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BINARY STAR OBSERVATIONS WITH THE *HUBBLE SPACE TELESCOPE* FINE GUIDANCE SENSORS. I. ADS 11300

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ABSTRACT

According to an orbit based on measures mostly near apastron, the binary ADS 11300 = Hu 581 = WDS 18229+1458 passed through periastron in 1984 at an angular separation below 0″.1. On the assumption that one accurate measurement near periastron may serve to define its orbit, ADS 11300 was selected for Early Release Observation (ERO) with the *Hubble Space Telescope* Fine Guidance Sensors (*HST*-FGS). It was observed on 1990 November 1 at an angular separation of 0″.066. Revised orbital elements predict that ADS 11300 will pass through periastron in 1992 and reach a separation below 0″.01, making it a challenging target for continued *HST*-FGS astrometry.

Subject headings: astrometry — stars: binaries — stars: individual (ADS 11300)

1. INTRODUCTION

When discovered by Hussey (1902) with the 36 inch (91 cm) Lick Refractor, ADS 11300 = Hu 581 = WDS 18229+1458 (8.8 and 9.4 mag) was near its maximum angular separation of 0″.30. Measured infrequently through 1909, the pair soon became unresolvable. Consistent observation did not resume until 1941. By 1970 a total of 84 measures had been made by 12 observers. Baize (1974), who had contributed 17 of this total, derived an orbit with an adopted period of 60.0 yr, rejecting measures made by Van Biesbroeck during 1930–1934 and by Voute in 1943.

Because the observations covered only a short arc near apastron, this orbit is uncertain. It does, however, indicate a period of at least 50 yr, large eccentricity, and high inclination. Most importantly, it suggests that the pair is now near periastron. Even one accurate measurement at this time could prove sufficient to define the orbit. We therefore proposed to carry out astrometry of ADS 11300 with the *Hubble Space Telescope* Fine Guidance Sensors (*HST*-FGS) during the Early Release Observation (ERO) phase.

2. THE *HST*-FGS OBSERVATIONS

On 1990 November 1 at 1^h13^m UT (1990.835), observation of ADS 11300 commenced with *HST*-FGS3 in the Transfer Function Scan mode. Once the target had been acquired in Coarse Track, the interferometers were backed off 0″.60 from the computed center of "nutation" in the FGS3 X-Y frame. Five scans were then made across ADS 11300 at a 45° direction in the spacecraft V2-V3 frame. Each scan lasted 100 s at a scan rate of 0″.017 s^{-1}. A sampling rate of 40 Hz thus yielded a point-to-point separation of 0.425 milli-arcsec along each scan.

A star previously verified as single was identically observed. It serves as a standard for the analysis of the ADS 11300 data. Details of the flight hardware and ground system for *HST* astrometry have been presented by Bradley et al. (1991).

3. DATA REDUCTION AND ANALYSIS

We assume the TF of a resolved binary star to be a linear superposition of two single-star functions. If $F(X)$ is the TF of a single star on the X-axis, a binary star should thus yield a TF of the form

$$D(X) = A \times F(X + Z) + B \times F(X + Z + S) ,$$

where A and B are the relative intensities of the two binary components such that $A + B = 1$. A zero point offset is represented by Z, while S is the component separation along the X-axis. An equivalent expression exists in Y. The S-values measured in X and Y yield the binary separation and, upon transformation from the FGS X-Y frame to equatorial coordinates, the position angle of the pair. The magnitude difference is given by $2.5 \times \log (A/B)$.

For accurate deconvolution, single-star data of high signal-to-noise ratio should be used. Such data can be obtained by co-addition of multiple scans. Five single-star scans available for our analysis are plotted in Figure 1. Displacements of zero crossings along the abscissa are evident.

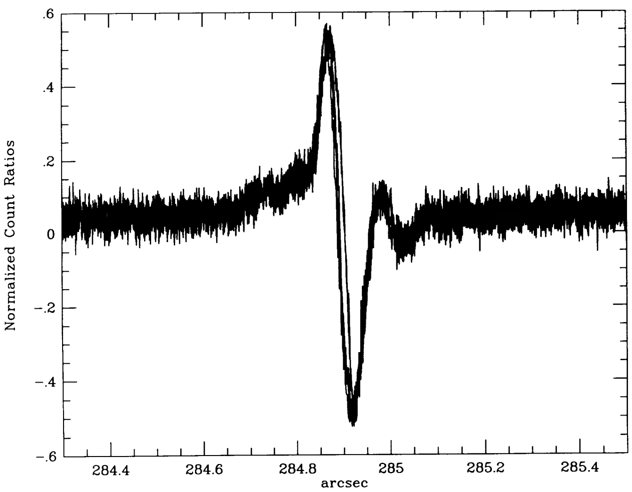

FIG. 1.—Five individual single-star scans in X

To co-add such data, we find those relative shifts on the abscissa which produce maximum cross-correlations among all scans. Applied to the data shown in Figure 1, such a procedure yields the averaged *TF* presented in Figure 2*a*. A smoothing spline technique produced the single-star *TF* plotted in Figure 2*b*. Smoothed single-star transfer functions thus obtained in X and Y were then fitted to the individual and to the co-added binary-star scans by a least-squares algorithm allowing for errors in both the dependent and independent variables (Jefferys 1980). Fits are illustrated in Figure 3.

Component separations (S) in the FGS3 X-Y frame and fractional intensities A are listed in Table 1. Averaged separation values were transformed from FGS3 X-Y coordinates to

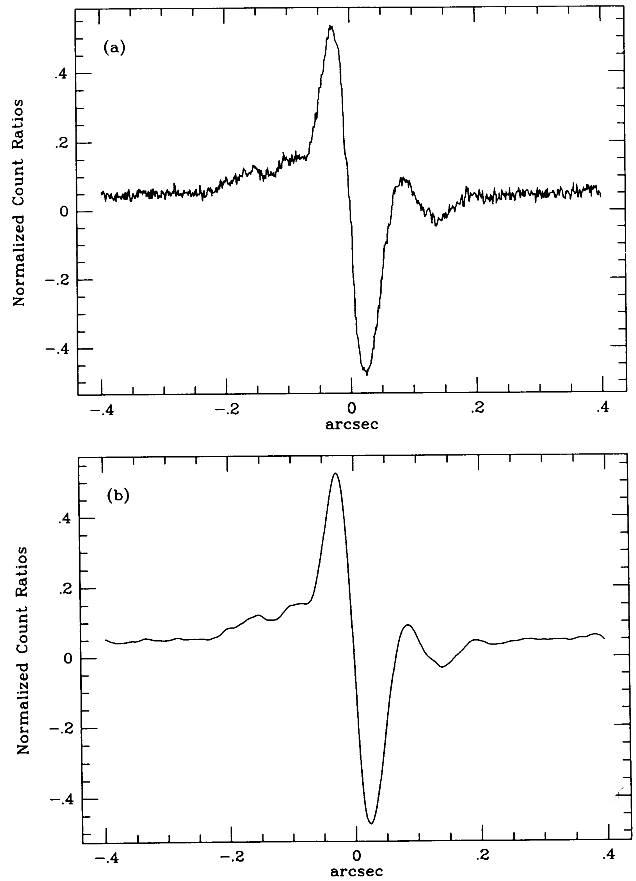

FIG. 2.—(*a*) Single-star transfer function produced by shifting, co-adding, and averaging the five individual scans shown in Fig. 1. Zero point has been shifted so that zero-crossing is at zero. (*b*) Single-star transfer function shown in (*a*) after smoothing.

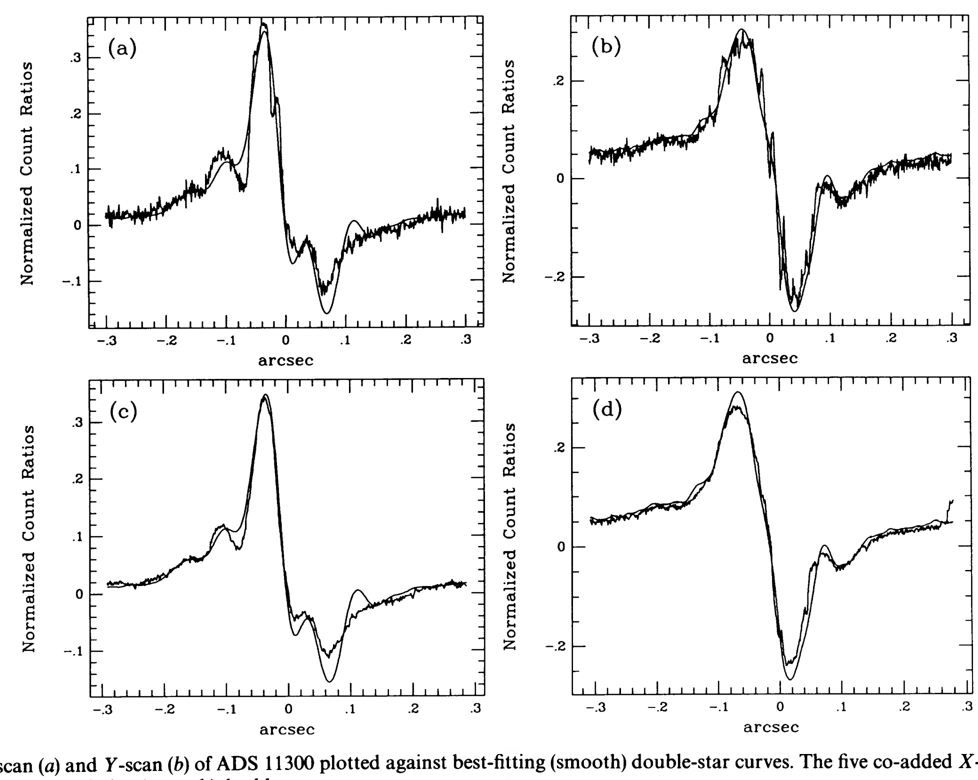

FIG. 3.—Single X-scan (*a*) and Y-scan (*b*) of ADS 11300 plotted against best-fitting (smooth) double-star curves. The five co-added X-scans (*c*) and Y-scans (*d*) of ADS 11300 plotted against best-fitting (smooth) double-star curves.

TABLE 1

ADS 11300: ANGULAR SEPARATIONS (*S*) IN THE FGS3 *X*-*Y* FRAME AND FRACTIONAL INTENSITY *A*

Scan	S_X	S_Y	*A* (*X* only)
1.............	0".051 ± 0".002	−0".043 ± 0".003	0.588 ± 0.023
2.............	0.051 ± 0.002	−0.043 ± 0.003	0.600 ± 0.020
3.............	0.051 ± 0.002	−0.043 ± 0.003	0.597 ± 0.019
4.............	0.051 ± 0.002	−0.042 ± 0.002	0.601 ± 0.021
5.............	0.051 ± 0.002	−0.043 ± 0.003	0.598 ± 0.020
Co-Add......	0.050 ± 0.002	−0.042 ± 0.002	0.594 ± 0.016

TABLE 2

ADS 11300: RELATIVE POSITION FOR EQUINOX OF *t* AND MAGNITUDE DIFFERENCE FROM *HST*-FGS DATA

t.........................	1990.835
x.........................	−0".064 ± 0".002
y.........................	+0".018 ± 0".003
P.A.......................	285°.76 ± 0°.05
Separation.............	0".066 ± 0".003
Δm.....................	0.41 ± 0.07 mag

the equatorial system for the equinox of observation. Rectangular coordinates *x* and *y*, the position angle (P.A.), the separation, and the magnitude difference (Δm) are listed in Table 2.

4. A REVISED ORBIT OF ADS 11300

From 1973 through 1977, four observers made 20 additional measures of ADS 11300, bringing to 104 the total recorded for this pair in the Washington Double Star (WDS) Observation Catalog as 40 yearly means.

To make effective use of the *HST* observation in a new orbit analysis, we must assign to it a realistic weight relative to the 40 visual data points. We must also assess all measures, particularly those rejected by Baize (1974). Using software developed at the Center for High Angular Resolution Astronomy at Georgia State University (Hartkopf et al. 1989), we computed families of orbits based on slightly different data sets. Within each family we tested several weights in the range of 1 to 100 for the *HST* observation. Unit weight was given to all visual data included in a set. These orbit solutions show that the VBS observations of 1930–1934 are indeed inconsistent with all other data, and incompatible with any plausible orbit. A 1977 measure by WAK is consistent with other measures only if its position angle is adjusted by 180°. We adopted a data set that excludes the VBS measures of 1930–1934 but includes the VOU point of 1943 and the adjusted WAK measure. (Observer designations are those used in the WDS.)

To set a weight for the *HST* point, we stipulated that its residual in *x* and *y* from any orbit should not exceed 0".009, that is, 3 times its formal error. This yields a lower weight limit of 10. Because the motion of ADS 11300 is clearly prograde, orbits with inclination of 90° or larger are unacceptable. This condition sets an upper weight limit near 40. We adopted 25 as the weight for the *HST*-FGS observation.

Revised orbital elements, together with those by Baize (1974), are listed in standard notation in Table 3. The combined *x*, *y* residual of the *HST* measure is 0".0076, while the rms residual of the 37 visual data points is 0".054. Had the *HST* observation been given unit weight, the rms residual of all 38 data points would be 0".052. Evidently, a weight of 25 has not unduly biased the solution in favor of the *HST* measure. A plot of the revised orbit and of the 38 data points is presented in Figure 4. An ephemeris for 1991.0 through 2000.0 is given in Table 4.

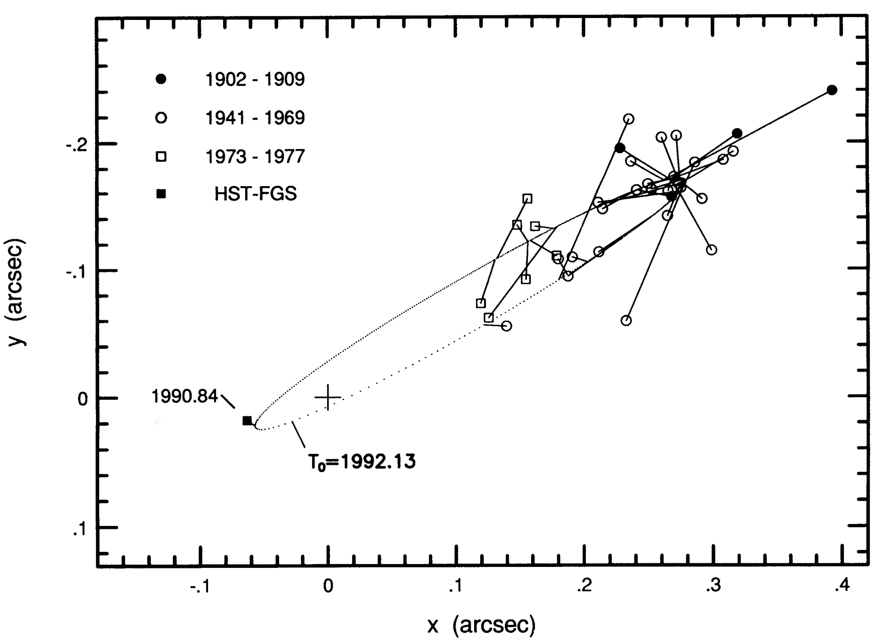

FIG. 4.—Revised orbit of ADS 11300 based upon 37 visual data points and the *HST*-FGS3 observation. The predicted time of periastron passage is indicated by T_0. A straight line connects each data point with its corresponding position on the apparent orbit.

TABLE 3

ADS 11300: ORBITAL ELEMENTS

	Baize (1974)	Revised (1991)
P........	60.0	54.11 ± 6.05 y
n........	6.000	6.654 ± 0.745 deg y^{-1}
a........	0.222	$0''.234 \pm 0''.046$
e........	0.54	0.797 ± 0.173
ω.......	152.0	$45°.0 \pm 16°.1$
Ω.......	122.8	$296°.7 \pm 16°.1$
i.........	84.0	$83°.2 \pm 59°.1$
T_0.......	1984.1	1992.13 ± 0.64
A.......	+0.09703	$+0''.091877 \pm 0''.024913$
B........	−0.17066	$-0''.138960 \pm 0''.024913$
F........	+0.07368	$-0''.056777 \pm 0''.087333$
G.......	−0.07651	$+0''.156525 \pm 0''.087333$

TABLE 4

ADS 11300: EPHEMERIS (EQUINOX OF t)

t	P.A.	Separation	x	y
1991.00......	292°03	0″062	0″023	−0″057
1991.20......	293.42	0.061	0.024	−0.056
1991.40......	294.87	0.059	0.025	−0.054
1991.60......	296.47	0.055	0.025	−0.049
1991.80......	298.39	0.049	0.023	−0.043
1992.00......	300.99	0.041	0.021	−0.035
1992.20......	305.23	0.030	0.017	−0.024
1992.40......	315.25	0.017	0.012	−0.012
1992.60......	4.08	0.007	0.007	0.000
1992.80......	85.57	0.013	0.001	0.013
1993.00......	100.72	0.026	−0.005	0.026
1994.00......	112.11	0.084	−0.032	0.078
1995.00......	114.50	0.128	−0.053	0.116
2000.00......	118.18	0.253	−0.119	0.223

5. CONCLUSIONS

Only the future will show whether the *HST* measure has served to define the orbit of ADS 11300. The revised dynamical elements indicate an orbit of somewhat shorter period and of much higher eccentricity than previously thought. They also predict that periastron passage is yet to occur, namely during 1992. According to the ephemeris (Table 4), this pair should undergo rapid orbital motion during 1991 through 1993, becoming closer than 0″01 soon after periastron passage.

Repeated observation of ADS 11300 during the next two years may prove an exceptional opportunity to test, calibrate, and challenge the performance of *Hubble Space Telescope* as a powerful tool for astrometry of close binary stars.

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