average distance of $\simeq$3 AU, to avoid the complications of mass exchange. The angular separation measurements from the FGS, analyzed with respect to the spectroscopic orbit, yield the system's inclination and the sum of the component masses. Concurrent POS mode astrometry provides a trigonometric parallax, a check on the inclination, and a mass ratio measurement.

In § 2 we describe the FGS observations, in § 3 we describe the analysis of TRANS mode measurements, and in § 4 we describe the analysis of POS mode measurements. Results are discussed in § 5 and summarized in § 6.

2. OBSERVATIONS

Table 1 gives the dates, roll (deg), and relative scale for the eight *HST* orbits or "visits" in which FGS astrometry was performed on β Sct, and up to six reference stars in its vicinity, under proposals 6495 (program 3EH) and 7486 (program 49B). For simplicity, we assign a sequential visit number in the first column instead of the discontinuous observation set identifiers. The column headed "stretch" contains scale values from the relevant plate constants (§ 4).

Position and magnitude information for the target and for reference stars selected from the Guide Star Catalog (GSC-II) are given in Table 2; the last two columns of the table are discussed in § 4. Two-color information from GSC-II was not available, mainly because special short exposures are needed to see the fainter stars in the glare of β Sct.

For these stars we requested and received CCD photometric observations from Gettysburg College (*BVRI*) and Lowell Observatory (*BV*). The latter included sufficient contemporaneous standards for good reductions to outside the atmosphere. The resulting V and $B - V$ values are given in Table 2 for the

TABLE 1
BASIC DATA FOR TRANS/POS OBSERVATIONS

Visit	Year/DOY	JD −2.45M	Roll	Stretch	REF Stars
1..........	1996/218	0300.95	80.31	0.99998	2, 3, 5, 6, 7
2..........	1996/249	0331.84	99.00	1.00001	all
3..........	1996/284	0367.03	98.40	≡1.000	all
4..........	1997/081	0530.44	271.79	1.00001	2, 3, 5, 6, 7
5..........	1997/119	0568.29	283.91	(0.99996)	3, 4, 6, 7
6..........	1997/265	0713.83	106.00	1.00008	2, 3, 5, 6, 7
7..........	1998/113	0927.18	280.00	1.00006	2, 3, 5, 6, 7
8..........	1999/120	1299.37	279.00	1.00011	all

reference stars. The value for HD 173764 itself is photoelectric (Hoffleit 1982).

The FGS observational strategy on each visit was to measure each available star 2 or 3 times in POS mode and the target β Sct in TRANS mode with 16–26 scans of length 1$''$.0 along each axis. The multiple POS measurements allow for the detection of and correction for drift of the *HST* during the visits of ~40 minutes duration each.

After allowing for target visibility constraints, we selected scheduling windows to get several measurements near apastron and several others distributed around the orbit of the binary (Fig. 1). The relative orbit, for arbitrary orientation and choice of inclinations, was calculated from β Scuti's SB1 orbital elements (Parsons 1983). The observation schedule was dictated by target orbit phase considerations, and not to maximize the parallax factor.

Because of the brightness of β Scuti, it had to be observed through the F5ND filter. This introduces a correction to the POS mode data and limits the available set of calibration TRANS scans for FGS3.

3. TRANS MODE ANALYSIS

The TRANS mode scans were first co-added using jitter information from the dominant guide star error signal. However, for visit 8 this correction made each scan worse, so in this one case the undejittered scans were used. This can happen if the guide star error signal is noisy and not well correlated with actual spacecraft motion. For visit 8, in fact, the average standard deviation in Y was 5.1 mas, larger than in other visits by 1–2 mas.

Averaged scans were analyzed as in Franz et al. (1998), by obtaining the best fit with the superposition of F5ND scans for a nonbinary cool star (HD 59149, $B-V=1.28$) and a nonbinary hot star (HD 176425, $B-V=0.00$) used as templates. For HD 59149, there are two data sets at different epochs

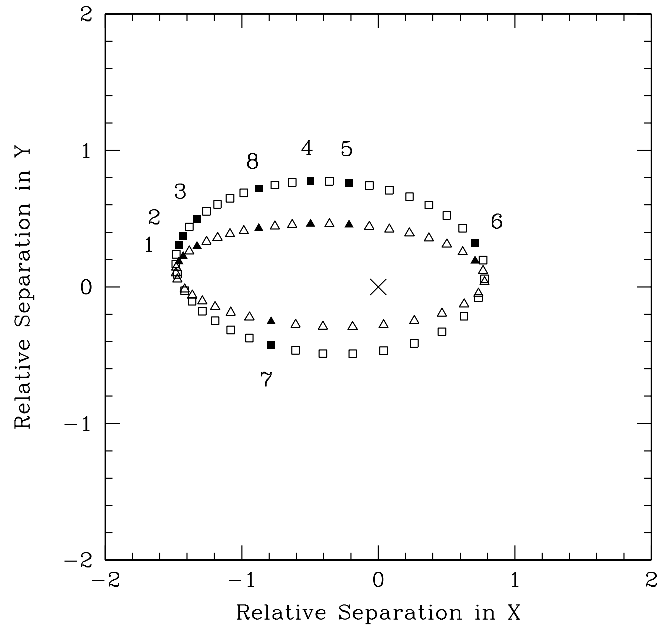

FIG. 1.—Relative binary orbit for HD 173764 projected on the sky. This predictive plot uses spectroscopic elements only and assumes an arbitrary $\Omega = 0$. Squares are for 125° inclination and triangles are for 110° (because all subsequent analysis indicates retrograde motion >90°). Points are separated by 20 days. Filled symbols represent dates of observation, labeled with their visit numbers.

(1995/258 and 1996/291) among the sets of calibration transfer functions.[1]

The TRANS observations of β Sct are not well fitted with only a cool star template, indicating indeed the presence of a secondary component. After experimenting somewhat with cool/hot star intensity ratios (in the FGS3 F583W broadband system), we found that the ratio 0.92/0.08 tended to give the best fits. This 2.65 mag difference translates to $\Delta V \doteq 2.80$ mag, using $\Delta(B-V) \simeq 1.00$ between the components from the spectral energy distribution (SED) fitting, and the linear relation with color term $-0.16\ (B-V)$ between FGS3 magnitude and standard V magnitude (Bucciarelli et al. 1994). Then, holding the intensity ratio fixed, we fitted all β Sct TRANS observations with shifted combinations of the single-star templates.

We found significantly different shift results between the two epochs of HD 59149 calibration scans, often placing the inferred companion to β Sct in different quadrants. Moreover, the

[1] See http://www.stsci.edu/hst/fgs/tmreference.html.

TABLE 2
TARGET AND REFERENCE STAR DATA

Name	GSC-I ID	R.A. (J2000.0)	Decl. (J2000.0)	V (mag)	$B-V$ (mag)	Spectral Type	$E(B-V)$
HD 173764	5122.01426	18 47 10.5	−04 44 52	4.22	1.10	G4+B9	0.18
REF-2...................	5122.00351	18 47 04.7	−04 43 28	13.22	0.76	F8	0.22
REF-3...................	5122.00462	18 47 27.7	−04 44 25	12.47	1.00	sgG5	0.24
REF-4...................	5122.00483	18 47 14.8	−04 43 07	13.24	0.76	F7	0.22
REF-5...................	5122.00747	18 46 57.7	−04 44 03	13.11	1.53	gK5	0.22:
REF-6...................	5122.00775	18 47 20.9	−04 45 30	12.56	0.68	F4	0.22
REF-7...................	5122.00813	18 47 01.8	−04 44 31	11.98	2.00	gM0:	0.46:

NOTE.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

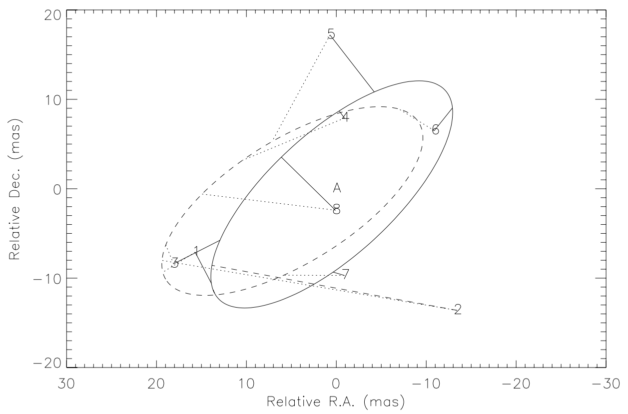

Fig. 2.—Orbit of β Sct secondary around primary from TRANS data. "A" marks the relative position of the primary star. Ordinal numbers are the visit numbers, plotted at their derived relative positions. The solid curve is the independently derived orbit with $a = 17$ mas, just from the TRANS mode results, when visit 2 is excluded (on the basis of its much greater residuals in S-curve fitting). The dashed curve comes from reflecting the POS orbit for the primary and scaling it to $a = 16$ mas. Straight lines connect the measurements with their epochs on the orbit models, and hence are indicative of the errors.

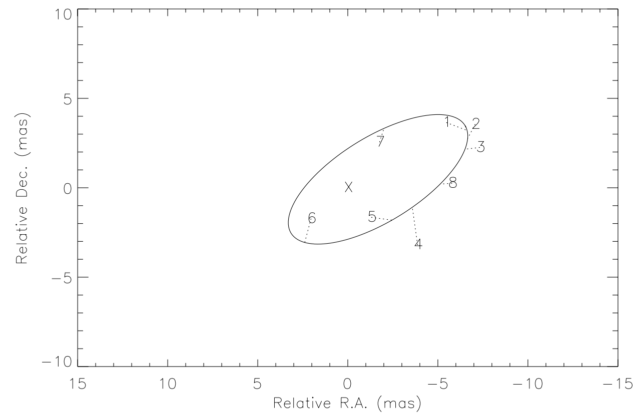

Fig. 3.—POS mode–derived orbit of the HD 173764 primary showing the motion of the photocenter. "X" marks the center of mass for the system. Ordinal numbers are the visit numbers, and straight lines connect these data points with their epochs on the orbit model, as in Figure 2. It may be seen that the orbit model, given under "POS Mode Solutions" in Table 3, fits the derived positions within 2 mas.

first three *HST* visits yielded conflicting quadrants, when the secondary near apastron should have been found at very similar position angles and separations. We concluded that the separations found, of order 20 mas or less, were not reliable. The differences between observed and fitted transfer functions are comparable to the time variations in the HD 59149 template. It seemed that our analysis of the scans was compromised by not understood short-term temporal variations in FGS3 behavior. It would not matter how contemporaneous the reference scans were with the binary's scans (this is not an issue with the improved FGS1r astrometer).

All HD 173764 scans were reanalyzed using the average of the two HD 59149 F5ND scans for the cool-star template. The resulting relative positions give a hint of orbital motion. Visit 2 can be excluded from the orbit solution because it shows significantly greater residuals than other visits in the TRANS solutions. When this is done and some of the spectroscopic parameters are adopted then, entirely independent of the POS mode analysis, a moderately convincing relative astrometric orbit is found (Fig. 2). The true separation near apastron is probably 22 mas or less.

4. POS MODE ANALYSIS

The FGS POS mode data can provide high-precision relative astrometry (cf. Benedict et al. 1999). Most of our visits used five or six reference stars (Table 1), with the target star HD 173764 centered in the field of regard.

The POS data were processed by CALFGSB as well as CALFGSA at the STScI. Then a cross-filter calibration (XFC) was applied to the X, Y positions of the target β Sct because it had to be observed through the F5ND filter, while the REF stars were too faint for that filter. The XFC corrections used were -4.9 mas in X and -7.0 mas in Y (E. P. Nelan 1998, private communication).

Each *HST* visit was treated as one "plate" in six-coefficient plate overlay solutions that are linear in X and Y yet allow for unequal scaling between X and Y. Visit 3, which included all six reference stars, was chosen as the reference frame, then the other visits' data were rotated and stretched for the best fit. Using visit 2 instead of visit 3 as the reference frame yields essentially the same results.

Separate overlay solutions were run with Lowell Observatory software and with University of Texas/STScI GAUSSFIT software. The resulting plate constants are similar, but the corresponding X and Y values differ by up to 15 mas between the two codes, especially for visit 5 with fewer REF stars. The GAUSSFIT code (Jefferys et al. 1987) has been used for most subsequent analysis because it is not limited to those REF stars common to *all* frames and it solves for all parameters simultaneously, including any desired constraints. This includes solving for the parallaxes and proper motions of the reference stars, which are generally constrained to average out to zero. The internal precision (differences among the measurements during one visit) averages 1.1 ± 0.4 mas in X and 0.5 ± 0.3 mas in Y among the eight visits.

A lateral color correction (LCC) was added to the GAUSSFIT model, contributing shifts of -0.9 mas in X and -0.2 mas in Y (Benedict et al. 1999) for each 1 mag difference in $B - V$ index between the target and the reference stars. The $B - V$ colors derived from Lowell Observatory images were used here.

The stretch factor from visit to visit (Table 1) was computed in the same way as the scalelike parameter S in Benedict et al. (1999, eq. [7]).

To the GAUSSFIT model provided, we also added rotation of the reference frame to celestial orientation using the *HST* roll angle, and the orbital motion of the β Sct primary. For the latter, we used equations from Binnendijk (1960) and some updated spectroscopic orbit parameters (§ 5.1). Orbit shape factors depending only upon P, T, e, and epoch were precomputed for each visit and input as constants into the model.

The series of solutions started with *Hipparcos* constraints on the parallax and proper motion of β Sct. We then varied these by 1 σ to find solutions with lower residuals. With the modified μ and π, we eliminated one star at a time to find that the removal of REF-7 led to a much improved solution overall. Then we unconstrained the proper motion of β Sct, and finally unconstrained its parallax. The lowest residuals are found for a surprisingly low *relative* parallax of 0.6 ± 0.8 mas. The relatively large parallax error is likely due to poor sampling of the parallactic ellipse.

Figure 3 shows the orbital fit to the relative POS mode positions after parallax and proper motion are removed. Although the amplitude of motion is not vastly greater than the errors, the orbit appears to be quite plausible.

TABLE 3
Orbital Data for HD 173764

Element	Spectroscopic SB1 Orbit	*Hipparcos* Solution[a]	TRANS Mode Solution[b]	POS Mode Solutions	Combined Solution
P (days)	832.8 ± 0.2	(834.0)/(832.5)	(832.5)	(832.8)	(832.8)
T (JD) $-2{,}400{,}000$	48305.4 ± 6.9	(48334.9)/(48292.3)	48134 ± 375/(48292.3)	(48305.4)	(48305.4)
γ (km s^{-1})	-21.9 ± 0.2	...	...	...	-21.9 ± 0.2
e	0.36 ± 0.02	(0.35)/(0.37)	0.05 ± 0.14/(0.37)	(0.36)	(0.36)
ω (deg)	38.3 ± 3.4	(33.9)/(35)	$339 \pm 166/246 \pm 9$	(38)	(38)
$a_1 \sin i$ (Gm)	162.5 ± 3.3	...	...	...	§ 5.1
$f(M)$ ($M_\odot$)	0.246 ± 0.015	...	...	...	§ 5.1
K_1 (km s^{-1})	15.2 ± 0.3	...	...	...	15.3 ± 1.9
Ω (deg)	...	$114.2 \pm 5.8/130 \pm 9$	$133^{c} \pm 11/323^{c} \pm 13$	124 ± 4	123 ± 4
i (deg)	...	$116.2 \pm 9.3/127 \pm 17$	$114 \pm 10/108 \pm 9$	115 ± 5	119 ± 6
a_p (mas)	...	$5.1 \pm 1.1/4.2 \pm 0.9$	...	5.6 ± 0.5	5.7 ± 0.5
$a_1 + a_2$ (mas)	...	...	$17.2 \pm 2.4/16.6 \pm 3.3$	...	14.4 ± 2.5
π (mas)	...	4.73 ± 0.79	...	2.5 ± 0.9	4.7 ± 0.1
μ_α, μ_δ (mas yr^{-1})	...	-7.7 ± 0.7, -15.9 ± 0.5	...	-8.6 ± 0.4, -16.2 ± 0.4	-9.2 ± 0.4, -16.0 ± 0.4

[a] Original/revised parameters (§ 5).
[b] With just P fixed/with P, T, and e fixed.
[c] 180° has been added or subtracted for consistency with other columns.

The derived semimajor axis a_p from POS mode data is really for the photocenter's orbit. To get the value for the primary relative to the center of mass, we compared zero-point offsets from TRANS scans fitted with single-star versus double-star templates, and derived a 4% correction. This yields the result 5.8 ± 0.5 mas for a_1.

From the Yale parallax catalog (van Altena et al. 1995, § 3.2, Fig. 2) we find the estimated statistical correction from relative to absolute parallax to be 1.7 mas. Using the $B - V$ and Two Micron All Sky Survey (2MASS) values for the REF stars and the COMBO SED analysis tool (Parsons & Ake 1998), we estimate their individual properties as given in the last two columns of Table 2. The giant nature of REF-5 and REF-7 is inferred from a $(J - H)/(H - K)$ diagram; the SED fits are ambiguous. Parallaxes calculated from spectroscopic M_v estimates (Cox 2000, Table 15.7) are generally concordant with the relative parallaxes of the POS solution when 1.7 mas is added to them.

Turning this around, using the POS solution's relative parallaxes +1.7 mas to calculate absolute magnitudes, we find $M_v \sim +3$ to +4 for all REF stars. Then the cooler ones, REF-5 and REF-7, as well as REF-3, are most likely subgiant stars. All but REF-7 have about the same interstellar extinction. The very red REF-7, omitted from the POS solution to improve its accuracy, has the largest relative parallax of the reference stars, so the large $E(B - V)$ is not explained by distance. Either REF-7 has an abnormal SED, has abnormal POS measurements, or is situated behind a small interstellar cloud within ~300 pc of the Sun.

The correction to absolute trigonometric parallax based on these data for five REF stars is 1.9 ± 0.1 mas (with REF-7 excluded). With this correction, the absolute result $\pi = 2.5 \pm 0.9$ mas is substantially less than the *Hipparcos* result, but with slight overlap at the 1.5 σ level.

5. RESULTS

5.1. *Orbital Parameters*

Table 3 compares some recent orbital parameter, parallax, and proper motion determinations or estimations for the β Sct system. Assumed values in a solution are enclosed in parentheses, sometimes taken from the spectroscopic binary solution by Parsons (1983). Reanalysis with the generalized Gudehus (2001) code[2] gives very similar results but with formal errors reduced by about a factor of 4. Three relatively recent CORAVEL radial velocities[3] (de Medeiros & Mayor 1999) were included in the new SB1 solution presented in the first data column, kindly run by Donald Gudehus; the period is changed slightly from the value of 832.5 days from Parsons (1983).

For comparison with present results, the *Hipparcos* solutions are given as published, and as recalculated for us upon request (L. Lindegren 1998, private communication) when we noted that the improved SB1 elements of Parsons (1983) had not been used for the catalog. The POS mode solution given in the fourth data column is in amazingly good agreement with *Hipparcos* and provides greater accuracy in orbital parameters.

Two of the possible fits to TRANS mode observations are given in Table 3, one with just the period constrained, and a second with P, T, and e set to the 1983 SB1 values. Interestingly in this latter case, the longitude of periastron, ω, and of the node, Ω, are very discordant, while other parameters are not much different from *Hipparcos* and FGS POS mode. When we constrained ω as well as P, T, and e, however, some other results were nonsense.

The TRANS orbit with only P constrained, while not in *quantitative* agreement with the spectroscopic orbit and with the POS-based reflex orbit (of component A), is nevertheless substantially *consistent* with these results. The TRANS measurements happen to be consistent with the POS solution in the inclination and in the location of the secondary being opposite to the location of the primary for most epochs (Fig. 4). The TRANS results are literally marginal, i.e., at the very limit of the capability of FGS3, and therefore should be viewed as a qualitative rather than a quantitative result.

The last column of Table 3 presents one of the simultaneous orbital solutions using the radial velocity, TRANS mode, and POS mode observations. The code by Gudehus (2001) was kindly run by its author, after some partially successful attempts

[2] Available at http://www.chara.gsu.edu/~gudehus/binary.html.
[3] Available under "Data" at http://obswww.unige.ch/~udry/cine/vsini/vsini.html.

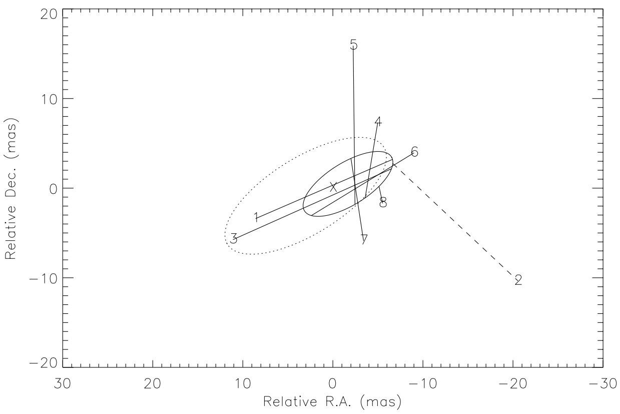

FIG. 4.—TRANS measurements with respect to combined orbits. Solid and dotted curves are the proposed orbits of the primary and secondary around the center of mass (X), in the latter case scaled to $a = 16$ mas, from the POS solution. Ordinal numbers are the visit numbers, plotted at the positions of the TRANS separations relative to the position of the primary in its orbit, as indicated by the straight lines connecting them. This is done to reduce the confusion that results from plotting the observed POS points. Visits 1, 3, and 6 have the most sensible TRANS measurements, as indicated by the proximity of their lines to the center of mass.

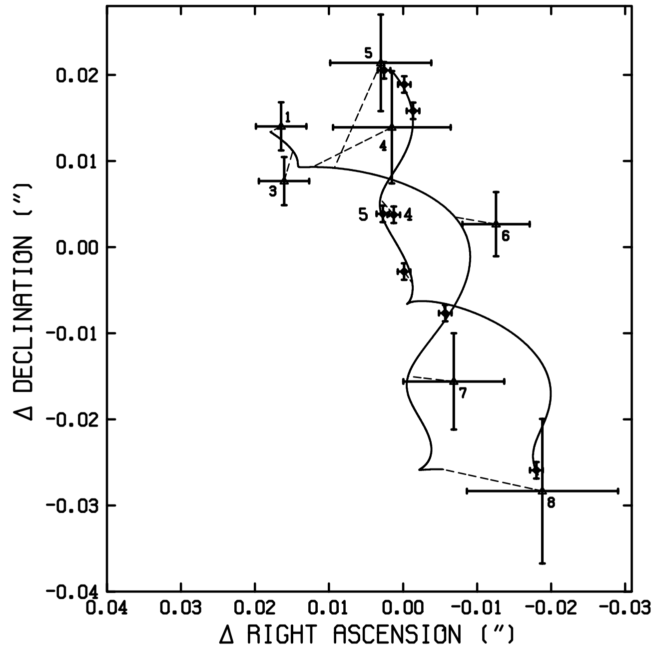

FIG. 5.—Motion of both β Sct components on the sky. The total proper, parallactic, and orbital motions of the HD 173764 system relative to the reference stars are shown in this figure provided by D. Gudehus. The position of the primary is indicated by the small (1 mas) error bars and is sequential from top to bottom for the eight visits; the small deviations from the combined solution model are shown with dashed lines, and visits 4 and 5 are labeled for clarity. For the secondary, visit 2 is omitted because of its large deviation; the other offsets from the primary according to the TRANS measurements are labeled with visit numbers. The error bars shown for the secondary range from 3 to 9 mas; they were distributed according to the angular differences in Fig. 4 between the secondary's position measurement and the center of mass, as seen from the position of the primary in the orbit.

to make it run under (no longer available) Tru64 Unix at STScI. With acceleration in μ constrained to zero and with P, T, e, and ω constrained to the SB1 orbit, this solution has residuals of 1.0 mas for the POS X and Y measurements and 1.6 km s^{-1} for the radial velocities. The TRANS measurements are weighted somewhat arbitrarily according to how sensible they are (Figs. 4 and 5). The code produces a value for $a_1 \sin i$, by the combination of other parameters, of 1.09 ± 0.14 AU (163.5 ± 20.6 Gm), in agreement with the SB1-only result. Other free parameters, except the parallax, agree well with the GAUSSFIT POS results. The combined solution code calculates primary and secondary masses of $3.2_5 \pm 1.5$ and $2.2_5 \pm 0.6$ $M_\odot$, lower than the evolutionary values but quite sensitive to details of the solution. The parallax value is not just trigonometric but is interrelated to other quantities; the given standard deviation is therefore not taken as a true indicator of its accuracy.

In round numbers, the semimajor axis of the system is ~16 ± 2 mas if credibility is given to the TRANS fits and a weighted mean is taken of the three solutions that use TRANS data. Weighted averages of the *Hipparcos*, POS, and combined solutions give $a_1 = a_p/0.96 = 5.7 \pm 0.4$ mas and $i = 116\overset{\circ}{.}8 \pm 2\overset{\circ}{.}0$. From these, the mass ratio of primary to secondary is then 1.8 ± 0.4 and the system semimajor axis a is 3.4 ± 0.5 AU.

The mass sum from Kepler's third law is then 7.6 ± 3.4 $M_\odot$, with the 15% error on a being cubed. Although hardly an accurate result, this agrees with the evolutionary mass estimates totalling ~7.2 $M_\odot$. The combined solution calculates 5.5 ± 2.0 for the mass sum.

5.2. *Implications*

Isochrone fitting with parameters stretched by their plausible errors can bring the resulting π down as low as the nominal *Hipparcos* value of 4.7 mas, at which $M_v = -2.9$, $\Delta V \simeq 3.6$, the component masses are ~5.0 and 2.7 $M_\odot$ (ratio 1.85), and the component separation from Kepler's third law is 16 mas. This stretch is consistent with the calibration in progress of parallaxes from isochrone fitting against *Hipparcos* values for a large sample of similar binaries; that comparison is indicating inaccuracy of ~10% in the isochrone parallaxes. The isochrone and POS mode parallaxes may be reconciled at the 2 σ level at $\pi = 4.3$ mas, well within 1 σ of the *Hipparcos* value.

An orbital parallax value (Herbison-Evans et al. 1971) comes directly from the ratio of $a_1 \sin i$ in angular units (mas) to the same quantity in physical units (AU) from the SB1 orbit. From the mean values above (§ 5.1) for a_1 and $\sin i$, we get $\pi_{\rm orb} = 4.7 \pm 0.4$ mas.

A weighted average of isochrone, *Hipparcos*, orbital, and POS trigonometric values gives 4.7 ± 0.8 mas (± 0.5 mas error of the mean).

6. SUMMARY

From analysis of *IUE* observations and the total UV-optical energy distribution, the β Sct secondary has a spectral class of B9 and a difference in visual luminosity of ~3 mag. Isochrone fitting using this ΔV and temperatures from the spectral types predicted a separation resolvable with FGS3 on *HST*.

The TRANS mode data from our GO proposals 6495 and 7486 demonstrate duplicity in the signal but fail to provide reliable separations and position angles even near apastron. Analysis of the scans is compromised by irregular temporal changes in FGS3 behavior. Most of the separations and position angles are consistent qualitatively with other data.

Analysis of POS mode data confirms the orientation of the orbit on the sky that was derived by *Hipparcos*, and yields greater precision in the parameters. The semimajor axis for the primary around the center of mass is found to be 5.7 ± 0.4 mas. The FGS parallax of the system should be given lower weight because of parallax factor considerations. It conflicts with evolutionary models that we have found in general to be consistent with cool-plus-hot binary parameters. We adopt a compromise value of 4.7 ± 0.5 mas for the most likely parallax of the system.

This paper is based on observations made with the NASA/ESA Hubble Space Telescope, obtained at the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5-26555. These observations are associated with proposal IDs 6495 and 7486. We thank STScI staff, especially Denise Taylor, Olivia Lupie, Ed Nelan, and Russ Makidon for assistance with the observations and the reductions, plus Catalogs and Surveys Branch staff for GSC-II information, and Jack MacConnell for rough classifications of the reference stars. We thank Barbara MacArthur and Fritz Benedict (University of Texas, Austin) for assistance with the reductions, Larry Marschall (Gettysburg College) and Marc Buie (Lowell Observatory) for CCD photometric observations, and *Hipparcos* staff member Lennart Lindegren for rerunning the orbit solution. We are very grateful to Donald Gudehus for much help in getting his programs to run under Tru64 Unix, and then for making multiple runs for us when the Tru64 platform was no longer available. Support for this work was provided by NASA through grant GO−06495.02-95A from the Space Telescope Science Institute. We thank an anonymous referee for some very useful, constructive feedback.

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