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HST-FGS PARALLAXES OF TWO HIGH-VELOCITY STARS

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ABSTRACT

Astrometric position measurements with the *Hubble Space Telescope's* Fine Guidance System have been used to measure the trigonometric parallaxes of two high-velocity stars, R50=G166-37 and W624 =G16-25. In both cases, the parallaxes are small and confirm large velocities in the galactocentric rest frame. We derive $\pi_{abs}=5.2\pm0.7$ mas and $V_{RF}=467$ km s^{-1} for R50. The results for W624 are $\pi_{abs}=3.8\pm1.0$ and $V_{RF}=326$ km s^{-1} with an uncertainty of about 30%. Our results support a value for the galactic escape velocity at the solar distance of about 475 km s^{-1}. *© 1997 American Astronomical Society.* [S0004-6256(97)04009-0]

1. INTRODUCTION

The escape velocity from the Galaxy, V_{esc}, at the solar distance from the center, $R_\odot$, is a fundamental parameter for modeling the kinematics and mass distribution of the Galaxy. The value is a measure of the ratio of the total mass of the Galaxy to that contained within the solar circle and provides important information on the amount of matter in the outer parts of the galactic halo. Unfortunately, the value of V_{esc} is difficult to determine.

A lower limit to V_{esc} is provided by the velocities of the most rapidly moving stars in the solar neighborhood. This was first pointed out by Oort (1926) in his classic analysis of the motions of high-velocity stars. Finding a sharp cut-off in their velocities in the direction of galactic rotation with none exceeding 63 km s^{-1} relative to the local standard of rest (LSR), he interpreted this to mean that V_{esc} is about 63 km s^{-1} larger than the circular velocity at the solar distance.

More recent studies have shown that V_{esc} is at least 100 km s^{-1} larger than Oort's value. Some results for the lower limit to V_{esc} include 380 km s^{-1} (Isobe 1974; Przybylski 1978), 450 km s^{-1} (Sandage & Fouts 1987; Ryan & Norris 1991), 475 km s^{-1} (Cudworth 1990), 500 km s^{-1} (Carney *et al.* 1988), 520 km s^{-1} (Ninkovic 1987), and between 550 and 650 km s^{-1} (Caldwell & Ostriker 1981). The wide variation in the results show that this important observational parameter is not well known.

The velocity of a star in the galactocentric rest frame, V_{RF}, is determined from its peculiar velocity and the rotational motion of the LSR. In turn, a star's peculiar velocity is found from its heliocentric radial and tangential velocities and the solar motion. There is a wide variation in the ease with which the required velocities can be obtained. The IAU has recommended adoption of 220 km s^{-1} for the rotational motion of the LSR (Kerr & Lynden-Bell 1986). The standard solar motion relative to the LSR is $U_\odot=-10.3$, $V_\odot=+15.3$, and $W_\odot=+7.7$ km s^{-1} (van de Hulst *et al.* 1954) where UVW are directed toward (l=180°, b=0°), (l=90°, b=0°) and (b=90°), respectively. These two motions have little effect on which stars are determined to have the largest rest frame velocities and hence those setting a lower limit to V_{esc}. The radial velocity of a star can be determined directly and with small error; V_{tang}, on the other hand, is derived from the annual proper motion and the distance, each of which may be difficult to measure. Precise proper motion and trigonometric parallax determinations traditionally require long time baselines, and the resulting parallaxes typically have uncertainties of the same order as the parallax itself for distances greater than about 200 pc. Photometric distance determinations are useful but may be compromised by reddening and abundance effects.

The past decade has seen the completion of three independent studies of the kinematics of stars in the galaxy based on much larger and more homogeneous samples than in previous surveys. The three works used observations of high-proper-motion stars to determine velocities relative to the local standard of rest. The published UVW velocity components allow V_{RF} to be determined once the LSR rotational motion is specified.

Sandage & Fouts (1987; SF87) used homogeneous photometry and radial velocities for 878 stars plus data from the literature for 247 additional objects to obtain their motions. Based on the eight stars of most extreme V_{RF}, they derived a lower limit to V_{esc} of $\sim$450 km s^{-1}. They noted that their survey was not designed to find the highest velocity stars.

Carney *et al.* (1988; CL88) used multi-band photometry, radial velocities, and spectroscopic metallicities for over 900 stars common to the Luyten NLTT (1979a,b, 1980a,b) and Giclas *et al.* (1971, 1978) proper motion surveys. These data produced $V_{esc}=500$ km s^{-1}, but that result was based

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TABLE 1. Stars suggested to have V_{RF} larger than 450 km s^{-1}.

	Coordinates					Dist.	Velocity source					
Star	α_{1950}	δ_{1950}	V	$B-V$	E($B-V$)	(pcs)	SF87	RN91	CL88	Cu90	CL94	Notes[a]
G112-1	070932	061154	14.31	0.64	0.07	396	–	–	481	406	452	Comp
G88-42	073259	191900	14.38	0.65	0.05	536	–	–	490	446	468	SB?
LP665-50[b]	083152	−075612	13.15	0.46	0.05	682	–	615	–	–	–	–
LP734-102	121549	−123524	12.92	0.39	0.02	613	–	463	–	–	–	–
G238-30	131554	643106	12.91	0.47	0.00	275	496	–	421	431	420	–
R50	143237	252324	12.64	0.67	0.00	176	–	–	468	461	461	CPM
G66-18	143539	−003748	13.10	0.86	0.09	207	469	–	–	430	–	–
HD134439	150728	−160830	9.09	0.76	0.00	28	314	459	403	373	399	CPM
W624	155854	053212	13.34	0.59	0.03	291	440	–	–	467	380	–
G233-27	224205	562812	15.52	0.97	0.05	253	–	–	422	468	–	Comp

[a] Comp—optical companion; SB?—possible spectroscopic companion; CPM—common proper motion companion.
[b] Listed incorrectly as LP655-50 in Table 7 of RN91.

mainly on the large velocities determined for three of the faintest stars in the survey, G88-42, G93-1, and G112-1, the last of which has a close optical companion.

Cudworth (1990; Cu90) subsequently re-examined the astrometric data for the stars of highest velocity in the CL88 and, to a lesser extent, the SF87 surveys. He determined new proper motions, corrected the photometric distances of stars with companions, and recomputed space velocities to derive a lower limit to V_{esc} of 475 km s^{-1}. He found the largest CL88 velocities to be generally too high and suggested R50 = G166-37, G233-27, and W624=G16-25 as the stars most critical in defining V_{esc}. Revised data for the CL88 survey published by Carney *et al.*(1994; CL94) produced velocities more in agreement with Cudworth's.

Ryan & Norris (1991; RN91) published space velocities for about 800 metal-weak, high-proper-motion stars from the NLTT catalogue and identified 10 stars with $V_{RF} \geqslant 400$ km s^{-1}. Neglecting one star of extreme but uncertain velocity, they derived $V_{esc} \sim$ 450 km s^{-1}. Their distances and hence velocities are compatible with those of SF87 but are about 20% larger than those of CL88.

A lower limit to V_{esc} is determined by the most extreme velocities found under the assumption that all stars are bound to the Galaxy. The three surveys above indicate that V_{esc} is at least 450 kms^{-1}. The key question is: Are there stars with V_{RF} significantly greater than this? From the extensive kinematical data of the three studies, rest-frame velocities $\geqslant 450$ km s^{-1} were found for only 10 stars; these are listed in Table 1. The table gives basic information about each object, taken from CL94 when possible, along with the velocities from the various studies. There were small differences in the various authors' treatment of solar motion and proper motion, but these have only a minor effect on V_{RF}, and we have elected to tabulate the velocities as published or as computed from their published UVW data assuming an LSR circular velocity of 220 km s^{-1}. The SF87 velocity for G238-30 is from their list of additional stars (where it is listed under the GCRV alias W7923; we thank W. P. Bidelman for pointing this out). Several of the stars in Table 1 have large radial velocities, but in all cases the high space motion depends primarily on the star's tangential velocity and hence on the adopted proper motion and photometric distance. Five of the stars have optical or physical companions which complicate the interpretation of the photometry and motion.

Errors in the derived velocities of the fastest moving stars obviously have an important influence on the determination of V_{esc}. In one-quarter of the cases, random observational and photometric calibration errors will combine to yield overestimates in both proper motion and distance resulting in anomalously large tangential velocities. Alexander (1982) cautioned that one must be circumspect of results based on distant stars whose large velocities result primarily from the tangential component, and he alluded to the improvement that might be made in the tangential velocities of distant, high-velocity stars with the advent of space astrometry.

Astrometric observations with the *Hubble Space Telescope* Fine Guidance System (FGS) are capable of determining a parallax with a mean error of better than 1 mas from observations over a one-year period (Benedict *et al.* 1995). Six of the stars in Table 1 have photometric distances less than 300 pc, indicating that their parallaxes should be measurable with *HST* at the 3-σ level. One of these, HD134439, with its common-proper-motion companion, HD 134440, is close and has a high-quality, ground-based, trigonometric parallax; π_{abs}=33.5± 1.7 mas (*General Catalogue of Stellar Trigonometric Parallaxes*, 4th ed., 1995). This paper presents the results of a project to use the FGS on board *HST* to determine trigonometric parallaxes and thereby improve the tangential velocities of two stars in Table 1 critical to determining V_{esc}. A secondary goal was to test the validity of the photometric distance determinations used in the kinematic surveys and perhaps obtain a measure of their uncertainties.

2. OBSERVATIONS

The *Hubble Space Telescope* Fine Guidance System consists of three dual-axis Koester's prism interferometers, referred to as the Fine Guidance Sensors. Each FGS measures a relative position with a precision of ± 3 mas for a single observation within an off-axis field of view that is roughly a quarter annulus of radii 10′ and 14′ from the telescope's optical axis. The unusually shaped field of view is referred to as a "pickle." Simultaneous observations of guide stars by

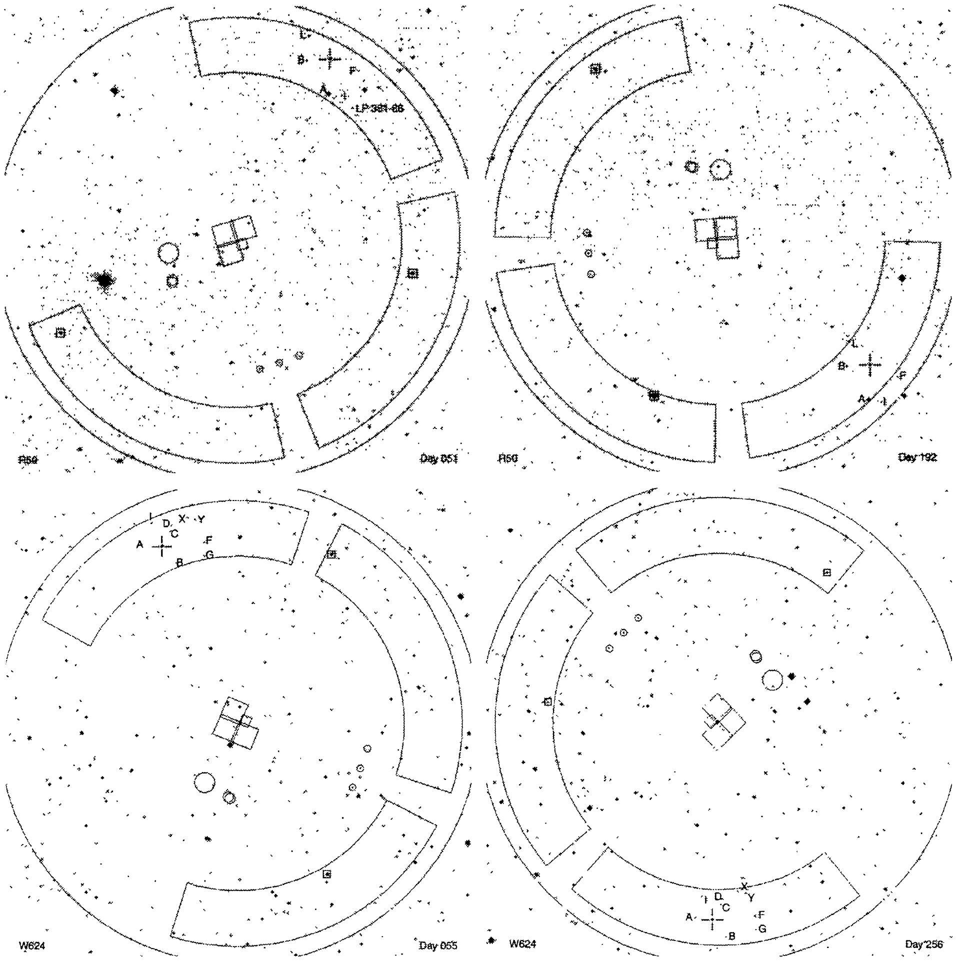

FIG. 1. The *HST* field of view for the two parallax stars and their reference frames at the early and late epoch each year. Each panel is 29′ on a side. The guide stars used are indicated by the squares, and the day number of the year is given in the lower right of each panel. North is to the top and East to the left in all panels.

two of the FGS' are required for precise pointing and control of the telescope. The third FGS, nominally FGS 3, has been used to make astrometric measurements over the first several years of *HST* operation.

The instrument has two observing modes. In the POSition mode, the FGS repeatedly measures the instantaneous null positions of the x- and y-axis sensors at 40 Hz, and these are averaged to produce a relative position of high precision; this is the mode employed for determination of parallax. In the TRANSfer-function mode, the FGS scans across the object to obtain an interference pattern which can be compared to a reference pattern to resolve and measure close binaries. More complete descriptions of the FGS system, its operation, and use for astrometry have been given by Bradley *et al.* (1991) and by Benedict *et al.* (1992).

Time on *HST* to carry out FGS POS-mode observations of three of the stars of largest V_{RF} was requested and approved for observing in Cycles 1–3; these stars are too faint for the *HIPPARCOS* program. Time sufficient for observing just two stars resulted from the reallocations mandated by *HST*'s spherical aberration and its effect on exposure times. R50 and G233-27 were selected for observation. Both are in Cudworth's list of the most-critical stars and have photometric parallaxes of 5.7 and 4.0 mas, respectively, well within the capabilities of the FGS; R50 is the nearest star in Table 1 without a trigonometric parallax. Preliminary TRANS-mode observations made to confirm that the selected stars were single and observable revealed a spoiler star of similar magnitude and color about 4″ from G233-27 which might have prevented the FGS from locking on G233-27. It was therefore replaced by the third of Cudworth's "critical stars," W624=G16-25. The space motion of W624 is almost entirely determined by its tangential component, so its distance is crucial in deriving its V_{RF}, but the photometric parallax, 3.4 mas, put it near the limit of FGS capability to determine a reliable parallax.

Charts of the R50 and W624 fields showing the parallax and reference stars as they were situated in FGS 3 at the early and late epoch each year are given in Figure 1. The guide stars used are indicated in the other FGS'. The original observing program called for observations of each field at five successive epochs. Three epochs of six observation sets each were to be made near one end of the annual parallax ellipse and would bracket two epochs of nine observations

TABLE 2. BVR photometry of the R50 and W624 fields.

Star	V	$(B-V)$	$(V-R_C)$	V (FGS)
R50	12.64 ±0.01	0.67±0.01	0.41±0.01	12.66
A	12.57 ±0.01	1.10±0.01	0.64±0.01	12.58
L	14.72 ±0.02	0.82±0.03	0.50±0.01	14.72
B	16.38 ±0.04	0.78±0.15	0.41±0.02	16.37
I	17.22 ±0.04	0.59±0.15	0.36±0.03	17.21
F	18.0 ±0.06	0.8 ±0.3	0.13±0.06	18.07:
W624	13.34 ±0.01	0.59±0.01	0.39±0.01	13.33
Y	15.70 ±0.02	0.70±0.02	0.41±0.06	15.65:
I	15.95 ±0.04	0.51±0.2	0.45±0.04	15.94
X	16.24 ±0.05	0.54±0.09	0.43±0.08	16.26:
F	16.30 ±0.01	0.43±0.15	0.53±0.06	16.33
D	16.57 ±0.02	0.62±0.07	0.46±0.04	16.59
C	16.88 ±0.03	0.8 ±0.2	0.46±0.04	16.88
G	17.20:±0.11	0.9 ±0.3	0.96±0.06	17.21
A	17.27:±0.13	0.8 ±0.35	0.4 ±0.15	17.35
B	17.56:±0.08	1.3 ±0.15	0.9 ±0.09	17.45

each near the other end. This would provide a 2.0-year time baseline with a total of 18 observations at each parallax factor extremum (which occur in February and August for both stars) leading to expected precisions in proper motion of about ± 2 mas yr^{-1} in each coordinate and of ± 0.7 mas in parallax (Benedict *et al.* 1994). Each observation set would begin and end with measurement of the program star to provide a control on the stability of the system. Some modifications in the observing program were made as the project proceeded as will be discussed below.

2.1 *Photometry of the Targets*

Photometry of the stars is necessary for converting the observed parallax, which is relative to the reference stars, to an absolute one. BVR_C CCD photometry of the targets was obtained in 1994 on five nights with the 0.8-m reflector at the National Undergraduate Research Observatory, Flagstaff. The results were available only after the first two epochs of FGS observation and revealed that our estimated magnitudes were too bright, thus causing problems of acquisition and lock by FGS 3.

Table 2 gives the results of our CCD photometry. The errors are fairly large for the fainter stars. Fortunately, the FGS is essentially a four-channel, high-speed photometer and can be used for V photometry (Bucciarelli *et al.* 1994). Comparing our ground-based V magnitudes with the FGS count rates led to the following approximate calibration of the FGS 3 instrumental system:

$$V = 19.98 - 2.5\log(CNT - 11.2)$$

where CNT is the sum of the average counts s^{-1} from the four photomultipliers. We found that V magnitudes down to 17 could be measured to a few percent. The FGS-derived magnitudes are given in the last column of Table 2.

Our results are in good agreement with previous photoelectric photometry of the parallax stars; these are summarized in Table 3.

2.2 *FGS Observations of R50*

Drawbacks of parallax observing with the FGS are that the target star must be positioned close to the center of the pickle, the reference stars should be grouped within two arcminutes of it and not close to the pickle edges, and at least one adequate guide star must be available in the other two pickles. The rather low star density at the high galactic latitude of R50 (67°) limited the availability of reference and guide stars and severely constrained when FGS observations could be made. This difficulty compromised a number of the observations. At the February epoch, only five reference stars were available, two of which are very faint.

At the August epoch, no guide stars were available; even with the largest permitted spacecraft roll (30° if pointing $>$ 90° from the Sun but only 5° otherwise), the August-epoch observations of R50 could not be made at parallax factor maximum nor could all reference stars be positioned in the FGS 3 pickle. For this reason, the observations were made in July and with only three reference stars, two of them uncomfortably close to the pickle edges.

The observations obtained for the stars in the R50 field are summarized in Table 4. The three entries for each epoch give the number of scheduled (attempted) observations, the number successfully observed, and the number eventually used in the final solution for parallax. Star A was positioned too near the pickle edge at the second epoch for reliable measures. Off-nominal roll allowed it to be observed in subsequent sets, but many observations were still compromised by proximity to the edge. The faintest stars were difficult to observe; the FGS was often not able to acquire them or lost lock during an observation. The success ratio drops off rapidly for stars of $V > 17$, and these were eliminated in later epochs in favor of repeated observations of the brighter stars. Because of the difficulties with the August observations, those planned for 1995 February were divided to permit an additional, intermediate point on the parallax ellipse. The

TABLE 3. Comparisons of photometry for parallax stars.

Star	Source	V	$(B-V)$	$(U-B)$	$(V-R_C)$	n
R50	Our results	12.64	0.67	–	0.41	3
	Carney & Latham (1987)	12.660	0.685	0.030	–	2
	Smith & Oswalt (1996)	12.62	0.68	–	0.41	2
W624	Our results	13.34	0.59	–	0.39	3
	Carney & Latham (1987)	13.345	0.605	−0.155	–	2
	Sandage & Kowal (1986)	13.34	0.58	−0.13	–	2
	Sandage (1964)	13.33	0.59	−0.12	–	3

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TABLE 4. Observations of the R50 field.

		Observations attempted		Observations obtained		Observations used in final solution	
Star	V	1993 Feb.	1993 Jul.	1994 Feb.	1994 Jul.	1995 Feb.	1995 Apr.
R50	12.64	12 - 12 - 12	18 - 18 - 12	12 - 12 - 12	18 - 18 - 18	9 - 9 - 9	15 - 15 - 15
A	12.57	6 - 6 - 6	–	12 - 12 - 12	18 - 18 - 17	6 - 2 - 0	10 - 2 - 0
L	14.72	6 - 6 - 6	9 - 8 - 6	6 - 6 - 6	9 - 9 - 9	6 - 6 - 6	10 - 10 - 10
B	16.38	6 - 4 - 4	9 - 2 - 1	12 - 5 - 4	18 - 9 - 9	6 - 4 - 4	10 - 9 - 9
I	17.22	6 - 3 - 3	–	6 - 2 - 2	–	–	–
F	18.0	6 - 0 - 0	–	–	–	–	–

failure to successfully observe sufficient reference stars forced elimination of some data sets in the solutions.

2.3 *The W624 Observations*

Table 5 summarizes the observations of the W624 field. As in the case of R50, there were difficulties in observing some reference stars, and the fainter ones were eliminated in the later sets in favor of more observations of the brighter stars. The planned fifth epoch of observations for W624 was not obtained.

3. DATA REDUCTION

The reduction made use of the packages developed by the University of Texas at Austin Astrometry Team and generally followed their procedures. These have been described in detail by Benedict *et al.* (1994). Briefly, the raw FGS 3 data were converted to relative positions in instrumental coordinates that account for spacecraft jitter, drift within an orbit, differential aberration, and optical field distortion. The program GaussFit, a robust estimation and least-squares program extensively used for reducing *HST* FGS data (Jeffreys *et al.* 1988), was then employed to combine the separate data sets and to solve for the parallax and proper motion of the program star. The initial reductions utilized x-y spacecraft coordinates, but for the final solutions, the data sets were first transformed into equatorial X-Y coordinates using the engineering telemetry for the spacecraft roll orientation, R:

$$X=-x\ \sin(R)-y\ \cos(R),$$

$$Y=x\ \cos(R)-y\ \sin(R).$$

GaussFit solves for the plate constants of each data set and the relative positions, proper motions (μ), and parallaxes (π) of all stars in the frame. The equations of condition were

$$\xi=aX+bY+c-\mu_{\alpha}t-P_{\alpha}\pi,$$

$$\eta=-bX+aY+d-\mu_{\delta}t-P_{\delta}\pi,$$

where $a,\ b,\ c,\ d$ are the plate constants of the data set, t the number of days from a selected epoch, and $P_{\alpha},\ P_{\delta}$ the parallax factors.

We tested our reduction techniques by independently analyzing FGS data for Barnard's star that have been described and reduced by Benedict *et al.* (1995, 1997). Several determinations of the absolute parallax of Barnard's star are given in Table 6. The final two lines of the table compare our results with those Benedict obtained using exactly the same data set. Taking into account that the direction of proper motion is uncertain by several tenths of a degree because of the uncertainties in the spacecraft orientation, our methods produce results in agreement with previous FGS reductions and with ground-based parallax determinations.

4. RESULTS

In neither case is the parallax solution very well constrained. This is due to the poor distribution, small number, and variation between observation sets of the reference stars. Consequently, several types of solutions were computed. Beside the normal case of a simultaneous solution for proper motion and parallax relative to reference stars having assumed zero proper motions and parallaxes, we solved cases where the program star's proper motion was constrained to

TABLE 5. Observations of the W624 field.

		Obs. attempted	Obs. obtained		Obs. used in final solution
Star	V	1993 Feb.	1993 Sept.	1994 Feb.	1994 Oct.
W624	13.3	12 - 12 - 12	18 - 18 - 14	12 - 12 - 12	27 - 27 - 27
Ha	12.7	6-6-6	–	–	–
Y	15.7	6 - 5 - 5	–	–	18 - 17 - 17
I	15.9	–	18 - 15 - 12	6 - 6 - 6	18 - 14 - 14
X	16.2	6 - 4 - 4	–	–	–
F	16.3	6 - 1 - 0	18 - 7 - 4	12 - 4 - 4	9 - 8 - 8
D	16.6	6 - 3 - 3	9 - 5 - 5	–	9 - 4 - 4
C	16.9	6 - 4 - 4	9 - 2 - 2	6 - 4 - 4	–
G	17.2	6 - 1 - 0	9 - 0 - 0	6 - 0 - 0	–
A	17.3	–	9 - 2 - 0	6 - 2 - 2	–
B	17.5	6 - 4 - 3	9 - 0 - 0	6 - 1 - 0	–

[a] Bright star west of F; measured by mistake in first data set.

TABLE 6. Proper motion and parallax data for Barnard's star.

Source	μ (″yr^{-1})	P.A. (deg)	Abs. Parallax (mas)	Notes
Yale Parallax Catalogue (1995)	10.310	355.8	545.6 ± 1.3	–
Benedict *et al.* (1995)	–	–	544.2 ± 2.8	1
Benedict *et al.* (1995)	–	–	542.0 ± 0.9	2
Benedict (priv. comm.)	10.374	355.4	546.6 ± 0.3	3
Present solution	10.371	355.9	546.2 ± 0.6	4

Notes to TABLE 6

1. The proper motion was constrained to Harrington & Dahn's (1980) determination of 10″.348 yr^{-1} at P.A.=355.5°.
2. Same data as previous solution but solved for proper motion as well as parallax.
3. An expanded data set from the two previous solutions.
4. The same data set as used in the previous (expanded) solution.

be an adopted value, where one or more of the reference stars might have significant motion or parallax, and where the data sets with few reference stars were removed. A comparison of the results provided a check on the validity of the formal errors from the least-squares solutions.

4.1 R50

The parallax determination for R50 was compromised by its sparse reference frame. One of the few stars in the field is R50's common proper motion companion, LP381-86, and thus is not suitable as a reference star. This star is 4 mag fainter and 3.3′ distant from R50 and is not included in the kinematics papers mentioned above. A. Smith and T. Oswalt (1996) have done *BVRI* photometry and low-resolution spectroscopy on this star and classify it as dM2. It would be interesting to determine its radial velocity to confirm its physical association with R50.

A second complication was that the preliminary reductions indicated that the brightest reference star, A, itself has a significant parallax and proper motion, and the adopted values have an important influence on the R50 parallax solution. The derived, relative values for star A are $\pi_{rel}=7.8\pm1.2$ mas and $\mu=41$ mas yr^{-1} at $\theta=306°$. This parallax is consistent with the photometric distance implied by the *BVR* values assuming the star is a dwarf.

An independent determination of star A's proper motion was made at STScI from scans of the POSS-I red survey plates and of the "Quick V" survey plates used to construct the *Guide Star Catalog*; the technique is explained in Williamson *et al.* (1995). The epoch difference between the plates is 32.2 years, and 21 reference stars were used. The resulting relative proper motion for A was 35 ± 8 mas yr^{-1} at 269 ± 13° which, although at the lower limit of the method, is consistent with the FGS-determined value.

Results of the proper motion and parallax determinations for R50 are given in Table 7. The first two lines give the Giclas and Luyten proper motion results. We consider these to be superseded by Cudworth's (1990) determination, and his relative and absolute proper motion values are given in lines 3 and 4. The final line gives our determination from the FGS measures. Two columns of parallax results are given; those with star A removed from the reference frame and then including it with its parameters constrained to the above values.

Our derived proper motion for R50 agrees with previous measures. The derived relative parallaxes range between 3.5 and 4.9 mas and depend on the adopted proper motion, particularly when A is included. A short time baseline makes it difficult to separate parallax and proper motion. We give the highest weight to the solutions where the proper motion was constrained to Cudworth's absolute result and adopt $\pi_{rel}=4.0\pm0.7$ mas.

The correction from relative to absolute parallax based on the magnitudes of the reference stars (assuming they are dwarfs and without star A) is 1.2 mas (van Altena 1996). Combining our parallax of $\pi_{abs}=5.2$ mas (190 pc) with Cudworth's value for the absolute proper motion yields velocities in galactocentric coordinates of $U=-310$, $V=-149$, and $W=342$ km s^{-1} giving $V_{RF}=467\pm31$ km s^{-1} assuming the standard solar and LSR motions. This is very close to the values derived by Cudworth and in the CL papers and is a vindication of the photometric method.

4.2 W624

The proper motion of W624 is less well determined from our data than that of R50, and the lack of a fifth epoch of observations made separating the parallactic and proper motions difficult. The results from a few of many GaussFit solutions are given in Table 8. The simultaneous solution for parallax and proper motion produced $\pi_{rel}=1.2\pm0.6$ mas but with either a spacecraft roll angle at least a degree different from the value in the data header or a proper motion angle significantly different from Luyten's and Cudworth's consistent values; neither case is likely. Constraining the proper motion to previously derived values yielded parallaxes in the range 2.3–4.3 mas. The clearly unrealistic result when Gi-

TABLE 7. Proper motion and parallax data for R50.

	Proper Motion			Trigonometric Parallax	
Source of p. m.	Type	″yr^{-1}	P.A. (deg)	Without A (mas)	With A[a] (mas)
Giclas *et al.* (1978)	Relative	0.35	184	–	–
Luyten (1980a)	Relative	0.331	188	–	–
Cudworth (1990)	Relative	0.329	187	4.1 ± 0.8	3.5 ± 0.3
Cudworth (1990)	Absolute	0.334	188	4.8 ± 0.8	4.1 ± 0.7
Present FGS data	Relative	0.333	186	4.5 ± 0.8	4.9 ± 0.3

[a] Star A was constrained to have $\pi_{rel}=7.8$ mas and $\mu_{rel}=41$ mas yr^{-1} at 306°.

TABLE 8. Proper motion and parallax data for W624.

Source of p.m.	Proper Motion Type	$''$ yr^{-1}	P.A. (deg)	Trig. Parallax (mas)
Giclas *et al.* (1978)	Relative	0.39	221	19.9 ± 3.8
Luyten (1980a)	Relative	0.432	228.6	2.3 ± 0.6
Cudworth (priv. comm.)	Relative	0.425	228	4.3 ± 0.8
Cudworth (priv. comm.)	Absolute	0.432	228	2.8 ± 0.8
Present FGS data	Relative	0.432	229.5	1.2 ± 0.6

clas' motion is adopted, which has been disregarded, illustrates the sensitivity of the solutions to the adopted proper motion. The inconsistency that the derived parallax is larger when Cudworth's relative proper motion is adopted than when using his absolute motion suggests that the 4.3 mas result is too large. We adopt $\pi_{rel}=3.3\pm1.0$ mas.

Converting to absolute parallax gives $\pi_{abs}=3.8$ mas, equivalent to a distance of 265 pc. As mentioned, the space velocity of this star is almost entirely determined by its tangential velocity and hence depends critically on distance. Unfortunately, the uncertainty in our result is a large fraction of the derived value. Using Cudworth's results for absolute proper motion, one obtains $U=-73$, $V=-503$, $W=142$ km s^{-1} and $V_{RF}=324\pm121$ km s^{-1}. Our derived distance and rest-frame velocity are somewhat smaller than the photometric results but, given our large uncertainty, our values are not inconsistent with them. We can conclude, however, that its V_{RF} cannot be significantly larger than 450 km s^{-1}. Finally, we call attention to the large negative V component of its space velocity which shows it moves in a retrograde galactic orbit with a speed well above the circular velocity at its position in the Galaxy.

5. CONCLUSIONS

We have utilized the *HST* Fine Guidance System to observe two of the stars of largest known space velocity. We find a distance for R50 of 190 pc which implies a speed in the galactocentric rest frame of 467 km s^{-1}. We know of no normal star with a confirmed rest-frame velocity larger than this. The derived distance of W624 is 265 pc but has an uncertainty of about 30%. The resulting rest-frame velocity is likewise very uncertain but is most likely less than 450 km s^{-1} and may be significantly smaller than the results based on photometric parallaxes. Our parallaxes indicate that the photometric distance determinations for these stars in the recent kinematic surveys are not seriously in error. Our space velocity results suggest that the galactic escape velocity in the solar neighborhood is not significantly larger than 475 km s^{-1}.

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