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Duplicity in *Hubble Space Telescope* Guide Stars: Fine Guidance Sensor Serendipitous Survey Results

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ABSTRACT. Data from the *Hubble Space Telescope* (*HST*) Fine Guidance Sensor (FGS) interferometers, covering 22 months of guide-star acquisition operations, have been analyzed for evidence of stellar duplicity. The data comprise a survey of observed guide stars, all of which are taken from the *HST* Guide Star Catalog, ranging in magnitude from 9 to 14. The survey results cover a parameter space for the newly found doubles, for the fainter stars, which are of smaller limiting angular separations than in any previous surveys. The normal *HST* engineering telemetry data from 13,979 acquisitions on 4882 stars have been processed. The FGS guidance data can reveal duplicity with separations ranging from approximately 30 mas, for the brighter stars, with small magnitude differences, up to the neighborhood of 500 mas, and in some cases to 1000 mas. The fraction of guide stars indicating duplicity is a function of the statistical criteria used but is over 5% at a very high level of confidence. It is possible that if some of the brighter and closer pairs could be identified as nearby, then their orbital motions would be rapid enough to allow a mass and distance determination on a timescale of a decade if followed with ground-based interferometric and spectroscopic instruments. A brief catalog of doubles is given, nearly all of which are of certain duplicity. Information for accessing on-line catalogs of large numbers of stars with lesser, but nevertheless strong, probabilities of duplicity and also for the solutions for duplicity from all acquisitions is provided.

1. INTRODUCTION

Observations with the *Hubble Space Telescope* (*HST*) require locking the Fine Guidance Sensors (FGSs) onto the interferometric fringes of guide stars. Normally, for maintaining a highly stable placement of targets in the various science instrument apertures, two guide stars are used, one in each of two FGS units (of three FGS units on board *HST*). Stars used for guidance are selected from the *HST* Guide Star Catalog (GSC). The GSC, which is available on CD-ROMs from various sources, has been thoroughly described in three papers (Lasker et al. 1990; Russell et al. 1990; Jenkner et al. 1990).

The stars used for guidance span the entire GSC magnitude range, from approximately 9 to 14 mag. Guide stars for each *HST* pointing are chosen by the *HST* Science Operations Ground System using a software system called the Guide Star Selection System, developed at STScI. The FGS instruments on *HST* are unique in their ability to detect quickly stellar duplicity at a small fraction of an arcsecond with high precision at the faint end of the GSC magnitude range, since ground-based interferometric techniques are generally limited to brighter stars. By comparison, the *Hipparcos* results are complete only to a magnitude of 10.5, with a limiting magnitude (sparsely covered) of 12.4 and with much lower resolution.

Prior to *HST* cycle 5, acquisition data were normally telemetered to the ground with a sampling rate of 1 Hz. This temporal resolution was too coarse to yield information on the shape of the interferometer fringes. Beginning in early 1995, a new engineering telemetry format called "HN" was adopted for normal operations to permit detailed engineering studies of the degrading mechanical behavior of the FGS star-selector servos. The HN format provides FGS servo positions and photomultiplier tube (PMT) counts at 40 Hz, and this allows the shapes of the star fringes from the interferometers to be analyzed and a serendipitous duplicity survey to be carried out in parallel with the planned research of *HST*.

The FGS instruments can also be used to determine accurately the relative positions of stars in the FGS fields of view and for double-star studies by high-resolution interferometer fringe scanning (Benedict et al. 1992). In the TRANS mode of astrometric observing, an FGS repeatedly scans the interferometric fringes of the target star in milliarcsecond or smaller steps and thereby achieves a much higher spatial resolution than is obtained in the normal guide-star acquisition mode. But observations for planned astrometric research require dedicated telescope time and must compete with all other scientific programs for approval. The astrometric information from *HST* guide-star acquisitions may be obtained at no additional cost of spacecraft time for all *HST* guide-star observations. The acquisition fringe information is obtained in a single scan with a spatial sampling of 6 mas along each of the two orthogonal interferometric axes. Roughly 7000 guide-star acquisitions per year take place as part of normal operations for all scientific programs.

Of the 13,979 acquisitions spanning 22 months of telescope operation in the present study, the number of unique stars observed was 4882 or about one-third of the total number of acquisitions. These numbers imply three walkdowns per star, but the repeated acquisitions are not equally distributed. Some scientific programs repeat observations many times on the same target while others involve only a single visit to a target.

The double-star detections from the FGS acquisition data are not biased by the duplicity screening process used in the formation of the GSC. The GSC has excluded stars that appear as double on the Schmidt astrograph plates, but the separation detection limit was a few arcseconds. The FGS double-star detections are well below that level.

The FGS interferometer fringes formed by the guide stars can reveal duplicity from roughly 30 mas to the neighborhood of 500 mas. Limits vary greatly depending on the star brightness, the magnitude of the companion, and other factors. Separations of over 1″ are possible in the rare cases of doubles that cause the Fine Guidance Electronics (FGE) to fail to recognize a fringe and thus continue the scan up toward 2″. Magnitude differences from 0 to 2 are typical, and higher values up to, and somewhat over, 3 are possible for stars at the bright end of the guide-star magnitude range and at the larger separations.

The brighter stars in the GSC are preferred for the best guiding performance, but the brightest stars available in the small FGS fields of view are often at the faint end of the GSC magnitude range. All-sky plots of the guide-star coordinates reveal a rather isotropic distribution of *HST* pointings. The *HST* extragalactic research programs select against the Galactic plane, leaving no predominance of low galactic latitudes and perhaps a slight deficit.

The incidence of binaries in the 9–14 mag range with separations of a small fraction of an arcsecond has not been well known in the past. The prelaunch estimates of the statistics of guide stars predicted higher FGS lock-failure rates due to duplicity than that found in operations. The overestimate was due in large part to overly pessimistic predictions of the instrument response to binaries (Hershey & Bély 1994).

The frequency of close binaries among the guide stars is of interest for the planning of the guidance of future space telescopes and interferometers, and all binary star statistical information relates in some degree to stellar formation and evolution. Some of the binaries discovered in this investigation could eventually yield stellar masses with extended study.

2. ACQUISITION OF GUIDE STARS BY *HST* FGS

Descriptions of the design and operation of the FGS instruments appear in various sources, such as in Bradley et al. (1991) and in STScI documents such as the Fine Guidance Sensor Instrument Handbook (Holfeltz 1996). The FGS operations of interest here are those that generate data while searching for the interferometer fringe after the "spiral search" and "coarse track" processes have located the position of the star to a few tens of milliarcseconds. The motion of the interferometer 5″ × 5″ instantaneous field of view (IFOV) is controlled by integrated units carrying stepper motors, encoders, and deflection optics, and these integrated units are called "star selectors." In preparation for the search for the null of the fringe visibility function, the center of the IFOV of the interferometer is offset approximately 0″.5 from the photocenter of the star in the positive direction of the FGS *X* and *Y* coordinates (the "backoff" position). The IFOV is stepped toward the star (the "walkdown"), nominally in steps of 6 mas in each coordinate, usually at a rate of 25 ms of time per step (40 Hz). At each step, the location of the IFOV and the PMT counts are read out to the telemetry stream, providing the data for generation of the fringe visibility functions. There are four PMTs in each FGS, two for each coordinate. When both coordinates have satisfied an algorithm that tests for the presence of a fringe, the FGS is put in the "lock" state in which a 40 Hz servo loop causes the star selectors to follow the null of the fringe in each coordinate as small telescope motions cause the star to shift in the FGS IFOV.

The walkdown distance in each coordinate is the angular length scanned on the sky by the interferometers. The geometry of the walkdown scan by the IFOV is shown schematically in Figure 1. Each interferometer null line is 5″ wide as it moves through the walkdown distance, generating the hatched parallelograms in Figure 1. At all times, each interferometer can receive photons from the entire IFOV, but the distance of a point source from the null line determines the degree of interference. The walkdown distance in each coordinate is the length of abscissae plotted in Figures 2 and 3 (which show eight walkdowns). Due to instrumental alignment differences, the walkdown distances vary between the two orthogonal interferometers in each FGS and among the FGS units. Table 1 gives the backoff and walkdown distances in each coordinate for the original three FGSs and for the new FGS installed in place of FGS1 in the 1997 February servicing mission, "FGS1R." The FGE allows only equal backoff distances in the two coordinates.

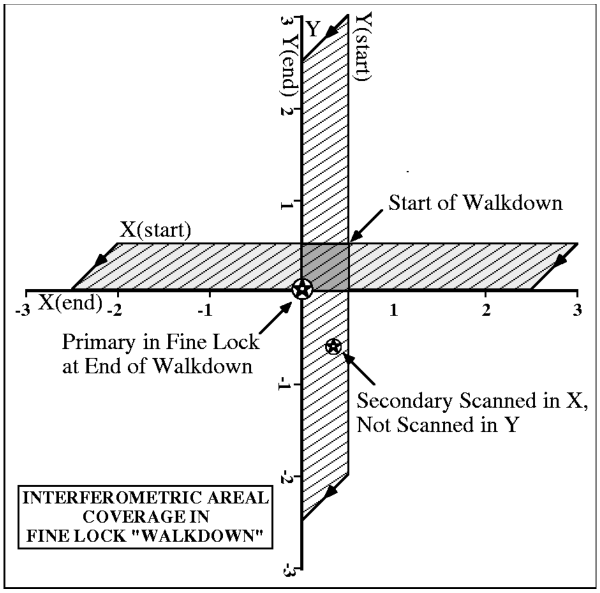

FIG. 1.—The geometry of the walkdown scan coverage in reaching lock. Each interferometer null line spans the IFOV. The IFOV in the "walkdown" is moved from the backoff position, as shown, to the lock position at the intersection of the two dark null lines. The sky coverage by the interferometer scan may be regarded as generated by a diagonal motion of two slits in the shape of a plus sign. Only the first quadrant is scanned in both coordinates. The third quadrant is not seen by the interferometers in the case of lock. The coverage is represented in the figure by the hatched parallelograms.

The relation generally adopted for the generation of a fringe visibility function from the pair of interferometer PMT counts in each axis is of the form $(A-B)/(A+B)$, where A and B are counts in an interferometer PMT pair. The interferometric fringes for unresolved-source visibility functions on each FGS axis, referred to alternatively as "*S*-curves" or "transfer functions" in the literature, are shown in the references to the FGS instrumental descriptions previously cited.

When the FGS detects a full lobe of the fringe structure, the interferometer moves to the central null, and only half an *S*-curve is seen in the telemetry. This is the normal or "lock" case of acquisitions. Figure 2*a* is representative of walkdowns reaching lock. The duplicity information for a close pair in lock, from half of their blended fringes, is of course far less well determined than from a full scan. If a fainter star lies in the walkdown path, $\gtrsim$150 mas from the primary, an *S*-curve of smaller amplitude but of complete spatial fringe structure will be generated (Figs. 2*c* and 2*d*). Doubles $\lesssim$150 mas in separation in one coordinate will show superposed components (Fig. 2*b*) and will appear as a single, broadened *S*-curve when separations are near or below 45 mas (Fig. 2*a* and Fig. 3*a*).

In less than 1% of the guide stars, the FGE fringe detection criterion is not met because of the presence of two stars of nearly equal brightness and separated fringes. Two stars in the interferometer cause the amplitude of each fringe to be half the normal size, as may be inferred from the visibility function above. The denominator of the visibility function carries the counts from both stars, but only the counts from one star generate the difference $A-B$ for the fringe at each star location. This is the "no-lock" case of the acquisition process, and the fringes of both stars are fully scanned, resulting in more accurately determined separations and magnitude differences (Fig. 3). Typically, several tries are made if such an acquisition failure occurs, giving multiple full scans. The failure to lock on guide-star fringes is increasingly unlikely to occur in two nearly equally bright stars as separations decrease below 40 mas (Hershey & Bély 1994) because the co-addition of the positive and negative parts of the *S*-curves from each star results in predominantly constructive summations.

3. EXTRACTION AND ANALYSIS OF WALKDOWN DATA

The temporal duration of the walkdown to fine lock normally is only several seconds. This is a very small fraction of the target visibility periods that are $\gtrsim$52 minutes long. Extraction of the 40 Hz astrometric guiding data from the engineering telemetry for the walkdown analysis has been automated by augmenting the Observatory Monitoring System (OMS) software at STScI. OMS normally processes the engineering telemetry for all of the spacecraft subsystems 1 or 2 days after it has been generated on *HST*.

When OMS processes the engineering data, flags for the states of the FGSs are tracked. The "fine-lock" flag is set when an FGS begins the walkdown process, and the "fine-lock data valid" flag is set when the FGE autonomously declares a lock in both coordinates. By special arrangement for this project, the OMS software writes a file of full 40 Hz resolution data instead of its normal 20 Hz format, from the two star-selector encoders and four PMTs for the time interval between the two flags.

The next stage of processing reads the files generated by OMS and decommutates and appropriately time tags the stream of the six parameters of interest (two encoder positions and four PMT counts for each FGS). The star-selector encoder positions are expressed in a curvilinear coordinate system in the *HST* focal plane and are converted to Cartesian coordinates internal to each FGS (see above references). The interferometer pairs (whose axes are orthogonal to each other) require the star selectors to be driven at separately varying rates by the FGE in order to generate a straight line in Cartesian coordinates for the walkdown. The PMT count pairs are converted to a fringe visibility function of the form discussed previously. The sum in the denominator provides a normalization factor only and so should not carry the noise of individual PMT readouts. It is formed in the analysis as a fixed mean of many readouts.

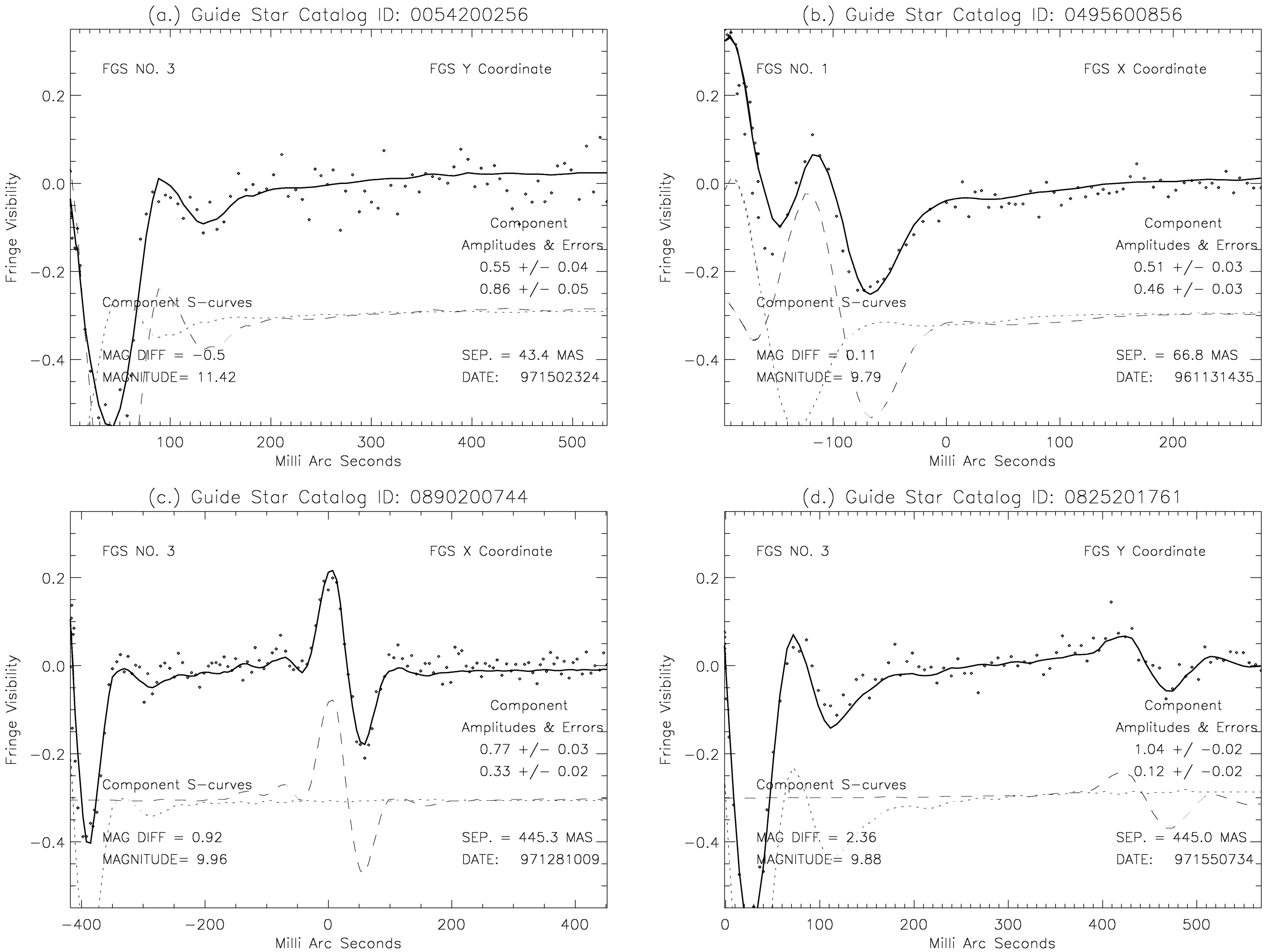

FIG. 2.—Examples of walkdowns on double stars reaching lock. (*a*) A case of lock that is representative of all normal lock cases in appearance. In this case, however, the solution gives evidence of blending with a companion. In panels (*b*), (*c*), and (*d*), the primary star is in lock, showing only half of its *S*-curve. The secondary is sufficiently faint that it does not reduce the amplitude of the primary below lock detection.

3.1. *S*-Curve–Fitting Technique

The separate or blended *S*-curves of a binary are represented as the linear superposition of two single-star *S*-curves with null points and amplitudes to be fitted to the data as represented by equations (1) and (2) for the *X* and *Y* instrument coordinates:

$$S(x) = B_{1x} * Sx_{\rm ref}(x - x_{1x}) + B_{2x} * Sx_{\rm ref}(x - x_{2x}); \qquad (1)$$

$$S(y) = B_{1y} * Sy_{\rm ref}(y - y_{1y}) + B_{2y} * Sy_{\rm ref}(y - y_{2y}). \qquad (2)$$

Here $S(x)$ and $S(y)$ represent the observed visibility data in the respective coordinates, and B_1 and B_2 are scaling factors, or *S*-curve amplitudes, to be found by the fitting process. $S_{\rm ref}$ is a single-star *S*-curve with its null at the zero point of its coordinate, $S_{\rm ref}(0) = 0$. The ratios of B_1 and B_2 represent the brightness ratio of the two stars. The arguments x_1 and x_2 of the $S_{\rm ref}$ function are the null points of each single-star *S*-curve to be found by a fitting process.

The single-star reference *S*-curves differ among the four FGSs (three current and one replaced) throughout the full fields of view accessible by the star selectors. Each FGS IFOV may be positioned in an arc-shaped field roughly 3′.5 by 15′ on the sky (commonly referred to as a "pickle") and defined by the instrument entrance apertures. The structure of the *S*-curves differs among the four FGSs, and for each FGS there is variation in the structure throughout the pickle. As part of the FGS calibration programs, reference *S*-curves were obtained

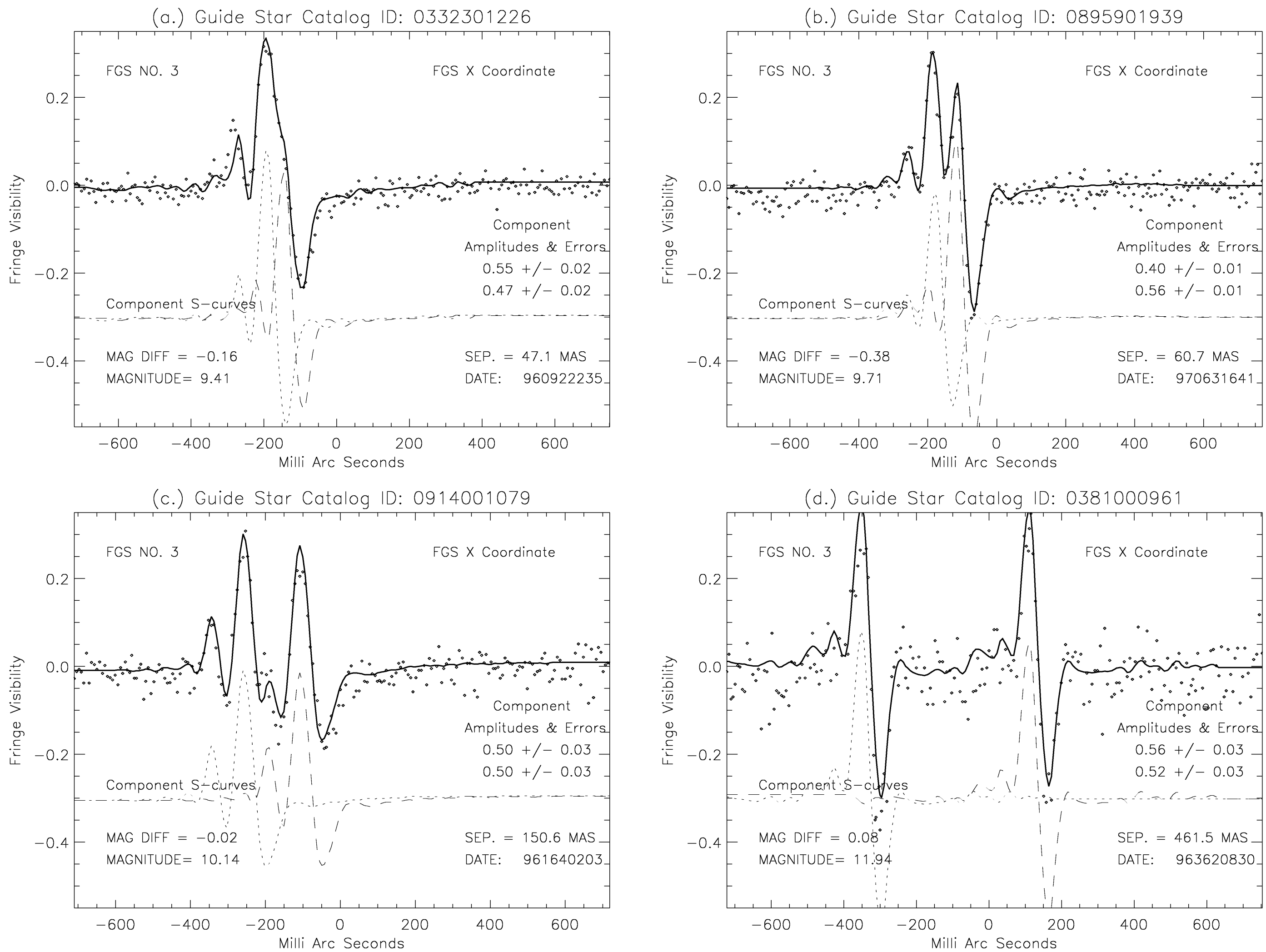

FIG. 3.—Examples of walkdowns on double stars with no-lock. In each panel, the interferometer has not met the requirements for lock because the amplitudes of the *S*-curves are diminished owing to the presence of two stars of similar magnitude. In panel (*d*), the full, separate *S*-curves are generated.

in a grid across the four FGS fields of view with high signal-to-noise ratio (S/N) by the astrometric TRANS mode programs on bright stars. These reference data were obtained, along with their locations in the four FGS instrument fields of view, from the STScI Hubble Data Archive. Before each walkdown was fitted, a reference *S*-curve was chosen from the same FGS, closest in distance in the pickle to the observed guide star.

Instrumental *S*-curves are not readily amenable to analytic representation, particularly since they are distorted into complex shapes by the spherical aberration of the *HST* primary mirror. (There have been no corrective optics installed on *HST* for the FGSs like there were for the scientific instruments.) Observed reference *S*-curves (rather than analytical models) are therefore used in the fitting process that employs numerical techniques.

A differential correction method for fitting was adopted. For each interferometer axis, the method assumes that starting values are available that are near the correct values. The starting values are used in the fitting equation to generate a set of residuals, $R(x)$. The residuals are represented as the total derivative with respect to the fitting parameters of equation (1), with corrections to the parameters to be determined:

$$R(x) = \sum \frac{\partial S(x)}{\partial p_i} \Delta p_i \text{ or } R(y) = \sum \frac{\partial S(y)}{\partial p_i} \Delta p_i. \qquad (3)$$

Here the p_i are the amplitudes and positions of equations (1) and (2). The amplitude derivatives in each coordinate are simply the values of the reference *S*-curve at the same distances from their nulls, but the derivatives with respect to position require a numerical differentiation of the *S*-curves. Least-squares fits are made for equations (3) to determine small cor-

TABLE 1
BACKOFF AND WALKDOWN DISTANCES (ARCSEC)

Distance	FGS1	FGS1R[a]	FGS2	FGS3
X backoff	0.45	0.45	0.10	0.28
Y backoff	0.45	0.45	0.10	0.28
X walkdown	0.43	0.53	0.68	0.88
Y walkdown	0.63	0.78	0.94	0.59

[a] FGS1 replacement, 1997 February Servicing Mission.

rections for each of the parameters. A fraction of the computed corrections is then applied to each parameter value, allowing a new set of residuals to be computed. The cycle is repeated until the corrections are a small fraction of their formal errors in the least-squares fit to the current residuals. If oscillation in the parameters occurs, the fraction of the correction used is reduced. A similar fitting method has been used successfully on lunar occultation fringes by Schneider (1985). Sufficient logic is included throughout the initial fitting program in order to provide the stability in the solutions that allows the initial processing of thousands of walkdowns in unattended computer runs.

In principle, the number of fitting constants could be reduced in equations (1) and (2) by constraining the ratio of the amplitudes to be the same in both coordinates. A code was developed for combined solutions, but independent *X* and *Y* solutions were made for the results presented here. Combined solutions are less convenient for automation with a differential correction technique because assumptions must be made as to the relative position of the fainter and brighter components for starting parameters.

S-curves can be transformed into simple energy profiles, resembling a slit-scan of the component stars, by a Fourier deconvolution method (Hershey 1992) and then fitted with scaled replicas of the profile of a single reference star. The method was developed for TRANS mode observations of complete *S*-curves that have much finer spatial sampling and much larger S/N than walkdown *S*-curves, a requirement for Fourier deconvolution. The method is most useful for interpreting TRANS mode scans of multiple stars (Lattanzi et al. 1994). It can be used to analyze the acquisition walkdown *S*-curves of higher S/N but introduces an additional processing step.

3.2. Analysis of Doubles in the "Lock" Case

The walkdown data appear in two basic forms, arising either from a "lock" or "no-lock" walkdown. Undoubtedly, many guide stars are double at the 30 mas level and should yield the fits often seen in the results, but spurious fits may be generated. As previously noted, the duplicity information on close pairs in the half *S*-curve is limited in the lock case. Plots of single-star walkdowns reaching lock closely resemble Figure 2*a*. However, the solution for Figure 2*a* indicates that the half-fringe is broadened as if the star is double. Without independent checks, it is not possible to assign a limit for close double detection in lock. Above about 60 mas separation, the blended half *S*-curves become more clearly distorted by the companion, if not too faint, and provide stronger constraints to the solution for duplicity (Figs. 2*b*–2*d*).

The lock cases have been fitted with the differential correction process by first assuming a blended pair with starting values of equal brightnesses and 45 mas separation. From that start, separations from 0 to over 100 mas can be reached by the differential-correction process. Usually one star dominates the fit and the other falls to an insignificant brightness. All final-fitting constants and their errors are recorded. For the possibility of a wider companion, the remaining 0″.5 of the walkdown outside the locked star fringe is checked for evidence of another *S*-curve. The most likely position, regardless of how weak, is taken as the starting position. Again, if the data do not support a wide companion, the amplitude coefficient, B_2, drops to a small value relative to its error, but the solution is recorded regardless of the results.

The normal walkdown to lock is not a full survey of the area surrounding the guide star. The nominal width of the interferometer IFOV is 5″. The walkdown is at 45° in the first quadrant of FGS coordinates. The scan can be thought of as the scan of a pair of slits arranged in the shape of a plus sign where the bars of the plus sign are 5″ in length (Fig. 1). The *X* interferometer covers part of quadrants 1 and 4 in a band 5″ wide, and the *Y* interferometer covers part of quadrants 1 and 2. In the case of lock, there is no coverage of quadrant 3, as shown in Figure 1. A companion will be detected in two coordinates only if it lies in quadrant 1. The fraction of doubles detected in two coordinates is predicted to be less than about 18% of all double detections from the ratio of areas in Figure 1 and a probability density function of separations (based on a weighted mean of the three FGSs). The percentage found is 13% from the data for the 13,000 walkdowns of this study.

3.3. Analysis of Doubles in the "No-Lock" Case

For the no-lock case, good starting values for the fitting parameters can generally be set and a solution made, as in Figure 3. Autonomously convergent solutions, however, are sometimes difficult to obtain with computed initial parameter values, and occasional data anomalies occur, which are not amenable to automated solutions. Starting values are initially generated by computer algorithms, but there are options to override computed starting values manually and to rerun the solutions. Some stars yield a lock in one coordinate but a no-lock case in the other. If a guide star fails lock, it is removed from the guide-star candidate list and thus, unfortunately for double-star science, is never seen again by the FGS interferometers.

Formal separation errors can be as small as a few milliarcseconds. In cases of repeated no-lock walkdowns on the same star, the errors in the solution parameters are determined from the differences of the individual acquisitions rather than from the internal formal errors of the fitting process. Separations have often repeated with standard deviations under 2 mas.

Duplicity data from the solutions are provided in Table 2. A full explanation of the tabular entries is given in the accompanying footnotes. For the many stars that have been observed more than once, the standard error of the separation measurements and magnitude differences is given in Table 2.

For either the lock or no-lock cases, double-star fitting accuracy is primarily a function of star brightnesses. The guide-star range of 9–14 magnitude corresponds to a range of a factor of 10 in photon noise. However, guide stars in the latter part of the 13th magnitude are acquired with a doubling of the integration time spent at each walkdown step in order to improve the reliability of the acquisition process, and thus the noise range is roughly a factor of 7 from brightest to faintest guide stars.

4. DOUBLE-STAR STATISTICS

The distributions of separations and magnitude differences (Δm) of the guide stars are shown in Figure 4. The magnitude distribution of the guide stars chosen for use by *HST* reflects that of the GSC. This, however, is not necessarily a perfectly unbiased sample since the brighter stars available in the FGS fields of view are preferentially selected.

The histogram of the angular separations of the doubles in Figure 4 is similar to the roughly (1/separation) distribution functions found in various double-star surveys and catalogs such as the Washington Double Star Catalog (Hogeveen 1990). Figure 4 includes single- and two-coordinate separations. The separation distribution seen in the guide stars is a convolution of their physical separation distribution with the distance distribution of the guide stars and is limited in range by the capabilities of the FGSs. The larger incidence of binaries at small separations is primarily due to the increase in the number of stars with magnitude and thus, statistically, with distance.

The separation distribution in Figure 4 and the number of doubles detected are a sensitive function of the statistical criteria for duplicity. If the detection threshold for duplicity is set too low, a clear excess of numbers appears near the limit of separation detection for the no-lock cases. The occurrence of such an excess serves as an independent guide on the setting of duplicity criteria for the half *S*-curve fits. A quantitative measure of the significance level of the fits for duplicity is the ratio of the *S*-curve amplitudes to their formal errors from the least-squares solutions.

Higher ratios of amplitude coefficients to their errors need to be met in the solutions for close pairs in the lock case, since only a half-fringe is available for fitting. As noted above, the half-fringes are susceptible to mismatches between reference and observed *S*-curves, compounded with all other sources of error (Fig. 2*a*). The solutions could generate a faint, spurious companion to improve the fit of the reference to observed half *S*-curves. The criteria for duplicity below 100 mas for the lock case have been set to increase as Δm increases above 1.0 and as separation decreases below 100 mas. Separations at 25 mas in lock with small Δm can meet very high significance criteria. Undoubtedly, there are many real doubles at this separation level; although without independent tests, clear limits of validity cannot be set. No-lock cases below 35 mas are included in Table 2. A few separations under 35 mas in Table 2 are no-lock cases.

Reducing the significance level required for the solutions for the companions can cause the percentage of doubles to rise to 10% or more, with significance levels that are quite strong by statistical standards. There are 269 unique star entries in Table 2, which represents a duplicity detection fraction of 5.5% of the 4882 unique guide stars in this study. With the detection criteria set to yield a conservative 5% duplicity fraction, visual inspection of the *S*-curves confirms unambiguously the presence of a companion in nearly all cases. Since quadrant 3 is not sampled in the lock cases, the duplicity fraction for the same detection criteria would rise to approximately 7% if corrected for incomplete sampling.

The distribution of Δm in Figure 4 remains roughly constant up to $\Delta m = 2$ then drops rapidly. The detection of companions is limited by the photon noise in the data; this photon noise is a function of the magnitudes of the components. For the close cases in lock, the presence of only half an *S*-curve severely limits the range of Δm. The doubles with $\Delta m > 2$ in Table 2 are generally more widely separated and of smaller systemic magnitudes.

Guide stars are observed across a time interval of a year or more if the scientific target is on a long-term proposal. If the target is visited across intervals spanning several months, then it is likely that the same guide stars are not used because the default roll of the telescope changes. Of the set of guide stars that are repeated across intervals of a year, only a small number show evidence of duplicity in both coordinates. Only a subset of those are likely to be physically close enough to show orbital motion. Detections in two coordinates are needed for a clear detection of orbital motion, unless the roll of the telescope remains the same. Thus far, these severe requirements leave no star with solutions in both *X* and *Y* and a large time interval in the 22 months of coverage. Two cases repeat across a year at different rolls but with one coordinate below the duplicity criterion.

The cases of single-coordinate detections carry limited spatial information. As suggested by Figure 1, a single-coordinate observation indicates the presence of a star somewhere along a line 5″ long and hence is only a projection of the true separation along the interferometer detection axis. The companion lies somewhere along a line with the position angle given in Table 2, with its closest distance from the primary given by the separation in the table. Single-coordinate detections, however, do yield unambiguous magnitude differences of the stellar components.

TABLE 2
SELECTED DOUBLES FROM *HST* ACQUISITION DATA

R.A.[a]	Decl.[b]	GSC No.[c]	Epoch[d]	Mag[e]	*XY*[f]	Sep[g]	P.A.[h]	Δ*M*[i]	s.e.[j]	N*x*[k]	Sep*X*[l]	s.e.[m]	EM[n]	N*y*[o]	Sep*Y*[p]	s.e.[q]	EM[r]
00 25 30.7	+00 12 13	0000300683	96 157 13:35	12.59	*XY*	331.7	176.1	1.55	0.21	1	91.8	…	…	1	318.7	…	…
00 57 20.6	+03 18 19	0001500284	97 322 04:48	9.85	*Y*	133.7	143.9	0.22	0.01	…	…	…	…	2	133.7	2.0	1.4
02 41 31.4	+07 26 27	0005300137	97 293 21:45	12.89	*X*	394.4	29.4	1.68	…	1	394.4	…	…	…	…	…	…
04 23 38.4	+02 15 15	0007500143	96 233 22:40	12.91	*X*	276.3	78.1	1.40	…	1	276.3	…	…	…	…	…	…
04 14 18.0	+05 15 16	0008000765	97 198 20:33	9.65	*XY*	349.4	168.8	0.05	0.01	2	66.1	2.1	1.5	2	343.1	1.6	1.1
08 32 10.1	+04 17 17	0021801129	96 077 12:58	10.89	*X*	248.9	2.4	0.43	…	1	248.9	…	…	…	…	…	…
10 55 38.4	+06 55 56	0026100391	97 088 11:55	13.45	*X*	479.5	35.0	0.77	…	1	479.5	…	…	…	…	…	…
12 19 47.8	+02 09 09	0028100228	97 032 19:36	12.63	*Y*	682.5	11.3	1.10	…	…	…	…	…	1	682.5	…	…
12 17 54.7	+01 26 26	0028100685	97 114 16:38	11.68	*XY*	81.8	174.6	0.81	0.11	3	−48.8	0.5	0.3	16	65.6	3.4	0.8
12 17 54.7	+01 26 26	0028100685	97 116 17:38	11.68	*X*	45.2	26.9	0.63	…	1	45.2	…	…	…	…	…	…
12 21 49.2	+01 19 19	0028200774	97 020 13:22	13.77	*X*	622.6	178.0	1.82	…	1	622.6	…	…	…	…	…	…
12 22 00.5	+04 16 16	0028500705	96 075 22:36	13.78	*Y*	505.4	74.0	1.40	…	…	…	…	…	1	505.4	…	…
12 30 30.5	+01 01 01	0028900652	96 192 22:53	12.79	*X*	85.7	20.2	1.26	…	1	85.7	…	…	…	…	…	…
14 22 04.1	+03 39 40	0032101239	97 187 03:39	13.48	*XY*	509.2	66.5	0.35	0.00	1	379.0	…	…	1	340.0	…	…
15 03 26.9	+00 56 57	0033400864	96 210 08:24	13.50	*Y*	132.4	109.2	1.80	0.00	…	…	…	…	2	132.4	66.5	47.0
15 06 28.8	+02 18 18	0033800021	97 191 14:12	13.65	*Y*	633.4	115.4	0.08	…	…	…	…	…	1	633.4	…	…
15 04 51.1	+01 57 58	0033800481	97 191 13:30	13.42	*Y*	395.0	115.3	1.52	…	…	…	…	…	1	395.0	…	…
15 16 51.4	+07 14 14	0034800590	97 222 06:47	12.35	*X*	53.3	20.0	1.88	…	1	53.3	…	…	…	…	…	…
16 01 41.3	+01 44 45	0036600155	96 223 22:11	11.54	*Y*	57.7	124.8	0.41	0.16	…	…	…	…	2	57.7	0.9	0.6
21 31 48.0	+00 19 19	0054200256	97 150 23:24	11.17	*Y*	43.4	66.3	0.49	…	…	…	…	…	1	43.4	…	…
00 25 16.8	+10 46 47	0059900863	97 189 16:54	11.88	*Y*	205.0	58.8	0.65	…	…	…	…	…	1	205.0	…	…
04 16 37.2	+11 21 21	0067500232	97 009 05:28	11.93	*Y*	214.5	70.3	0.01	…	…	…	…	…	1	214.5	…	…
04 24 39.8	+13 45 45	0068000719	97 034 23:14	9.43	*Y*	509.1	77.7	0.03	…	…	…	…	…	1	509.1	…	…
05 02 33.4	+11 53 54	0069301528	97 085 10:51	13.08	*Y*	719.6	178.2	1.15	…	…	…	…	…	1	719.6	…	…
06 21 32.2	+09 50 51	0073502891	97 107 23:30	12.32	*X*	50.4	7.7	1.37	0.20	2	50.4	0.2	0.1	…	…	…	…
06 41 01.4	+09 15 15	0074601824	96 088 06:13	10.67	*Y*	102.6	86.0	0.40	0.00	…	…	…	…	2	102.6	0.0	0.0
08 54 09.6	+12 03 04	0081400939	97 127 01:48	10.85	*X*	124.8	106.3	1.65	…	1	124.8	…	…	…	…	…	…
10 48 01.4	+12 23 24	0084900462	97 099 15:59	12.27	*Y*	90.4	39.8	1.38	…	…	…	…	…	1	90.4	…	…
12 13 45.6	+09 44 45	0086600416	97 084 22:49	9.13	*Y*	255.5	173.8	2.42	…	…	…	…	…	1	255.5	…	…
12 34 44.2	+08 21 21	0087400037	96 173 06:03	13.27	*Y*	525.4	108.5	1.10	…	…	…	…	…	1	525.4	…	…
12 30 12.0	+07 47 48	0087400971	96 123 14:14	10.94	*X*	672.4	126.5	1.60	…	1	672.4	…	…	…	…	…	…
12 30 57.8	+12 28 28	0087700297	96 184 12:13	11.87	*X*	293.2	23.6	2.10	…	1	293.2	…	…	…	…	…	…
12 36 02.2	+12 24 24	0087800489	97 016 20:14	13.75	*XY*	400.5	233.9	0.95	0.20	4	109.6	11.2	5.6	4	385.2	12.9	6.5
12 24 59.3	+12 47 48	0087900299	97 021 16:17	13.97	*XY*	281.4	219.1	0.74	0.19	8	112.4	4.8	1.7	1	258.0	…	
12 34 44.9	+14 20 21	0088000077	96 138 16:05	13.24	*Y*	415.3	123.0	1.30	…	…	…	…	…	1	415.3	…	…
18 04 36.2	+10 52 52	0101200409	96 246 15:31	12.83	*Y*	118.6	101.8	1.80	…	…	…	…	…	1	118.6	…	…
19 51 23.3	+08 46 46	0105801741	97 246 11:55	12.48	*X*	135.4	108.7	0.91	…	1	135.4	…	…	…	…	…	…
21 51 38.4	+12 43 43	0113000098	96 210 14:40	10.95	*X*	939.2	121.7	0.11	…	1	939.2	…	…	…	…	…	…
21 51 16.3	+12 20 20	0113000524	96 339 22:35	13.03	*X*	323.0	158.3	1.10	…	1	323.0	…	…	…	…	…	…
21 50 01.9	+12 45 45	0113001244	96 217 16:35	13.06	*XY*	593.8	338.9	0.59	0.17	13	422.1	7.4	2.1	15	417.6	4.4	1.1
22 14 40.1	+13 39 39	0114901428	96 111 02:03	13.65	*X*	164.7	175.8	1.60	…	1	164.7	…	…	…	…	…	…
22 36 31.7	+13 37 37	0115700813	97 129 20:52	13.65	*X*	424.3	166.7	1.69	…	1	424.3	…	…	…	…	…	…
22 50 30.7	+14 30 30	0115900555	97 176 20:41	11.48	*Y*	498.8	61.1	0.90	…	…	…	…	…	1	498.8	…	…
00 19 10.3	+16 26 27	0117900100	97 030 00:52	12.84	*Y*	481.2	148.7	1.43	…	…	…	…	…	1	481.2	…	…
00 27 44.2	+16 58 59	0118000852	97 288 11:41	13.13	*X*	59.2	136.1	0.34	0.29	10	59.2	5.3	1.7	…	…	…	…
00 27 44.2	+16 58 59	0118000852	97 288 15:01	13.13	*X*	61.7	138.1	0.33	0.20	12	61.7	2.6	0.8	…	…	…	…
03 40 30.2	+19 40 41	0124300607	97 234 14:31	11.99	*XY*	70.2	10.2	1.40	0.33	8	39.0	3.1	1.1	2	58.5	2.9	2.0
03 41 08.6	+19 21 22	0124300688	97 233 06:34	13.47	*X*	251.6	156.5	1.95	…	1	251.6	…	…	…	…	…	…
04 09 41.5	+16 51 51	0125100216	96 059 08:43	13.09	*Y*	233.2	79.7	1.79	…	…	…	…	…	1	233.2	…	…
04 12 06.2	+17 12 13	0125500167	97 221 22:00	13.73	*X*	158.1	168.5	0.46	…	1	158.1	…	…	…	…	…	…
04 31 25.2	+18 16 16	0126900469	97 320 19:28	10.23	*Y*	73.0	95.8	1.19	0.00	…	…	…	…	2	73.0	0.1	0.1
04 31 58.6	+18 18 19	0126900641	97 327 19:19	13.08	*XY*	245.2	318.7	0.25	0.16	1	−236.8	…	…	2	63.7	8.5	6.0
05 35 06.7	+22 07 07	0130901689	97 219 15:14	13.07	*Y*	59.8	86.4	0.71	…	…	…	…	…	1	59.8	…	…
09 06 21.1	+16 59 59	0140101339	97 320 22:46	12.25	*XY*	932.4	86.0	0.24	0.16	1	923.4	…	…	1	129.2	…	…
12 28 23.0	+16 51 52	0144500496	97 163 12:32	13.71	*X*	75.2	27.1	0.05	…	1	75.2	…	…	…	…	…	…
12 56 13.7	+21 56 57	0145501107	97 153 00:53	12.90	*Y*	75.9	113.9	0.90	0.76	…	…	…	…	2	75.9	51.6	36.5
13 56 25.2	+18 08 09	0147000113	96 130 01:05	12.08	*X*	434.6	133.0	0.29	0.18	13	434.6	7.0	2.0	…	…	…	…
13 55 27.8	+18 13 14	0147000363	97 192 10:35	13.84	*Y*	334.5	113.5	1.41	…	…	…	…	…	1	334.5	…	…
13 56 34.6	+18 26 27	0147000701	96 128 21:22	13.07	*Y*	276.4	133.0	2.00	…	…	…	…	…	1	276.4	…	…
14 57 38.9	+21 21 21	0149100862	97 078 02:27	11.95	*X*	369.8	161.3	2.04	…	1	369.8	…	…	…	…	…	…

TABLE 2
(CONTINUED)

R.A.[a]	Decl.[b]	GSC No.[c]	Epoch[d]	Mag[e]	*XY*[f]	Sep[g]	P.A.[h]	Δ*M*[i]	s.e.[j]	N*x*[k]	Sep*X*[l]	s.e.[m]	EM[n]	N*y*[o]	Sep*Y*[p]	s.e.[q]	EM[r]
15 34 56.6	+15 01 01	0149401144	96 267 01:56	13.57	*X*	454.9	168.8	1.60	…	1	454.9	…	…	…	…	…	…
15 44 01.9	+18 10 10	0149801006	97 017 04:50	11.40	*XY*	282.4	356.5	0.88	0.60	2	237.3	1.6	1.1	4	153.1	1.9	1.0
15 50 17.5	+21 17 18	0150201040	97 208 08:51	13.11	*X*	585.2	135.0	1.63	…	1	585.2	…	…	…	…	…	…
20 42 15.8	+19 21 22	0164201002	97 145 04:36	12.16	*XY*	410.9	47.1	2.45	0.00	1	396.0	…	…	1	109.8	…	…
21 14 49.0	+17 45 45	0165400039	97 303 02:26	13.47	*Y*	172.2	80.7	1.85	…	…	…	…	…	1	172.2	…	…
04 02 29.0	+22 57 58	0181301582	97 327 15:47	11.70	*Y*	81.4	114.3	0.43	0.00	…	…	…	…	2	81.4	0.0	0.0
04 22 11.5	+27 03 04	0182400375	97 302 02:37	12.88	*Y*	135.6	93.0	1.62	…	…	…	…	…	1	135.6	…	…
04 33 48.0	+23 46 47	0182900574	97 218 21:25	12.32	*X*	106.2	168.0	0.37	0.10	4	106.2	0.3	0.2	…	…	…	…
04 38 14.6	+25 42 42	0183400003	97 248 12:51	12.86	*X*	137.6	99.1	1.74	…	1	137.6	…	…	…	…	…	…
05 02 24.7	+25 27 27	0184901616	97 312 17:31	12.81	*X*	115.7	96.0	1.68	…	1	115.7	…	…	…	…	…	…
08 30 35.3	+24 15 16	0194101610	96 302 02:43	11.96	*X*	311.1	115.6	0.40	…	1	311.1	…	…	…	…	…	…
08 29 09.8	+25 19 19	0194401555	97 066 18:39	12.25	*X*	140.9	116.9	0.09	…	1	140.9	…	…	…	…	…	…
10 01 11.8	+25 02 03	0196401058	96 124 09:42	12.26	*XY*	432.7	279.6	0.29	0.26	12	244.7	4.7	1.4	1	−356.9	…	
10 04 46.6	+29 11 11	0197400921	96 345 01:52	13.61	*Y*	324.6	103.6	1.86	…	…	…	…	…	1	324.6	…	…
10 03 58.3	+28 49 49	0197400927	96 345 00:08	13.58	*X*	297.4	13.6	1.56	…	1	297.4	…	…	…	…	…	…
11 08 28.8	+24 02 03	0197801373	96 107 13:43	12.44	*X*	63.1	35.3	0.50	…	1	63.1	…	…	…	…	…	…
12 25 50.4	+22 46 47	0198901471	97 162 08:18	13.68	*X*	252.2	19.8	1.33	0.27	2	252.2	0.2	0.2	…	…	…	…
13 01 52.8	+27 34 34	0199500823	97 193 12:13	13.25	*XY*	589.0	270.2	0.50	0.00	1	563.7	…	…	1	170.6	…	…
12 58 56.9	+27 51 52	0199501980	96 136 01:39	11.70	*X*	63.5	48.1	0.24	0.10	3	63.5	1.6	0.9	…	…	…	…
12 51 26.4	+27 59 59	0199502429	96 173 12:32	13.18	*Y*	421.2	116.2	0.90	…	…	…	…	…	1	421.2	…	…
13 41 52.3	+28 35 35	0200400832	96 221 00:55	13.72	*Y*	260.3	98.3	1.60	…	…	…	…	…	1	260.3	…	…
15 35 28.3	+26 46 47	0202900426	97 246 06:56	12.88	*Y*	581.5	178.4	1.52	…	…	…	…	…	1	581.5	…	…
21 51 40.8	+28 51 52	0221401684	96 331 18:23	12.34	*X*	570.7	69.2	1.64	…	1	570.7	…	…	…	…	…	…
22 42 06.5	+29 50 50	0223200311	96 144 22:23	11.46	*X*	42.2	76.1	0.15	…	1	42.2	…	…	…	…	…	…
01 33 54.0	+30 48 49	0229300519	97 216 15:57	11.78	*X*	419.4	154.2	0.78	0.09	3	419.4	1.6	0.9	…	…	…	…
01 33 40.6	+30 53 53	0229300763	97 163 21:30	13.27	*X*	146.4	173.5	0.10	…	1	146.4	…	…	…	…	…	…
01 33 40.6	+30 53 53	0229300763	97 168 22:59	13.27	*XY*	191.1	43.1	0.49	0.30	4	150.9	3.0	1.5	1	117.3	…	
01 38 11.3	+33 05 06	0229700838	96 363 11:26	12.08	*X*	485.0	78.2	1.77	…	1	485.0	…	…	…	…	…	…
02 21 33.1	+35 40 40	0232201239	97 231 21:14	13.52	*X*	50.3	155.4	1.61	…	1	50.3	…	…	…	…	…	…
07 37 56.2	+35 19 19	0246101974	97 139 02:27	12.81	*X*	131.4	89.3	2.05	…	1	131.4	…	…	…	…	…	…
07 16 05.8	+36 47 48	0246300941	97 077 04:34	11.80	*Y*	66.1	106.4	1.05	0.00	…	…	…	…	2	66.1	0.2	0.1
09 57 48.0	+32 33 33	0250501382	96 165 01:28	13.99	*XY*	303.0	66.0	0.85	0.37	1	251.4	…	…	6	169.1	9.8	4.0
12 14 17.5	+32 51 52	0252701307	97 149 02:45	13.14	*Y*	440.3	33.4	0.96	0.21	…	…	…	…	3	440.3	6.9	4.0
12 52 53.8	+31 16 16	0253100098	97 210 18:46	13.54	*XY*	161.7	166.4	0.17	0.00	1	48.9	…	…	1	−154.1	…	…
13 24 05.3	+30 52 53	0253600284	96 065 11:46	12.70	*Y*	678.6	135.0	1.60	…	…	…	…	…	1	678.6	…	…
13 39 20.2	+33 23 24	0254000330	97 134 11:43	10.85	*X*	66.4	60.3	0.22	…	1	66.4	…	…	…	…	…	…
13 15 26.2	+36 10 11	0254100372	96 191 19:33	13.63	*Y*	130.9	108.2	1.80	…	…	…	…	…	1	130.9	…	…
13 54 12.5	+33 42 42	0254700860	97 245 03:57	10.40	*X*	254.5	67.6	0.81	…	1	254.5	…	…	…	…	…	…
16 01 58.3	+37 27 27	0257900283	96 225 12:51	13.99	*Y*	210.8	106.6	1.60	…	…	…	…	…	1	210.8	…	…
16 18 07.2	+32 15 16	0258001393	97 311 21:28	13.62	*X*	406.8	115.9	1.81	…	1	406.8	…	…	…	…	…	…
16 31 38.2	+30 26 27	0258102282	97 266 05:59	13.47	*X*	112.8	168.3	1.69	0.28	2	112.8	4.9	3.5	…	…	…	…
16 13 46.1	+33 53 53	0258302033	96 282 21:34	13.89	*Y*	311.2	58.9	1.50	…	…	…	…	…	1	311.2	…	…
20 13 26.6	+32 52 52	0267500056	97 244 13:12	12.42	*Y*	170.9	132.0	1.98	…	…	…	…	…	1	170.9	…	…
00 37 30.5	+39 41 41	0278801003	97 226 11:31	13.00	*X*	168.7	137.6	0.02	…	1	168.7	…	…	…	…	…	…
00 41 40.1	+40 09 10	0280100458	96 324 17:43	11.67	*Y*	214.5	27.4	1.59	…	…	…	…	…	1	214.5	…	…
00 42 34.8	+41 20 21	0280502180	96 345 11:19	12.60	*X*	273.0	5.0	0.63	0.02	2	273.0	3.8	2.7	…	…	…	…
03 19 40.6	+41 35 36	0285601426	97 227 20:49	12.31	*X*	84.3	166.0	0.67	0.17	10	84.3	1.5	0.5	…	…	…	…
07 38 35.8	+39 04 04	0295800575	97 322 21:28	13.72	*Y*	341.1	79.3	0.80	…	…	…	…	…	1	341.1	…	…
08 55 14.4	+43 56 56	0298900647	96 272 14:44	13.14	*X*	256.2	30.2	1.40	…	1	256.2	…	…	…	…	…	…
10 34 01.0	+39 39 40	0300200979	97 031 22:54	13.14	*X*	47.9	64.1	0.23	…	1	47.9	…	…	…	…	…	…
11 14 13.2	+40 43 44	0301001294	97 081 23:53	13.70	*XY*	801.8	86.0	2.39	0.00	1	−217.6	…	…	1	−771.7	…	…
12 09 47.3	+39 15 15	0301702022	97 196 07:56	12.00	*Y*	88.2	89.5	1.85	…	…	…	…	…	1	88.2	…	…
13 33 15.4	+38 00 00	0302500972	97 211 10:24	13.62	*XY*	72.9	53.7	1.62	0.80	2	54.5	3.5	2.5	1	48.5	…	
13 36 11.8	+37 47 47	0302601053	97 196 21:11	12.47	*X*	48.9	106.4	0.29	…	1	48.9	…	…	…	…	…	…
13 52 21.1	+39 42 43	0302700281	97 182 03:25	11.50	*Y*	284.2	122.2	1.84	…	…	…	…	…	1	284.2	…	…
13 31 10.1	+41 16 17	0302800671	97 299 01:05	13.17	*X*	399.8	170.8	1.85	…	1	399.8	…	…	…	…	…	…
17 06 41.8	+44 08 09	0308401370	97 254 06:55	13.84	*X*	220.6	1.3	0.18	…	1	220.6	…	…	…	…	…	…
19 20 01.4	+37 44 44	0313401904	96 312 00:29	12.26	*Y*	240.6	63.5	1.40	…	…	…	…	…	1	240.6	…	…
23 41 09.8	+44 21 21	0324400148	97 196 15:02	13.00	*X*	514.5	144.3	1.77	…	1	514.5	…	…	…	…	…	…
01 42 34.6	+50 39 40	0329101035	96 288 22:41	12.82	*X*	348.3	8.4	1.10	…	1	348.3	…	…	…	…	…	…

TABLE 2
(Continued)

R.A.[a]	Decl.[b]	GSC No.[c]	Epoch[d]	Mag[e]	*XY*[f]	Sep[g]	P.A.[h]	Δ*M*[i]	s.e.[j]	N*x*[k]	Sep*X*[l]	s.e.[m]	EM[n]	N*y*[o]	Sep*Y*[p]	s.e.[q]	EM[r]
03 12 31.7	+51 49 50	0332301226	96 092 22:36	9.40	*X*	46.6	135.6	0.17	0.01	2	46.6	0.7	0.5	…	…	…	…
03 12 29.0	+52 06 06	0332301440	96 092 22:37	12.77	*Y*	54.3	135.6	1.90	…	…	…	…	…	1	54.3	…	…
06 14 33.8	+47 57 58	0337900462	97 085 02:41	11.67	*Y*	360.5	0.2	2.00	…	…	…	…	…	1	360.5	…	…
08 53 47.3	+51 26 27	0342301425	97 033 11:35	13.00	*Y*	85.1	160.2	1.09	…	…	…	…	…	1	85.1	…	…
10 24 19.2	+47 17 17	0343500226	97 180 10:47	13.55	*X*	96.0	170.0	1.74	…	1	96.0	…	…	…	…	…	…
11 44 36.5	+49 51 52	0345400785	97 073 13:31	13.05	*Y*	83.8	3.0	1.69	…	…	…	…	…	1	83.8	…	…
12 17 31.9	+47 06 07	0345500642	97 325 23:07	12.41	*X*	73.9	41.0	0.83	0.05	4	73.9	3.1	1.5	…	…	…	…
14 30 03.4	+47 37 37	0347600015	97 007 17:59	9.72	*X*	322.4	28.5	1.19	0.05	7	322.4	3.3	1.2	…	…	…	…
14 18 19.7	+52 15 15	0347800286	97 174 01:57	12.46	*X*	47.5	129.4	1.16	…	1	47.5	…	…	…	…	…	…
15 57 47.0	+47 25 26	0349001040	96 193 10:33	12.89	*XY*	103.8	265.9	1.15	0.51	1	71.3	…	…	4	75.4	3.8	1.9
16 00 01.0	+47 21 21	0349100660	97 143 17:40	10.89	*XY*	249.8	239.6	1.46	0.77	1	217.0	…	…	3	123.7	1.1	0.6
17 38 52.3	+47 44 44	0351400238	97 120 22:06	9.99	*X*	68.8	136.7	0.24	0.00	2	68.8	0.1	0.1	…	…	…	…
17 23 43.7	+50 07 08	0351600330	97 294 06:15	12.92	*XY*	398.5	277.9	0.21	0.10	22	287.4	4.3	0.9	10	−276.1	4.4	1.4
18 14 35.3	+48 27 27	0352901975	97 129 09:49	13.10	*X*	112.1	136.0	0.54	…	1	112.1	…	…	…	…	…	…
23 30 29.8	+52 24 24	0364901333	96 222 13:48	11.81	*X*	137.6	33.2	1.90	0.00	2	137.6	27.7	19.6	…	…	…	…
00 20 31.0	+59 29 30	0366500755	97 159 16:12	12.96	*Y*	39.9	90.0	0.19	0.21	…	…	…	…	2	39.9	1.6	1.1
01 08 33.6	+54 43 44	0367300528	96 282 09:10	12.07	*X*	98.5	8.3	0.90	0.22	7	98.5	5.3	2.0	…	…	…	…
05 06 02.4	+52 32 32	0373400374	96 114 00:51	13.13	*XY*	235.9	196.9	0.28	0.27	15	176.1	5.8	1.5	13	156.9	4.6	1.3
05 06 34.8	+52 34 35	0373400788	96 117 15:01	12.97	*X*	661.8	146.6	1.60	…	1	661.8	…	…	…	…	…	…
05 04 50.6	+52 57 58	0373401210	96 228 13:44	12.34	*X*	399.2	98.4	1.80	…	1	399.2	…	…	…	…	…	…
06 54 27.4	+53 57 57	0376701120	97 262 23:58	13.32	*Y*	358.5	105.0	1.62	…	…	…	…	…	1	358.5	…	…
09 34 27.4	+55 33 33	0381000961	96 362 08:31	12.02	*XY*	774.4	11.6	0.03	0.01	1	461.5	…	…	2	621.9	2.3	1.6
11 59 31.2	+55 31 31	0383600201	96 090 13:03	11.33	*X*	442.6	97.7	0.80	…	1	442.6	…	…	…	…	…	…
14 04 23.5	+55 45 46	0385501150	97 181 03:40	12.65	*X*	823.7	120.2	1.12	…	1	823.7	…	…	…	…	…	…
14 41 15.1	+53 14 14	0386000975	97 240 02:31	12.88	*X*	96.4	164.0	1.79	…	1	96.4	…	…	…	…	…	…
14 36 26.9	+58 57 57	0386600032	97 012 13:13	12.85	*X*	107.9	118.0	1.46	…	1	107.9	…	…	…	…	…	…
14 36 18.5	+58 40 41	0386601334	97 012 12:36	12.68	*Y*	187.1	118.0	1.54	…	…	…	…	…	1	187.1	…	…
15 37 35.8	+58 06 07	0387501116	97 009 14:32	13.23	*Y*	292.3	115.8	1.37	…	…	…	…	…	1	292.3	…	…
20 35 24.7	+59 55 55	0396200243	96 253 18:27	12.88	*Y*	356.3	48.2	1.70	…	…	…	…	…	1	356.3	…	…
06 52 33.1	+60 52 53	0411000647	96 231 08:29	11.95	*X*	488.7	125.8	1.60	…	1	488.7	…	…	…	…	…	…
07 57 06.0	+60 26 27	0411300970	97 254 15:09	12.48	*XY*	698.9	82.2	1.33	0.00	1	527.0	…	…	1	459.1	…	…
07 55 04.1	+62 27 28	0411700201	96 340 12:23	12.23	*XY*	1171.3	4.8	0.90	0.23	1	669.9	…	…	1	960.8	…	…
09 35 02.2	+61 30 30	0413600910	97 311 22:42	13.32	*X*	108.3	17.2	0.16	0.00	2	108.3	0.2	0.2	…	…	…	…
09 43 46.3	+67 14 15	0414200341	96 108 06:26	13.32	*X*	698.1	32.1	1.70	…	1	698.1	…	…	…	…	…	…
12 01 09.6	+61 41 41	0415400880	97 132 02:10	12.31	*X*	56.3	40.0	1.49	…	1	56.3	…	…	…	…	…	…
14 46 27.6	+63 38 38	0417600981	97 143 12:20	10.80	*Y*	117.9	162.0	0.45	…	…	…	…	…	1	117.9	…	…
15 12 48.2	+61 48 49	0418000935	96 262 16:15	12.61	*X*	217.9	56.2	1.60	…	1	217.9	…	…	…	…	…	…
18 23 14.6	+64 39 39	0422202265	96 090 02:31	12.93	*X*	205.5	175.4	0.68	0.51	4	205.5	9.0	4.5	…	…	…	…
18 23 14.6	+64 39 39	0422202265	97 053 21:03	12.93	*XY*	204.0	83.3	1.83	0.54	2	161.8	5.9	4.1	3	124.3	2.0	1.1
07 28 36.7	+69 21 21	0436000976	97 308 08:15	12.59	*XY*	621.1	157.1	0.14	0.04	2	133.7	0.8	0.5	1	−606.6	…	
07 28 36.7	+69 21 21	0436000976	97 325 09:34	12.59	*XY*	612.2	305.3	0.16	0.17	1	−293.4	…	…	4	537.3	7.2	3.6
09 46 38.2	+67 32 33	0438301828	96 054 12:35	11.03	*X*	78.9	78.4	0.59	…	1	78.9	…	…	…	…	…	…
11 08 15.4	+72 29 30	0438800309	97 185 14:38	12.80	*Y*	90.1	71.0	0.67	0.01	…	…	…	…	2	90.1	0.0	0.0
13 53 34.1	+69 32 33	0440301512	97 016 01:39	13.98	*X*	190.6	6.1	0.64	…	1	190.6	…	…	…	…	…	…
13 38 20.9	+70 04 04	0440500149	97 094 16:42	11.75	*X*	79.6	11.1	1.42	…	1	79.6	…	…	…	…	…	…
13 38 20.9	+70 04 04	0440500149	97 127 18:28	11.75	*X*	212.7	167.5	1.54	…	1	212.7	…	…	…	…	…	…
21 29 05.5	+73 29 30	0447300170	96 356 03:09	13.61	*Y*	495.9	48.0	1.55	…	…	…	…	…	1	495.9	…	…
06 48 28.3	+79 23 24	0453400416	97 153 13:55	12.90	*Y*	306.3	35.9	0.97	0.55	…	…	…	…	3	306.3	3.2	1.8
00 01 37.2	−00 44 44	0466300554	97 183 22:05	12.88	*X*	160.0	66.7	1.64	…	1	160.0	…	…	…	…	…	…
00 29 05.8	−01 57 57	0466500441	96 351 18:15	13.86	*X*	42.4	146.9	0.48	…	1	42.4	…	…	…	…	…	…
01 09 41.0	−02 16 17	0468101078	97 036 02:09	13.02	*X*	101.8	164.0	1.68	…	1	101.8	…	…	…	…	…	…
02 06 17.8	−00 27 27	0468901162	96 282 17:25	12.67	*XY*	298.4	246.9	1.85	0.00	1	92.2	…	…	1	283.8	…	…
05 35 13.4	−05 30 31	0477400842	97 109 18:56	11.82	*X*	95.0	16.9	1.71	…	1	95.0	…	…	…	…	…	…
05 35 40.6	−05 27 27	0477400888	97 103 06:29	12.43	*X*	113.4	8.1	1.68	…	1	113.4	…	…	…	…	…	…
06 52 27.8	−00 32 32	0480000537	97 236 00:57	10.44	*XY*	83.3	221.3	0.03	0.01	1	69.1	…	…	3	46.5	0.8	0.5
06 44 32.2	−02 04 05	0480300476	97 116 10:47	11.25	*Y*	172.4	15.5	1.11	…	…	…	…	…	1	172.4	…	…
08 46 18.7	−00 05 05	0486401078	97 139 10:42	13.06	*X*	44.3	17.5	0.43	…	1	44.3	…	…	…	…	…	…
12 14 08.4	−01 31 32	0494000380	97 178 21:57	13.28	*X*	506.2	22.5	1.36	…	1	506.2	…	…	…	…	…	…
12 38 37.4	−04 00 00	0495100818	97 192 02:14	12.57	*X*	178.4	27.1	1.76	…	1	178.4	…	…	…	…	…	…
12 56 22.8	−05 24 24	0495600856	96 113 14:35	10.11	*X*	66.9	7.0	0.10	0.00	2	66.9	0.1	0.1	…	…	…	…

TABLE 2
(CONTINUED)

R.A.[a]	Decl.[b]	GSC No.[c]	Epoch[d]	Mag[e]	*XY*[f]	Sep[g]	P.A.[h]	Δ*M*[i]	s.e.[j]	N*x*[k]	Sep*X*[l]	s.e.[m]	EM[n]	N*y*[o]	Sep*Y*[p]	s.e.[q]	EM[r]
17 22 51.4	−00 09 09	0506700354	97 128 01:21	13.80	*X*	148.3	152.6	0.56	…	1	148.3	…	…	…	…	…	…
09 32 21.4	−11 03 04	0546400241	96 125 10:60	13.31	*Y*	154.1	105.7	0.70	…	…	…	…	…	1	154.1	…	…
12 47 12.2	−08 03 03	0553500097	96 049 12:53	12.95	*Y*	389.6	115.5	2.00	…	…	…	…	…	1	389.6	…	…
14 23 12.5	−14 53 53	0557400661	97 239 10:13	12.45	*X*	780.1	109.2	1.22	…	1	780.1	…	…	…	…	…	…
14 50 01.0	−09 55 55	0558200775	97 037 16:35	13.73	*XY*	190.3	77.8	0.28	0.09	2	159.3	2.8	1.9	1	104.2	…	
18 19 47.3	−09 17 18	0567700530	96 207 13:56	13.31	*Y*	423.4	112.3	0.90	0.14	…	…	…	…	2	423.4	4.5	3.2
18 18 31.0	−13 43 43	0568900663	97 096 04:20	11.03	*Y*	50.4	84.0	0.04	0.06	…	…	…	…	2	50.4	0.8	0.6
20 21 06.7	−14 29 29	0575301286	96 107 04:48	13.15	*Y*	230.1	77.4	1.40	…	…	…	…	…	1	230.1	…	…
20 20 19.0	−14 38 38	0575301649	96 118 10:03	12.33	*X*	125.5	76.4	1.70	0.28	2	125.5	5.5	3.9	…	…	…	…
20 50 51.6	−08 15 15	0575700162	97 185 04:31	13.62	*X*	450.3	149.5	1.97	…	1	450.3	…	…	…	…	…	…
20 44 03.4	−10 37 38	0576001295	96 282 00:56	13.01	*XY*	331.2	28.0	2.55	0.00	1	212.6	…	…	1	254.0	…	…
21 31 02.9	−10 05 06	0579000312	97 155 20:23	10.18	*Y*	99.0	158.0	0.19	0.12	…	…	…	…	4	99.0	10.9	5.4
23 25 36.0	−11 55 56	0582500782	96 209 17:37	12.09	*XY*	212.3	34.7	2.35	0.00	1	162.0	…	…	1	137.2	…	…
04 42 05.8	−20 38 39	0589801162	97 093 17:53	13.81	*Y*	160.9	108.2	0.37	…	…	…	…	…	1	160.9	…	…
04 52 30.7	−18 22 23	0590300498	97 096 22:47	12.11	*XY*	281.1	119.7	0.33	0.00	1	−275.7	…	…	1	54.6	…	…
06 46 00.2	−16 45 45	0594902700	96 247 02:04	11.88	*X*	114.2	161.4	1.60	…	1	114.2	…	…	…	…	…	…
07 47 49.7	−19 04 05	0598900943	97 283 23:17	13.10	*Y*	109.5	93.2	1.85	…	…	…	…	…	1	109.5	…	…
09 29 56.2	−20 15 16	0603800533	97 121 12:01	12.20	*Y*	505.1	169.8	1.80	…	…	…	…	…	1	505.1	…	…
10 16 38.4	−20 53 53	0607200013	97 192 03:45	13.78	*Y*	103.4	132.5	1.69	…	…	…	…	…	1	103.4	…	…
12 00 04.8	−19 12 12	0609700588	96 208 18:26	11.90	*XY*	147.7	275.6	1.55	0.00	1	131.2	…	…	1	67.8	…	…
13 12 51.6	−19 34 35	0611601039	96 355 17:34	13.66	*Y*	194.6	107.6	0.84	…	…	…	…	…	1	194.6	…	…
15 00 29.3	−19 55 56	0617601080	97 117 12:13	13.29	*X*	696.1	29.1	1.65	…	1	696.1	…	…	…	…	…	…
14 58 56.6	−19 57 58	0617601140	97 117 11:46	12.68	*XY*	90.1	354.2	0.51	0.20	39	73.9	5.4	0.9	2	51.5	4.9	3.5
18 50 48.5	−21 11 12	0629301074	97 307 21:27	11.20	*Y*	231.2	84.1	2.05	…	…	…	…	…	1	231.2	…	…
19 36 21.1	−15 48 48	0629902113	96 142 01:13	13.10	*Y*	172.1	99.3	1.00	…	…	…	…	…	1	172.1	…	…
19 51 11.0	−20 23 24	0632001943	96 226 11:32	12.49	*Y*	295.4	166.4	1.40	…	…	…	…	…	1	295.4	…	…
20 28 55.2	−19 28 29	0633701680	97 289 01:11	13.79	*Y*	111.0	70.0	0.73	0.00	…	…	…	…	2	111.0	0.1	0.0
21 04 56.9	−17 28 29	0635000102	97 310 05:26	13.01	*XY*	126.3	45.9	0.47	0.00	1	108.2	…	…	1	65.1	…	…
21 23 43.7	−17 43 43	0636400104	96 271 12:25	13.19	*X*	42.9	163.4	0.18	…	1	42.9	…	…	…	…	…	…
22 04 04.3	−20 22 22	0638300154	97 302 04:25	11.94	*XY*	823.5	75.3	0.63	0.00	1	−814.1	…	…	1	124.4	…	…
22 06 43.9	−20 26 26	0638300719	97 247 07:51	13.90	*Y*	311.2	41.0	0.43	…	…	…	…	…	1	311.2	…	…
00 39 44.9	−23 55 56	0642100778	96 294 04:43	10.39	*X*	61.0	119.9	0.75	0.06	4	61.0	1.7	0.9	…	…	…	…
01 43 01.0	−25 26 26	0642901711	97 290 03:16	12.89	*X*	407.4	82.4	1.81	…	1	407.4	…	…	…	…	…	…
10 20 50.4	−29 37 37	0663101217	96 186 17:03	11.88	*X*	280.7	40.7	1.30	…	1	280.7	…	…	…	…	…	…
10 38 06.0	−27 45 45	0664100298	96 167 09:57	12.80	*X*	34.7	27.3	0.03	…	1	34.7	…	…	…	…	…	…
15 47 25.4	−29 10 10	0679001400	97 265 00:55	10.43	*Y*	42.4	107.7	0.60	0.11	…	…	…	…	2	42.4	1.0	0.7
16 26 00.7	−24 00 01	0679400377	97 158 11:52	12.74	*X*	300.6	172.2	0.59	…	1	300.6	…	…	…	…	…	…
17 46 03.1	−28 56 57	0684000326	97 257 12:39	11.31	*Y*	85.3	90.9	2.19	…	…	…	…	…	1	85.3	…	…
18 04 26.4	−29 45 46	0685404139	96 250 03:17	12.52	*X*	500.1	80.0	1.20	…	1	500.1	…	…	…	…	…	…
18 39 44.9	−22 48 48	0685801898	96 209 01:55	11.91	*X*	102.3	176.3	1.70	…	1	102.3	…	…	…	…	…	…
18 40 05.5	−23 22 23	0685802555	96 220 13:51	11.59	*X*	114.2	85.9	1.70	…	1	114.2	…	…	…	…	…	…
18 42 28.1	−23 23 24	0685900757	96 212 04:51	12.97	*X*	470.0	85.4	1.30	…	1	470.0	…	…	…	…	…	…
18 42 07.7	−23 07 07	0685901443	96 212 06:53	11.18	*XY*	280.6	27.1	0.28	0.06	2	147.6	1.6	1.2	2	238.7	3.5	2.5
18 51 36.2	−22 34 34	0686000627	96 061 01:55	12.62	*X*	31.4	175.0	0.35	…	1	31.4	…	…	…	…	…	…
18 59 17.3	−22 52 53	0687300197	96 180 04:25	11.68	*Y*	69.7	83.9	0.90	0.17	…	…	…	…	3	69.7	2.1	1.2
22 28 08.4	−27 09 09	0696500288	97 315 08:28	11.83	*X*	98.0	154.9	0.07	0.05	11	98.0	4.1	1.2	…	…	…	…
02 41 36.0	−33 57 58	0701400745	97 236 13:26	12.48	*Y*	355.5	8.3	1.51	…	…	…	…	…	1	355.5	…	…
02 40 47.0	−34 18 18	0701400911	96 157 02:45	12.81	*Y*	528.4	34.0	0.33	0.25	…	…	…	…	3	528.4	6.1	3.5
03 34 16.6	−35 21 21	0702700428	97 320 12:46	12.33	*XY*	330.9	315.7	0.14	0.00	1	305.4	…	…	1	127.5	…	…
03 24 41.0	−36 32 32	0702700523	97 267 16:33	13.39	*Y*	88.4	95.0	1.70	…	…	…	…	…	1	88.4	…	…
03 37 34.3	−35 24 24	0703400573	97 106 03:59	13.02	*X*	166.2	52.0	1.90	…	1	166.2	…	…	…	…	…	…
05 44 59.8	−32 35 36	0706100563	97 286 01:12	13.35	*X*	129.5	18.7	0.86	…	1	129.5	…	…	…	…	…	…
07 12 30.2	−35 47 47	0711500344	96 255 17:24	12.88	*Y*	216.7	72.0	1.70	…	…	…	…	…	1	216.7	…	…
10 16 37.4	−33 43 43	0718701036	97 164 14:13	12.11	*X*	152.3	28.9	1.27	…	1	152.3	…	…	…	…	…	…
13 40 09.4	−31 27 27	0726600045	97 207 06:49	13.82	*Y*	538.6	100.0	1.58	…	…	…	…	…	1	538.6	…	…
15 50 29.0	−33 30 31	0733201547	96 236 14:15	13.13	*X*	352.5	1.3	1.10	…	1	352.5	…	…	…	…	…	…
15 57 33.1	−36 20 21	0734100981	96 261 02:54	11.55	*X*	376.5	107.6	1.70	…	1	376.5	…	…	…	…	…	…
17 49 56.2	−37 19 20	0738900964	96 298 13:21	11.66	*Y*	101.7	101.7	0.97	0.12	…	…	…	…	11	101.7	2.8	0.9
18 43 47.5	−32 21 22	0741100319	97 183 13:40	12.07	*Y*	75.4	5.0	1.89	…	…	…	…	…	1	75.4	…	…
22 59 42.7	−34 54 54	0750800195	97 299 14:37	12.43	*Y*	380.4	40.0	1.84	…	…	…	…	…	1	380.4	…	…

TABLE 2
(CONTINUED)

R.A.[a]	Decl.[b]	GSC No.[c]	Epoch[d]	Mag[e]	*XY*[f]	Sep[g]	P.A.[h]	Δ*M*[i]	s.e.[j]	N*x*[k]	Sep*X*[l]	s.e.[m]	EM[n]	N*y*[o]	Sep*Y*[p]	s.e.[q]	EM[r]
22 59 31.2	−34 45 45	0750800199	97 319 17:05	13.14	*X*	785.4	131.0	1.85	…	1	785.4	…	…	…	…	…	…
01 58 16.1	−44 47 48	0754901036	96 114 10:51	11.46	*X*	250.6	2.1	1.70	…	1	250.6	…	…	…	…	…	…
03 27 07.9	−38 27 28	0756801070	96 192 15:56	12.65	*X*	844.9	142.8	0.80	…	1	844.9	…	…	…	…	…	…
12 35 42.7	−40 04 04	0776200070	97 194 12:32	13.53	*Y*	301.0	102.0	1.95	…	…	…	…	…	1	301.0	…	…
13 25 44.2	−43 11 11	0779900062	97 223 05:23	10.24	*Y*	79.7	121.6	1.97	0.00	…	…	…	…	2	79.7	0.0	0.0
16 08 57.4	−38 52 53	0785100115	97 185 17:22	12.60	*X*	141.7	58.9	1.87	…	1	141.7	…	…	…	…	…	…
16 54 45.8	−39 49 49	0787200030	96 172 14:04	12.14	*X*	499.7	35.9	1.50	…	1	499.7	…	…	…	…	…	…
16 57 43.2	−40 14 14	0787201174	96 163 14:09	12.20	*X*	76.7	108.3	0.42	0.20	3	76.7	0.6	0.3	…	…	…	…
16 54 02.4	−39 43 43	0787201333	96 141 16:47	12.57	*X*	128.7	160.5	1.40	…	1	128.7	…	…	…	…	…	…
00 39 26.6	−51 24 25	0803000624	96 212 16:16	13.46	*Y*	225.4	104.4	1.90	…	…	…	…	…	1	225.4	…	…
00 48 22.6	−52 02 03	0803700296	97 157 00:50	12.00	*Y*	171.0	158.5	1.95	…	…	…	…	…	1	171.0	…	…
00 50 04.3	−51 58 58	0803700322	97 177 09:25	13.46	*Y*	236.2	69.7	1.82	…	…	…	…	…	1	236.2	…	…
05 46 18.0	−50 59 60	0809900313	97 174 22:09	12.71	*Y*	867.3	0.9	1.19	…	…	…	…	…	1	867.3	…	…
07 32 28.3	−50 28 29	0814100740	97 182 22:36	11.83	*Y*	72.9	168.2	2.03	…	…	…	…	…	1	72.9	…	…
07 34 53.8	−50 26 26	0814100928	97 183 01:49	10.68	*X*	46.1	78.2	0.75	0.07	5	46.1	0.8	0.4	…	…	…	…
13 26 16.6	−47 47 47	0825201761	96 181 06:55	10.38	*XY*	485.9	152.7	3.10	0.00	1	273.7	…	…	1	401.5	…	…
13 26 16.6	−47 47 47	0825201761	97 155 06:47	10.38	*Y*	446.2	76.3	2.32	0.07	…	…	…	…	4	446.2	1.2	0.6
17 29 46.8	−46 37 38	0834201822	97 250 22:04	10.69	*X*	174.1	179.8	1.73	…	1	174.1	…	…	…	…	…	…
20 51 05.5	−51 53 54	0842000355	97 072 21:59	13.40	*X*	509.2	139.1	0.41	…	1	509.2	…	…	…	…	…	…
17 40 06.0	−53 30 30	0872901617	96 066 23:17	11.89	*Y*	41.7	87.0	0.10	…	…	…	…	…	1	41.7	…	…
17 41 07.4	−53 53 53	0872902390	96 275 23:46	12.17	*X*	116.8	98.5	1.90	…	1	116.8	…	…	…	…	…	…
06 27 55.9	−64 06 07	0890200744	97 128 10:57	9.76	*X*	445.8	47.2	0.90	0.03	2	445.8	0.6	0.5	…	…	…	…
11 15 33.8	−61 18 18	0895901343	97 095 06:36	9.95	*Y*	153.1	30.4	0.16	…	…	…	…	…	1	153.1	…	…
11 16 04.3	−61 31 31	0895901505	97 224 20:38	10.93	*X*	58.6	156.2	1.56	0.27	10	58.6	7.9	2.5	…	…	…	…
11 16 04.3	−61 31 31	0895901505	97 237 20:56	10.93	*X*	72.9	165.4	1.14	0.16	2	72.9	3.3	2.3	…	…	…	…
11 16 00.5	−61 11 12	0895901939	97 063 16:50	9.54	*X*	59.6	86.6	0.33	0.04	3	59.6	1.1	0.6	…	…	…	…
11 16 00.5	−61 11 12	0895901939	97 063 19:06	9.54	*X*	57.8	78.2	0.34	0.01	2	57.8	1.3	0.9	…	…	…	…
11 16 31.2	−61 00 01	0895902197	97 129 02:26	10.89	*X*	138.9	55.0	2.15	…	1	138.9	…	…	…	…	…	…
00 27 00.0	−72 10 11	0913701767	96 282 14:16	12.79	*Y*	448.5	16.0	1.80	…	…	…	…	…	1	448.5	…	…
00 22 48.7	−72 05 06	0913703769	96 271 19:04	12.96	*Y*	421.3	178.5	1.00	…	…	…	…	…	1	421.3	…	…
01 06 29.3	−72 22 22	0913902189	96 218 15:17	12.06	*X*	101.5	113.1	1.80	…	1	101.5	…	…	…	…	…	…
01 08 43.2	−72 07 08	0913902192	96 223 18:43	11.75	*Y*	170.3	118.8	0.70	0.10	…	…	…	…	3	170.3	1.2	0.7
00 18 57.1	−74 06 07	0914001079	96 164 02:03	10.02	*X*	150.6	136.5	0.02	…	1	150.6	…	…	…	…	…	…
05 03 26.2	−68 17 17	0916101097	96 334 01:39	12.29	*X*	395.0	170.0	1.57	…	1	395.0	…	…	…	…	…	…
06 19 06.0	−71 25 26	0917200529	96 316 07:28	12.80	*X*	239.2	135.0	1.50	…	1	239.2	…	…	…	…	…	…
15 38 29.3	−71 43 44	0926800932	96 278 01:25	12.23	*XY*	136.8	5.8	0.06	0.00	1	−83.6	…	…	1	108.3	…	…
21 59 17.8	−69 56 57	0932700041	96 275 12:51	13.63	*X*	886.7	129.5	1.87	…	1	886.7	…	…	…	…	…	…
00 34 43.7	+85 22 22	3788900104	96 221 05:14	11.48	*XY*	263.1	260.4	1.03	0.05	1	−231.9	…	…	3	124.3	4.0	2.3

[a] Right ascension (in units of hours, minutes, and seconds), equator and equinox, J2000.0, GSC position.

[b] Declination (in units of degrees, arcminutes, and arcseconds), equator and equinox, J2000.0, GSC position.

[c] Guide Star Catalog number.

[d] Mean epoch of observation: year, day of year, hour and minute.

[e] Magnitude from the GSC (photographic *V* in northern hemisphere, *J* in southern hemisphere; see GSC references).

[f] Symbol for the FGS coordinate of duplicity detection. *X*: *X*-only duplicity. *Y*: *Y*-only duplicity. *XY*: duplicity in both *X* and *Y*.

[g] Separation in units of milliarcseconds, with two definitions. If a single coordinate, the separation is only the projection of the separation of the double onto the FGS coordinate of observation. If a two-coordinate observation, it is the angular separation of the components. The scale errors of the separations are estimated to be at the level of a few parts per thousand.

[h] Position angle with two definitions. For one-coordinate observations, it is the position angle (equatorial coordinates) of the FGS coordinate at the time of observation (0°–180°). For a two-coordinate observation, it is the traditional double-star position angle, the angle from north to east of the fainter component relative to the brighter component.

[i] Magnitude difference between the components as computed from the ratio of the amplitudes of the component *S*−curves. The bandpass of the FGSs in guidance is centered near the *V* photometric band but spans spectra that range from the *U* to the *R* bands, the mid-3000s to 7000s in angstrom units.

[j] Standard error of the observations that formed the delta magnitude mean if more than one observation.

[k] Number of observations in the *X* coordinate combined to form the entries in the table line.

[l] Mean of the *X* separations, or the *X* separation if only one observation in units of milliarcseconds.

[m] Standard error of the observations that formed the *X* in units of milliarcseconds.

[n] Error of the mean separation *X* in units of milliarcseconds.

[o] Number of observations in the *Y* coordinate combined to form the entries in the table line.

[p] Mean of the *Y* separations, or the *Y* separation if only one observation in units of milliarcseconds.

[q] Standard error of the observations that formed the *Y* mean in units of milliarcseconds.

[r] Error of the mean separation in *Y* in units of milliarcseconds.

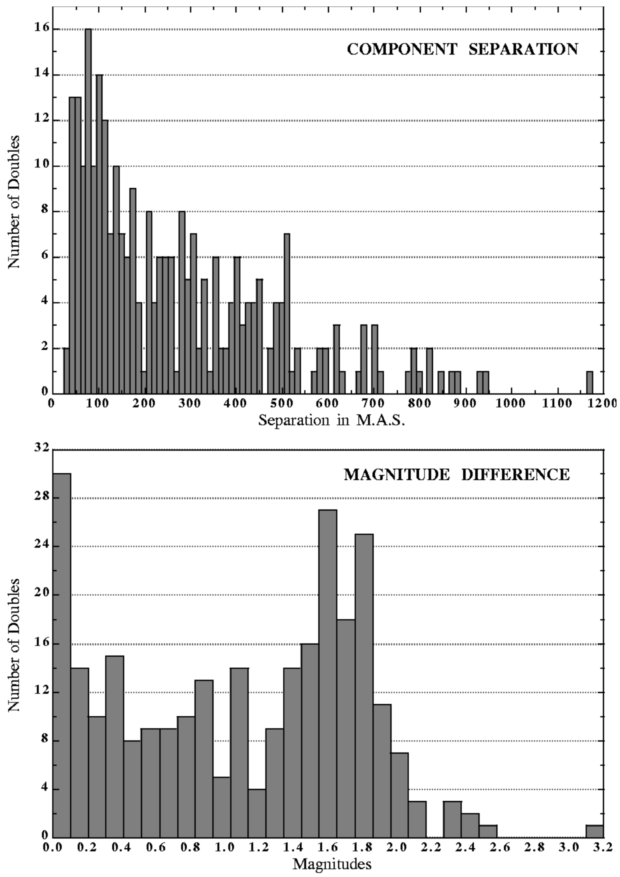

FIG. 4.—Histograms of separation and Δm for the selected doubles in Table 2. The histogram of the angular separations of stars is similar to other catalogs, with the general form of a (1/separation) function.

5. FOLLOW-UP OBSERVATIONS

Many of the pairs discovered by the FGS acquisitions are expected to be middle main-sequence objects and thus meet the physical separation requirements that would allow mass determination on a timescale on the order of a decade if followed with ground-based spectroscopy and by ground- or space-based astrometric instruments. For example, a 9th magnitude double, with both components nominal main-sequence G stars of 10th magnitude, would be at 100 pc. A near-maximum separation of 50 mas in a circular, highly inclined orbit would be due to a semimajor relative orbital axis of 5 AU. The pair would have an orbital period of 7.9 yr and a relative radial velocity half-amplitude of 19 km s^{-1}. Distance, luminosity, and individual masses can be determined without a parallax from a double-lined spectroscopic binary and the relative astrometric orbit. The FGS acquisition doubles could be screened for the best prospects for mass determination by taking spectra that could distinguish the relatively nearer main-sequence stars from the giants and also by proper motions where available. The separation limits for FGS double-star detection from walkdown data could be clarified by *HST* TRANS mode astrometry observations, which would help further define a candidate list.

6. CONCLUSION

The FGS walkdown observations survey stars for duplicity, and these stars are generally closer and fainter than in any previous surveys. Double-star separation and magnitude statistics at any level have relevance to star formation and evolution. The statistics of close double stars in the magnitude range $9 < V < 14$ are of interest in the design of guiding systems for future large space-based telescopes and interferometers (e.g., the *Next Generation Space Telescope* and Space Interferometry Mission).

A discovery rate of 5% doubles occurs if the duplicity criteria are set at a level that yields certain duplicity for nearly all of the selected cases and that yields about 130 discoveries per year from the guidance data. Undoubtedly, many more of the stars are double and lie nearer the limits of detection. Criteria that would yield a 10% duplicity rate produces candidates with a high probability of duplicity. Observations on a test set of candidates with higher spatial resolution and larger S/N would be needed to check this estimate.

A master catalog is kept with all walkdowns and their fitting parameters, GSC numbers, coordinates, and all relevant telescope parameters such as roll, filter, FGS servo *K*-factors, etc. The catalog can be searched with any significance criterion for duplicity. Subcatalogs of double stars for various criteria will be generated. Data will be available electronically.[1] The catalogs of all solutions for duplicity can be checked for the presence of a specific guide-star number and the significance level found for the solutions for the presence of a double.

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[1] Available at http://nicmosis.as.arizona.edu:8000/pub/gsdoubles.html, which is maintained by Steward Observatory, University of Arizona.

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