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THE SOLAR NEIGHBORHOOD. XVII. PARALLAX RESULTS FROM THE CTIOPI 0.9 m PROGRAM: 20 NEW MEMBERS OF THE RECONS 10 PARSEC SAMPLE

Todd J. Henry,[1] Wei-Chun Jao,[1] John P. Subasavage,[1] and Thomas D. Beaulieu[1]
Department of Physics and Astronomy, Georgia State University, Atlanta, GA 30302-4106; thenry@chara.gsu.edu, jao@chara.gsu.edu, subasavage@chara.gsu.edu, beaulieu@chara.gsu.edu

Philip A. Ianna[1]
Department of Physics and Astronomy, University of Virginia, Charlottesville, VA 22903; pai@virginia.edu

and

Edgardo Costa[1] and René A. Méndez[1]
Departamento de Astronomía, Universidad de Chile, Santiago, Chile; costa@das.uchile.cl, rmendez@das.uchile.cl
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ABSTRACT

Astrometric measurements for 25 red dwarf systems are presented, including the first definitive trigonometric parallaxes for 20 systems within 10 pc of the Sun, the horizon of the RECONS sample. The three nearest systems that had no previous trigonometric parallaxes (other than perhaps rough preliminary efforts) are SO 0253+1652 (3.84 ± 0.04 pc, the 23rd nearest system), SCR 1845−6357 AB (3.85 ± 0.02 pc, 24th nearest), and LHS 1723 (5.32 ± 0.04 pc, 56th nearest). In total, seven of the systems reported here rank among the nearest 100 stellar systems. Supporting photometric and spectroscopic observations have been made to provide full characterization of the systems, including complete $VRIJHK_s$ photometry and spectral types. A study of the variability of 27 targets reveals six obvious variable stars, including GJ 1207, for which we observed a flare event in the V band that caused it to brighten by 1.7 mag. Improved parallaxes for GJ 54 AB and GJ 1061, both important members of the 10 pc sample, are also reported. Definitive parallaxes for GJ 1001 A, GJ 633, and GJ 2130 ABC, all of which have been reported to be within 10 pc, indicate that they are beyond 10 pc. From the analysis of systems with (previously) high trigonometric parallax errors, we conclude that parallaxes with errors in excess of 10 mas are insufficiently reliable for inclusion in the RECONS sample. The cumulative total of new additions to the 10 pc sample since 2000 is now 34 systems: 28 by the RECONS team and six by other groups. This total represents a net increase of 16% in the number of stellar systems reliably known to be nearer than 10 pc.

Key words: astrometry — solar neighborhood — stars: distances — stars: low-mass, brown dwarfs — stars: statistics — surveys

1. INTRODUCTION

Trigonometric parallax determinations provide one of the most fundamental measures of the cosmos. Their beauty lies in their simplicity: they are based only on geometric techniques and are the straightforward result of Earth orbiting the Sun. Trigonometric parallaxes help define solar neighborhood membership, allow for accurate mass calculations in binary systems, provide distances to fundamental stellar clusters, and supply benchmarks for stellar population studies in the Milky Way and nearby galaxies. With concerted effort, trigonometric parallaxes with accuracies of ~1 mas are possible, yielding distances good to 10% even at 100 pc and allowing astronomers to create an accurate three-dimensional map of the nearby Galaxy. Much like early explorers' discoveries creating a more complete map of our Earth, accurate trigonometric parallaxes create a more detailed picture of the solar neighborhood, filling in the blank regions of nearby space.

Van Altena et al.[2] compiled decades of ground-based work by dedicated astrometrists in the General Catalogue of Trigonometric Stellar Parallaxes (also known as the Yale Parallax Catalog [YPC]). The YPC includes 15,994 total trigonometric parallaxes for 8112 stars measured using photographic plates and CCDs published before the end of 1995. The *Hipparcos* space mission, launched in 1989 August, provided ~118,000 parallaxes (Perryman et al. 1997,[3] hereafter HIP), and was essentially complete for stars with $V = 7.3$–9.0, while reaching to observe a few dozen stars even fainter than $V \sim 13$. However, *Hipparcos* could not measure most nearby white, red, and brown dwarfs, which comprise more than 80% of the solar neighborhood population, and many of these systems have not yet had their distances measured via ground-based trigonometric parallax efforts.

Here we present results for nearby star systems observed during our Cerro Tololo Inter-American Observatory Parallax Investigation (CTIOPI). Twenty systems are new members of the Research Consortium on Nearby Stars (RECONS) sample, meeting the RECONS requirements that they have trigonometric parallaxes π_{trig} larger than 100 mas with errors less than 10 mas (see § 6.1). We provide a brief dossier for each new system, including $VRIJHK_s$ photometry and spectral types. We also provide improved π_{trig} for two additional important systems previously known to be within 10 pc, GJ 54 AB and GJ 1061, and for three systems that have reported π_{trig} larger than 100 mas, but that, in

[1] Visiting Astronomer, Cerro Tololo Inter-American Observatory. CTIO is operated by the Association of Universities for Research in Astronomy, Inc., under contract to the National Science Foundation.

[2] VizieR Online Data Catalog, I/238A (W. F. van Altena et al., 1995).

[3] VizieR Online Data Catalog, I/239 (M. A. C. Perryman et al., 1997).

TABLE 1
GROUND-BASED TRIGONOMETRIC PARALLAXES FOR STARS WITHIN 10 pc SINCE YPC

Reference	Observing Method	Total Number of Parallaxes[a]	Number of New 10 pc Systems[b]	New 10 pc Systems[b]
		Other Parallax Programs		
Tinney (1996)	Optical CCD	13	1	LP 944−020 (=BRI 0337−3535)
Dahn et al. (2002)	Optical CCD	28	2	2MASS 0036+1821, 2MASS 1507−1627
Reid et al. (2003a)	Optical CCD	1	1	2MASS 1835+3259
Vrba et al. (2004)	IR array	40	3	2MASS 0415−0935, 2MASS 0727+1710, 2MASS 0937+2931
Total (other programs)		82	7	
		RECONS Efforts		
Henry et al. (1997)	Photographic plates	1	1	GJ 1061
Jao et al. (2005)	Optical CCD	46	5	GJ 754, GJ 1068, GJ 1123, GJ 1128, DENIS 1048−3956[c]
Costa et al. (2005)	Optical CCD	31	2	GJ 2005 ABC, LP 647−013
Costa et al. (2006)	Optical CCD	31	1	DENIS 0255−4700
This paper	Optical CCD	27	20	See Table 3
Total (RECONS)		136	29	

NOTE.—Papers listed describe new systems within 10 pc having parallax errors less than 10 mas.
[a] Reference star parallaxes not included in counts.
[b] Error in weighted mean of all π_{trig} must be less than 10 mas.
[c] Also reported in Costa et al. (2005) from CTIOPI at the 1.5 m telescope.

truth, lie beyond the 10 pc horizon. In total, we report 27 new trigonometric parallax measurements for 25 systems.

2. CTIOPI AND OTHER RECENT TRIGONOMETRIC PARALLAX EFFORTS

Since the publication of the YPC and HIP results, only ~250 ground-based parallaxes and a handful of space-based parallaxes from the *Hubble Space Telescope* (e.g., Benedict et al. 1999) have been published in the refereed literature. We provide a comprehensive tally of ground-based trigonometric parallax measurements published for new RECONS systems in Table 1 since the 1995 cutoff date of the YPC.[4] The transition of data-acquisition techniques from photographic plates to CCDs and infrared arrays is nearly complete, although approximate parallaxes for the nearest objects can still be derived from large archival databases that include scanned plates (Deacon & Hambly 2001; Teegarden et al. 2003; Deacon et al. 2005). These parallaxes are useful but necessarily crude, given the limited number of epochs available and the coarse plate scales. The most recent change in parallax work is the advent of IR arrays (e.g., Vrba et al. 2004).

Our CCD parallax effort, CTIOPI, began as an NOAO Surveys Program in 1999 August using both the 0.9 m and 1.5 m telescopes at CTIO, and has continued on the 0.9 m as part of the SMARTS (Small and Moderate Aperture Research Telescope System) Consortium beginning in 2003 February. The primary goals of CTIOPI are to discover and characterize any nearby objects that remain unidentified in the solar neighborhood, primarily red dwarfs, brown dwarfs, and white dwarfs. Although CTIOPI concentrates on southern hemisphere systems, we also target important nearby star candidates as far north as $\delta = +30°$. Most of the stellar systems observed during CTIOPI have been selected because available astrometric data (high proper motions or crude parallaxes) or photometric/spectroscopic distance estimates indicate that they might be within 25 pc, the horizon of the Catalog of Nearby Stars (Gliese & Jahreiss 1991, hereafter CNS) and NStars (Henry et al. 2003) compendia. Objects possibly nearer than 10 pc are given the highest priority. The parallaxes we measure typically have errors less than 3 mas, corresponding to distance errors of only 1%–3% for systems within 10 pc. At the beginning of 2006, we continued to observe roughly two-thirds of the more than 400 systems targeted for parallax measurements during the 0.9 m telescope program. Under SMARTS, we have expanded CTIOPI to carry out a program to search for low-mass companions to nearby stars, called ASPENS (Astrometric Search for Planets Encircling Nearby Stars), in collaboration with D. Koerner at Northern Arizona University.

This paper is the fourth publication in this series that includes CTIOPI parallaxes. Jao et al. (2005) presented 46 parallaxes for high proper motion systems observed at the 0.9 m. Costa et al. (2005, 2006) presented 62 total parallaxes for fainter systems, including brown dwarf candidates, observed at the 1.5 m telescope. In this paper we concentrate on systems observed at the 0.9 m telescope that were candidates for the 10 pc sample and present 27 total parallaxes.

3. PHOTOMETRY

Because of the significant investment in observing time required to determine a trigonometric parallax (roughly one integrated night over at least 2 yr for each target) it is prudent to obtain characterization photometry of nearby star candidates before placing them on the astrometric program. As shown in Henry et al. (2004) the combination of V_J, R_{KC}, and I_{KC} (hereafter without subscripts)[5] photometry and infrared J, H, and K_s photometry from the Two Micron All Sky Survey (2MASS) can be used in a suite of color–absolute magnitude relations to estimate distances of main-sequence stars with 15% accuracy.

VRI photometry is reported in Table 2. Two names are often given, followed by the new optical *VRI* photometry and the number

[4] All parallaxes in Reid et al. (2000) were updated in Dahn et al. (2002). Two objects, TVLM 513−46546 (Tinney et al. 1995; Dahn et al. 2002) and 2MASS 1047+2124 (Tinney et al. 2003; Vrba et al. 2004), are borderline objects; the Tinney parallaxes place the objects closer than 10 pc, whereas the Dahn and Vrba USNO parallaxes place them beyond 10 pc. Weighted means of the two values for each object yield distances larger than 10 pc, so neither is included as a new 10 pc system in Table 1.

[5] Subscripts: "J" indicates Johnson, and "KC" indicates Kron-Cousins. The central wavelengths for V_J, R_{KC}, and I_{KC} are 5475, 6425, and 8075 Å, respectively.

TABLE 2

PHOTOMETRIC AND SPECTROSCOPIC RESULTS

Name (1)	Alternate Name (2)	V_J (3)	R_{KC} (4)	I_{KC} (5)	No. of Nights (6)	π Filter (7)	σ (mag) (8)	No. of Nights (9)	No. of Frames (10)	J (11)	H (12)	K_s (13)	d_{phot} (14)	No. of Relations (15)	Sp. Type (16)
New 10 pc Members															
LHS 1302	G159−003	14.49	13.00	11.17	5	*R*	0.021v	26	141	9.41	8.84	8.55	10.99 ± 1.84	12	M4.5 V
APMPM J0237−5928	...	14.47	12.96	11.08	5	*R*	0.013v	27	166	9.28	8.70	8.34	9.22 ± 1.49	12	M4.5 V
SO 0253+1652	...	15.14	13.03	10.65	3	*I*	0.006	16	95	8.39	7.88	7.59	4.00 ± 0.75	12	M6.0 V
LP 771−095 A	...	11.22	10.07	8.66	4	*V*	0.012	22	109	7.29	6.77	6.50	8.91 ± 1.43	12	M2.5 V
LP 771−095 BC	LP 771−096	11.37J	10.13J	8.58J	4	*V*	0.043	21	98	7.11J	6.56J	6.29J	6.43 ± 1.04	12	M3.0 VJ
LHS 1610	G006−039	13.85	12.42	10.66	5	*V*	0.024v	23	128	8.93	8.38	8.05	9.47 ± 1.52	12	M4.0 V
LHS 1723	...	12.22	10.87	9.18	5	*V*	0.020v	27	207	7.62	7.07	6.74	6.34 ± 1.09	12	M4.0 V
G099−049	LTT 17897	11.31	10.04	8.42	4	*V*	0.012	23	145	6.91	6.31	6.04	5.10 ± 0.81	12	M3.5 V
SCR 0630−7643 AB	...	14.82J	13.08J	11.00J	4	*I*	0.005	12	69	8.89J	8.28J	7.92J	5.46 ± 0.86	12	M5.0 VJ
G089−032 AB	LTT 17993	13.25J	11.81J	9.97J	4	*R*	0.009	32	215	8.18J	7.61J	7.28J	6.02 ± 0.93	12	M4.5 VJ
GJ 300	LHS 1989	12.15	10.85	9.22	3	*V*	0.016v	31	191	7.60	6.96	6.71	6.15 ± 0.98	12	M4.0 V
G041−014 ABC	...	10.92J	9.67J	8.05J	3	*V*	0.009	22	160	6.51J	5.97J	5.69J	4.40 ± 0.69	12	M3.5 VJ
LHS 2090	...	16.10	14.11	11.84	2	*I*	0.007	15	71	9.44	8.84	8.44	5.67 ± 0.88	12	M6.0 V
LHS 2206	G042−024	14.02	12.63	10.85	3	*R*	0.011	20	118	9.21	8.60	8.33	11.38 ± 1.88	12	M4.0 V
LHS 288	...	13.90	12.31	10.27	3	*R*	0.007	13	68	8.49	8.05	7.73	6.90 ± 1.73	12	M5.0 V
SCR 1138−7721	...	14.78	13.20	11.24	4	*I*	0.004	12	59	9.40	8.89	8.52	9.44 ± 1.71	12	M5.0 V
LHS 337	...	12.75	11.44	9.74	3	*R*	0.006	10	50	8.17	7.76	7.39	9.19 ± 1.86	12	M4.0 V
WT 460	...	15.63	13.90	11.78	3	*I*	0.008	28	151	9.67	9.04	8.62	7.33 ± 1.15	12	M5.5 V
GJ 1207	LHS 3255	12.25	11.00	9.43	5	*V*	0.263v	27	124	7.97	7.44	7.12	9.33 ± 1.57	12	M3.5 V
SCR 1845−6357 AB	...	17.40J	15.00J	12.46J	5	*I*	0.004	18	117	9.54J	8.97J	8.51J	4.64 ± 0.76	10	M8.5 VJ
LHS 3746	...	11.76	10.56	9.04	4	*V*	0.013	33	213	7.60	7.02	6.72	8.14 ± 1.26	12	M3.0 V
Known 10 pc Members															
GJ 54 AB	LHS 1208	9.82J	8.70J	7.32J	5	*V*	0.015	20	149	6.00J	5.41J	5.13J	4.90 ± 0.77	12	M2.5 VJ
GJ 1061	LHS 1565	13.09	11.45	9.46	5	*R*	0.010	27	186	7.52	7.02	6.61	3.56 ± 0.61	12	M5.0 V
Not 10 pc Members															
GJ 1001 A	LHS 102	12.86	11.64	10.10	2	*R*	0.010	14	61	8.60	8.04	7.74	12.25 ± 1.89	12	M3.0 V
GJ 633	LHS 3233	12.66	11.55	10.18	4	*V*	0.007	14	64	8.89	8.31	8.05	19.70 ± 3.11	12	M3.0 V
GJ 2130 A	CD −32 13297	10.50	9.49	8.34	4	*V*	0.009	12	71	7.11	6.53	6.25	10.69 ± 1.73	12	M1.5 V
GJ 2130 BC	CD −32 13298	11.51J	10.34J	8.86J	4	*V*	0.010	13	113	7.46J	6.86J	6.59J	8.21 ± 1.27	12	M3.0 VJ

NOTE.—"J" means the photometry or spectral type is for more than one object, i.e., joint.

of nights on which observations were taken during CTIOPI. Photometry was acquired at the CTIO 0.9 m telescope using the same filter and detector combination as used for the astrometry frames (see § 5 for details of the instrumental setup). All observations were taken between 1999 November and 2005 December.[6] Data were reduced via IRAF with typical bias subtraction and dome flat-fielding using calibration frames taken at the beginning of each night. Standard star fields from Graham (1982), Bessel (1990), and/or Landolt (1992) were observed several times each night to derive transformation equations and extinction curves. Apertures 14″ in diameter were used to determine the stellar fluxes to match the apertures used by Landolt, except in cases when close sources needed to be deconvolved (LP 771−095 ABC) or excised (LHS 288, WT 460), in which case smaller apertures were used and aperture corrections were done. Further details about data reduction, transformation equations, etc., can be found in Jao et al. (2005).

As discussed in Henry et al. (2004), representative total errors in the *VRI* photometry are ±0.03 mag. Of the 81 *VRI* photometric values reported here, 69% have formal total 1 σ errors of 0.03 or less. Only eight values have errors in excess of 0.05 mag: G099−049, GJ 300, GJ 2130A, LHS 1610, and LHS 1723 at *V* with errors of 0.05–0.07 mag, and WT 460 with errors of 0.09, 0.06, and 0.05 at *V*, *R*, and *I*, respectively, because it is crowded by nearby sources and required apertures of 5″ or smaller and large aperture corrections.

A detailed variability study for the parallax targets has been carried out by comparing the photometry of the target stars to that of the reference stars that set the astrometric grid for each field. Our methodology matches that of Honeycutt (1992), in which details of the algorithm used can be found. Columns (7)–(10) of Table 2 list the filter used for the parallax frames, the standard deviation of the target's magnitude in that filter, the number of different nights the target was observed, and the total number of frames evaluated for variability. In general, stars with standard deviation values (relative to the reference stars) greater than 0.02 mag are obviously variable, those with values 0.01–0.02 mag are variable at a level of a few percent, and those with values less than 0.01 mag are "steady." However, these cutoffs are not absolute, because if the reference stars used to measure the flux modulations are faint, an artificially high standard deviation value may result. Therefore, a "v" is given after the value in column (8) if variability has been detected reliably. In total, we identify six of the 27 targets to be certain variables, a rate of 22%. This is lower than the 49% rate (21 of 43 red dwarfs) found by Weis (1994), primarily because our variability threshold is roughly twice as high as that of Weis.

Inspection of the photometric results indicates that many of the 20 new nearby systems are relatively bright, with eight systems having $V < 13$. Only one of these systems, LP 771−095 ABC, was observed by *Hipparcos*, but the close proximity of the two sources A and BC resulted in a trigonometric parallax with high error, 92.97 ± 38.04 mas.

Infrared photometry in the JHK_s system (rounded to the nearest hundredth) has been extracted from 2MASS and is given in columns (11)–(13) of Table 2. Because of the stars' generally large proper motions, each identification was confirmed by eye. The JHK_s magnitude errors, which include target, global, and systematic terms, i.e., the j_sigcom, h_sigcom, and k_sigcom errors, are almost always less than 0.05 mag and are typically 0.02–0.03 mag. The only two exceptions are *H*-band magnitude errors for LHS 337 (0.06 mag) and GJ 1207 (0.08 mag).

Column (14) of Table 2 provides a distance estimate and error for each system based on the suite of photometric distance relations in Henry et al. (2004). Column (15) lists the number of distance relations valid and used for each target, where the maximum is 12. These distances are compared to the distances determined from the trigonometric parallaxes reported in § 6 to confirm or reveal new multiple systems, as discussed in § 7.2.

4. SPECTROSCOPY

After the acquisition of optical and infrared photometry and the subsequent distance estimates, a final spectroscopic check is typically done to confirm the likely proximity of a candidate. Spectral types are useful for the separation of dwarfs, subdwarfs, and the occasional giant that slips through the photometric net.

As part of a long-term program to characterize nearby star candidates, spectra were acquired between 2002 March and 2004 September on the CTIO 1.5 m and 4.0 m telescopes. On the 1.5 m telescope, observations were made using a 2″0 slit in the RC Spectrograph with grating 32 and order blocking filter OG570 to provide wavelength coverage from 6000 to 9500 Å and resolution of 8.6 Å on the Loral 1200 × 800 CCD. On the 4.0 m telescope, observations were made using a 2″0 slit in the RC Spectrograph with grating G181 and order blocking filter OG515 to provide wavelength coverage from 5000 to 10700 Å and resolution of 5.6 Å on the Loral 3K × 1K CCD. At least two sequential exposures were taken of each target to permit cosmic-ray removal. Reductions were accomplished using standard methods in IRAF, and mild fringing, a result of the rear-illuminated CCD on the 4.0 m telescope, was removed with a tailored IDL routine.

As shown in column (16) of Table 2, all of the new nearby stars are red dwarfs, with types spanning M2.5 V–M8.5 V. What is somewhat surprising is that many of the new systems are *not* late-type M dwarfs: 17 of the 20 primaries in the new RECONS systems have spectral types earlier than M6.0 V. Thus, there remain many midtype M dwarfs near the Sun that are not yet recognized as solar neighbors.

5. ASTROMETRY OBSERVATIONS AND REDUCTIONS

The 0.9 m telescope is equipped with a 2048 × 2048 Tektronix CCD camera with a 0″401 pixel^{-1} plate scale that has remained on the telescope throughout CTIOPI. All observations of the parallax targets ("pi stars") listed in Table 3 (coordinates in epoch and equinox J2000.0) were made through *VRI* filters using the central quarter of the chip, yielding a 6′8 square field of view. The same filter (col. [7] of Table 2 and col. [4] of Table 3) is used for all astrometric observations for a given pi star. The basic data reduction for the astrometry CCD frames includes overscan correction, bias subtraction, and flat-fielding, using calibration frames taken at the beginning or end of each night.

An extensive discussion of the data acquisition and reduction techniques is given in Jao et al. (2005). Briefly, 5–10 parallax frames are typically taken for a parallax field at each epoch to provide multiple measurements of pi and reference star centroids. Frames are usually taken within ±30 minutes of a pi star's transit in order to minimize the corrections required for differential color refraction (DCR), with the goal of having some frames on both sides of the meridian on each night that a field is observed. All observations for a given field are made with a set of reference stars suitably positioned on the chip within a few pixels of their original locations. Good reference star configurations include 5–15 stars

[6] The Tek 2 *VRI* filter set at CTIO has been used. However, the Tek 2 *V* filter cracked in 2005 March and was replaced by the very similar Tek 1 *V* filter. Reductions indicate no significant differences in either astrometric or photometric results from the two filters.

TABLE 3
Astrometric Results

Name (1)	R.A. (J2000.0) (2)	Decl. (J2000.0) (3)	Filter (4)	N_{sea} (5)	N_{frm} (6)	Coverage (7)	Years (8)	N_{ref} (9)	π(rel) (mas) (10)	π(corr) (mas) (11)	π(abs) (mas) (12)	μ (mas yr^{-1}) (13)	P.A. (deg) (14)	V_{tan} (km s^{-1}) (15)	Notes (16)
New 10 pc Members															
LHS 1302	01 51 04.09	−06 07 05.1	*R*	7c	141	1999.71−2005.96	6.25	6	100.14 ± 1.89	0.64 ± 0.06	100.78 ± 1.89	597.1 ± 0.9	115.5 ± 0.17	28.1	
APMPM J0237−5928	02 36 32.46	−59 28 05.7	*R*	7c	160	1999.64−2005.96	6.32	6	102.38 ± 1.11	1.34 ± 0.11	103.72 ± 1.12	724.9 ± 0.5	52.2 ± 0.08	33.1	
SO 0253+1652	02 53 00.89	+16 52 52.7	*I*	3c	95	2003.53−2005.88	2.35	6	258.48 ± 2.68	2.15 ± 0.21	260.63 ± 2.69	5106.8 ± 3.1	138.2 ± 0.07	92.9	1
LP 771−095 A	03 01 51.39	−16 35 36.0	*V*	6c	109	1999.64−2005.96	6.33	5	145.44 ± 2.92	0.95 ± 0.14	146.39 ± 2.92	477.0 ± 1.4	234.4 ± 0.34	15.4	2
LP 771−095 BC	03 01 51.04	−16 35 31.0	*V*	6c	99	1999.64−2005.96	6.15	5	138.75 ± 4.99	0.95 ± 0.14	139.70 ± 4.99	479.4 ± 2.5	235.5 ± 0.59	16.3	
LHS 1610	03 52 41.76	+17 01 04.3	*V*	7c	128	1999.71−2005.96	6.25	6	100.24 ± 2.07	1.33 ± 0.12	101.57 ± 2.07	767.0 ± 1.0	146.1 ± 0.15	35.8	3
LHS 1723	05 01 57.43	−06 56 46.5	*V*	7c	207	1999.81−2005.95	6.14	11	186.20 ± 1.25	1.72 ± 0.19	187.92 ± 1.26	769.4 ± 0.7	226.9 ± 0.10	19.4	
G099−049	06 00 03.52	+02 42 23.6	*V*	7c	145	1999.91−2005.96	6.06	7	189.43 ± 1.82	1.50 ± 0.50	190.93 ± 1.89	312.5 ± 0.8	97.5 ± 0.24	7.8	4
SCR 0630−7643 AB	06 30 46.61	−76 43 09.0	*I*	3c	69	2003.94−2005.97	2.03	8	112.07 ± 1.84	2.09 ± 0.19	114.16 ± 1.85	455.7 ± 3.0	356.9 ± 0.53	18.9	
G089−032 AB	07 36 25.13	+07 04 43.1	*R*	7c	216	1999.91−2005.95	6.05	13	115.67 ± 0.97	0.93 ± 0.08	116.60 ± 0.97	396.9 ± 0.5	143.0 ± 0.14	16.1	
GJ 300	08 12 40.88	−21 33 06.8	*V*	7c	191	1999.91−2005.95	6.05	8	122.40 ± 0.90	3.20 ± 0.37	125.60 ± 0.97	698.8 ± 0.5	178.7 ± 0.06	26.4	5
G041−014 ABC	08 58 56.33	+08 28 26.0	*V*	7c	159	1999.97−2005.96	5.99	5	145.40 ± 1.97	2.26 ± 0.22	147.66 ± 1.98	502.7 ± 0.9	130.0 ± 0.20	16.1	
LHS 2090	09 00 23.55	+21 50 04.8	*I*	4c	71	2002.28−2005.20	2.92	9	155.98 ± 2.67	0.89 ± 0.06	156.87 ± 2.67	773.9 ± 2.2	221.2 ± 0.33	23.4	
LHS 2206	09 53 55.19	+20 56 46.8	*R*	7c	118	2000.06−2005.97	5.91	6	107.89 ± 2.30	0.50 ± 0.03	108.39 ± 2.30	522.6 ± 1.0	321.1 ± 0.22	22.9	
LHS 288	10 44 21.23	−61 12 35.6	*R*	5s	63	2000.06−2005.13	5.07	10	207.73 ± 2.73	1.22 ± 0.16	208.95 ± 2.73	1642.9 ± 1.2	347.7 ± 0.07	37.3	6
SCR 1138−7721	11 38 16.76	−77 21 48.5	*I*	3s	59	2003.23−2005.33	2.09	11	120.25 ± 2.91	2.02 ± 0.28	122.27 ± 2.92	2147.6 ± 5.1	286.9 ± 0.25	83.3	
LHS 337	12 38 49.10	−38 22 53.8	*R*	4s	50	2002.28−2005.47	3.19	14	155.37 ± 1.99	1.41 ± 0.14	156.78 ± 1.99	1464.3 ± 1.8	206.4 ± 0.13	44.3	
WT 460	14 11 59.94	−41 32 21.3	*I*	6c	152	2000.14−2005.57	5.43	10	105.58 ± 1.51	1.83 ± 0.13	107.41 ± 1.52	690.4 ± 0.9	260.0 ± 0.12	31.0	
GJ 1207	16 57 05.73	−04 20 56.3	*V*	7c	124	1999.62−2005.71	6.09	10	113.36 ± 1.44	2.03 ± 0.44	115.39 ± 1.51	608.5 ± 0.8	127.1 ± 0.15	25.0	7
SCR 1845−6357 AB	18 45 05.26	−63 57 47.8	*I*	3c	117	2003.24−2005.81	2.57	12	258.29 ± 1.11	1.16 ± 0.08	259.45 ± 1.11	2664.4 ± 1.7	76.6 ± 0.06	48.7	8
LHS 3746	22 02 29.39	−37 04 51.3	*V*	7c	213	1999.71−2005.88	6.17	7	133.14 ± 1.20	1.15 ± 0.11	134.29 ± 1.31	820.7 ± 0.8	105.1 ± 0.09	29.0	
Known 10 pc Members															
GJ 54 AB	01 10 22.90	−67 26 41.9	*V*	6c	149	2000.57−2005.96	5.39	8	139.28 ± 3.32	1.92 ± 0.62	141.20 ± 3.38	682.5 ± 2.1	33.1 ± 0.34	22.9	9
GJ 1061	03 35 59.71	−44 30 45.4	*R*	7c	186	1999.62−2005.95	6.33	7	270.98 ± 1.34	0.94 ± 0.08	271.92 ± 1.34	826.3 ± 0.8	117.7 ± 0.10	14.4	10
Not 10 pc Members															
GJ 1001 A	00 04 36.46	−40 44 02.7	*R*	5s	61	1999.64−2005.95	6.32	6	75.83 ± 3.97	1.03 ± 0.07	76.86 ± 3.97	1627.0 ± 1.8	156.7 ± 0.12	100.3	11
GJ 633	16 40 45.26	−45 59 59.3	*V*	6s	62	1999.64−2005.71	6.07	10	41.78 ± 1.75	2.71 ± 0.57	44.49 ± 1.84	528.4 ± 1.4	136.6 ± 0.30	56.3	12
GJ 2130 A	17 46 12.75	−32 06 09.3	*V*	5s	71	1999.64−2005.71	6.07	8	68.85 ± 2.55	2.60 ± 0.68	71.45 ± 2.64	277.8 ± 2.4	196.2 ± 0.87	18.4	13
GJ 2130 BC	17 46 14.42	−32 06 08.5	*V*	5s	113	1999.64−2005.71	6.07	8	67.63 ± 1.93	2.60 ± 0.68	70.23 ± 2.05	277.4 ± 1.8	196.4 ± 0.66	18.7	

Notes.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds. Coordinates are epoch and equinox J2000.0; each target's coordinates were extracted from 2MASS and then transformed to epoch J2000.0 using the proper motions and position angles listed here. (1) Parallax of 410 ± 90 mas in Teegarden et al. (2003). (2) Parallax of 92.97 ± 38.04 mas in HIP. (3) Parallax of 70.0 ± 13.8 mas in YPC. (4) Parallax of 186.2 ± 10.1 mas in YPC. (5) Parallax of 169.9 ± 15.0 mas in YPC. (6) Parallax of 222.5 ± 11.3 mas in YPC. (7) Parallax of 104.4 ± 13.6 mas in YPC. (8) Parallax of 282 ± 23 mas in Deacon et al. (2005). (9) Parallaxes of 120.5 ± 10.1 mas in YPC and 122.86 ± 7.53 mas in HIP. (10) Parallax of 273.4 ± 5.2 mas in Henry et al. (1997). (11) Parallax of 104.7 ± 11.4 mas in YPC. (12) Parallax of 104.0 ± 13.7 mas in YPC. (13) Parallax of 161.77 ± 11.29 mas in HIP.

surrounding the pi star (the number of reference stars is given in col. [9] of Table 3). Typically, selected reference stars have at least 1000 counts at the peak and minimal proper motion and parallax (the ensemble of proper motion and parallax values for reference stars is set to zero during reduction). These reference stars are used as the grid against which the pi star astrometry is measured, to correct for any field translation or rotation caused by temporal shifts in the telescope/camera combination, and as comparison stars for variability studies. In addition, *VRI* photometry is obtained for the reference stars and used to make DCR corrections and to estimate distances to each star photometrically to permit the conversion from relative to absolute parallax.

To decouple parallactic and proper motions in the final astrometric solution, observations are typically taken over at least 2 yr, including four high parallax factor seasons. Columns (5)–(8) of Table 3 list the number of seasons, total number of frames, epochs of observation, and length of time for each pi star frame series. As in previous papers, in the seasons column, "c" indicates a continuous set of observations throughout the seasons and "s" indicates scattered observations, meaning that the target was observed on only one night during one or more seasons (or was missed entirely during a season); continuous observations are superior to scattered observations. The set of observations for a given pi star usually includes at least 20 evening and 20 morning frames. However, because the pi stars in this paper were likely to be within 10 pc, they were given high-priority status throughout their tenures on the observing list; thus, the total number of frames given for each target often far exceeds the typical 40 total frames for a pi star.

6. ASTROMETRY RESULTS

The trigonometric parallax results are given in Table 3, including both relative (col. [10]) and absolute (col. [12]) parallaxes, as well as the correction between the two (col. [11]). The corrections are generally less than ~2 mas, so systematics in the corrections should not significantly affect the final results. Proper motions and position angles of the proper motions are given in columns (13) and (14), and the derived tangential velocity is given in column (15). The final column indicates whether previous trigonometric values were available, with notes following the table. After outlining the definition of a RECONS system, we discuss each system individually.

6.1. *Definition of RECONS Systems*

Stars targeted in this study include potential new 10 pc sample members with no trigonometric parallaxes and stars supposedly within 10 pc with large trigonometric parallax errors. The second category of targets allows us the opportunity to evaluate the threshold of reliability for available trigonometric parallaxes. As supported by the results described below, we formally define the parameters for inclusion in the RECONS 10 pc sample as follows: *it must be a system comprised of stars, brown dwarfs, and/or planets (and any associated surrounding material) for which a trigonometric parallax of at least 100 mas has been determined and for which the parallax has a formal error of 10 mas or less*.

The advantages of this definition are (1) it assigns a clear "in" or "out" status for each system, rather than using probabilities for systems, in particular those near the 10 pc border; (2) it establishes a uniform 10 mas error cutoff for every system in the sample; and (3) it provides a limit on the "worst case" for any system because the distance is known to better than 10% in all cases. This final benchmark is superior to current photometric or spectroscopic distance estimates that, when done correctly, are not better than 15% (Henry et al. 2004) for red dwarfs, the dominant component of the nearby star population.

In truth, we do not consider a trigonometric parallax "definitive" unless its error is less than 3 mas, and this value may change when large numbers of stars are measured more accurately via future efforts. However, we include systems with parallax errors of 3–10 in the RECONS sample to bolster the statistics until we can acquire improved data, as is our goal during CTIOPI. We *do not* include systems with parallax errors in excess of 10 mas, because, as shown in § 6.4, many systems with errors this large do not prove to be within 10 pc.

One awkward aspect of the adopted definition is that it excludes systems with very large parallaxes and large parallax errors until accurate data are in hand. Examples include stars with approximate parallaxes measured using a few photographic plates, such as SO 0253+1652 and SCR 1845−6357 AB, and systems with $\pi_{\rm trig}$ from more extensive plate series having errors slightly in excess of 10 mas, such as G041−014 ABC and LHS 288, both of which were reported to be within 5 pc (see § 6.2). LHS 288 is a particularly subtle example of applying the RECONS criteria for membership. Ianna & Bessell (1986) determined a parallax of 221 ± 8 mas, but the YPC, which carries out a systematic assessment of parallaxes and errors, gives an error of 11.3 mas for LHS 288's parallax. Thus, this star did not meet the formal definition for a RECONS member because we used the YPC for sample definition. These "nearly certain" members were generally observed early and intensely in CTIOPI to bring them formally into the sample.

6.2. *New RECONS Systems*

Here we report 20 new RECONS stellar systems based on the trigonometric parallaxes given in the top portion of Table 3. Previously, none of these systems had trigonometric parallaxes with errors less than 10 mas, and 12 had no trigonometric parallaxes of any kind. Of the 20 new systems, five have proper motions in excess of 1″.0 yr^{-1}, 11 have motions between 1″.0 and 0″.5 yr^{-1}, and four have motions less than 0″.5 yr^{-1}. These numbers indicate that there are likely to be large numbers of stars within 10 pc of the Sun that have low, but not negligible, proper motions.

Many of these systems have been recovered through our extensive efforts to estimate reliable distances for stars included in a large collection of potentially nearby objects. The collection includes various types of astrometric, photometric, and spectroscopic data that have been converted to standard systems, evaluated for reliability, and then used to pinpoint systems potentially nearer than 10 pc. Primary sources include (1) the valuable CNS, which includes many stars with photometric parallaxes, (2) the Luyten Half Second Catalogue (Luyten 1979), which includes 3602 objects with proper motions in excess of 0″.5 yr^{-1} and which still accounts for 87% of all such known objects as of this writing (see Subasavage et al. 2005b), and (3) the monumental work of Weis and collaborators, who provided accurate optical photometry and computed photometric parallaxes for thousands of stars (Weis 1984, 1986, 1987, 1988, 1991a, 1991b, 1993, 1996; Booth et al. 1988).

More recently, large-scale work by Reid and collaborators (Reid & Cruz 2002; Reid et al. 2002, 2003a, 2003b, 2004; Cruz & Reid 2002; Cruz et al. 2003; Reid 2003) has identified additional new systems from proper-motion compendia, and has reidentified and confirmed many of the systems noted by others. In addition, our own new recent proper-motion survey, known as the SuperCOSMOS-RECONS (SCR) effort (Hambly et al. 2004; Henry et al. 2004; Subasavage et al. 2005a, 2005b), has already provided three new systems described in this paper. The initial dates for the astrometric series listed in Table 3 indicate when the targets were first observed, illustrating that many targets were placed on the parallax program before most of the more recent distance-estimating efforts.

Here we provide a brief dossier for each new RECONS sample system. The notes to Table 3 list previously available trigonometric parallaxes, which are also given here in the text alongside the photometric or spectroscopic distance estimates. It is also important to note that the trigonometric parallaxes given in the 1991 edition of the CNS are from a preliminary version of the YPC. Thus, they are of the same origin as the definitive YPC, published in 1995, and are therefore not listed explicitly here. The final YPC parallaxes often have somewhat larger errors determined systematically during construction of the catalog, and errors in excess of 10 mas excluded some stars from the RECONS sample until the present study, even though their CNS errors were less than 10 mas.

LHS 1302: This star was reported to have photometric distances of 10.0 ± 1.8 pc by CNS and 10.2 ± 1.3 pc by Reid & Cruz (2002). The distance is 9.92 ± 0.19 pc, consistent with previous estimates and near the horizon of the RECONS sample. There is a hint of a perturbation in the right ascension residuals that may be confirmed or refuted via ASPENS. The star was variable at a level of 0.05 mag in the R band during 26 nights of observation and flared by 0.13 mag in R on UT 2004 November 22 during a sequence of 10 frames spanning 37 minutes.

APMPM J0237−5928: This star is an X-ray source reported by Scholz et al. (1999) to have a photometric distance between 11 and 14.5 pc based on a spectral type of M5 V. The distance is 9.64 ± 0.10 pc. The star is mildly variable, with a standard deviation of 0.013 mag in the R band during 27 nights of observation, with a full variability range of 0.06 mag.

SO 0253+1652: This star was reported by Teegarden et al. (2003) to have a crude trigonometric parallax of 410 ± 90 mas (2.4 ± 0.6 pc) that was described as a "lower limit on the true parallax." Based on this value, claims were made that it was the third-nearest star system, was an extremely metal-poor subdwarf, or had a radius only 60% that of a comparable star, GJ 1111. However, their photometric estimate (3.6 ± 0.4 pc) and our group's estimate (3.7 ± 0.6 pc; Henry et al. 2004) are better matches to the actual distance of 3.84 ± 0.04 pc determined here. Rather than being an exotic object, SO 0253+1652 is a normal red dwarf with $M_V = 17.22$ and spectral type M7.0 V and is the 23rd nearest system to the Sun.

LP 771−095 ABC: This system is a triple system (A is LP 771−095 and the close pair BC is LP 771−096) with separations of 7.″22 at position angle (P.A.) = 315° for A-BC (Jao et al. 2003) and 1.″30 at P.A. = 138° for B-C (this paper), with no change in position angle noted during the 6 years of our observations. A and BC have separate photometry, with A brighter than BC at V and R, but fainter at I (see Table 2). The magnitude differences between B and C are $\Delta V = 0.86 \pm 0.09$, $\Delta R = 0.75 \pm 0.03$, and $\Delta I = 0.66 \pm 0.07$.

The CTIOPI reference field is faint and sparse, and as few as four reference stars were used to boost the frame count. Nevertheless, we measure consistent parallaxes for A and BC, although the parallax error for BC (4.99 mas) is large because of elongated images due to its duplicity that result in poorly determined centroids. The weighted mean of the two parallaxes is 144.68 ± 2.52 mas (6.91 ± 0.12 pc), a factor of 15 improvement in the 92.97 ± 38.04 mas (10.8 ± 5.3 pc) value measured by *Hipparcos*. The system was reported to have photometric distances of 7.6 ± 1.8 pc (for A and BC) in CNS, 7.8 pc in Weis (1991b), and 10.3 pc for A and 12.1 pc for BC in Reid et al. (2004). After deconvolving BC, the latter authors estimate a distance of 10.2 pc. The system is actually closer than all photometric estimates.

On UT 1999 August 22 the BC pair showed a 0.30 mag decrease in brightness. No other night shows such a decrease, so we cannot confirm that this is an eclipsing event but note it for future monitoring. Neither the A component nor any of the reference stars show this anomaly. The standard deviations in variability for both A and BC are artificially high because the reference stars are faint; neither source is obviously variable.

LHS 1610: This star has a trigonometric parallax in YPC of 70.0 ± 13.8 mas (14.3 ± 2.9 pc). The parallax value and its large error both exclude the star from the RECONS sample. LHS 1610 was reported to have photometric distances of 9.6 ± 1.4 pc in CNS and 10.5 ± 1.2 pc in Reid & Cruz (2002). The distance is 9.85 ± 0.20 pc, consistent with the photometric estimates and near the horizon of the RECONS sample.

The star is obviously variable, with a standard deviation of 0.024 mag in the V band during 23 nights of observation. Parceling the data into individual nights shows that the star varies by 0.08 mag, possibly regularly. Continuing observations as part of ASPENS will provide additional epochs of photometry to further investigate the periodicity.

LHS 1723: This star was reported to have photometric distances of 6.1 ± 1.0 pc in CNS, 9.2 pc in Henry et al. (1994), 9 pc in Patterson et al. (1998), and 5.7 ± 0.5 pc in Reid et al. (2002). The distance is 5.32 ± 0.04 pc. The star is obviously variable, with a standard deviation of 0.020 mag in the V band during 27 nights of observation, with a full variability range of 0.09 mag.

G099−049: This star has a trigonometric parallax in YPC of 186.2 ± 10.1 mas (5.4 ± 0.3 pc). The large error excluded the star from the RECONS sample until the present study.

The formal correction from relative to absolute parallax is 4.50 ± 0.82 mas because the reference stars are red. The field is in Orion, so the redness is artificial, thereby causing the reference stars to appear much nearer than they are, with photometric parallaxes of 3−17 mas. The reference stars' trigonometric parallaxes and proper motions are well behaved, being less than 1 mas and 10 mas yr^{-1}, respectively. We have therefore adopted a reasonable "mean" correction to the absolute parallax of 1.50 ± 0.50 mas (assuming a large error) instead of the erroneous formal correction.

The star exhibits a possible perturbation of the photocenter at a level of ~20 mas in the right ascension residuals; further investigation during ASPENS will help confirm or refute the perturbation. The source 6″ to the northwest in late 2005 is a background source and might be affecting the centroids. Our derived proper motion, 0.″313 yr^{-1}, and direction of the proper motion, 98°, are significantly different than given in CNS, 0.″241 yr^{-1} at 108°. Lépine & Shara (2005) reported a proper motion of 0.″314 yr^{-1} at 98°, consistent with our value.

SCR 0630−7643 AB: This system was first reported in Henry et al. (2004) to be a potential nearby binary with an estimated photometric distance of 7.0 ± 1.2 pc, assuming magnitude differences in *VRIJHK* of 0.25 mag. Subasavage et al. (2005a) estimated a distance of 6.9 pc based on photographic plate and 2MASS magnitudes.

The separation of AB is 0.″90 at P.A. = 34°, with no change in P.A. noted during the 2 yr period of the observations. The magnitude differences between A and B are $\Delta V = 0.20 \pm 0.03$, $\Delta R = 0.23 \pm 0.06$, and $\Delta I = 0.21 \pm 0.10$, thereby confirming that the two stars are similar in brightness and color. Frames with seeing better than 1.″2 were removed from the reduction because the images are elongated. The trigonometric parallax reported here corresponds to a distance of 8.76 ± 0.14 pc, farther than previous estimates. The projected separation is 7.9 AU, which implies an orbital period of nearly 50 yr for two stars with masses of 0.10 $M_\odot$ each.

G089−032 AB: This system was reported to be a single star with photometric distances of 5.8 pc by Weis (1986), 6.2 ± 1.0 pc in CNS, and 8.1 pc by Henry et al. (1994). The distance is 8.58 ± 0.07 pc; the distance estimates were generally too low because the system is a close double.

The system was first reported to be a binary with separation 0″.7 and of nearly equal brightness at *K* by Henry et al. (1999). During CTIOPI, the resulting FWHM measurements were typically >1″.5 because the unresolved B component stretches the images. The components are too close together for any clear measurements of magnitude differences in CTIOPI frames, but we can estimate the P.A. of the companion to be ∼300°, with no obvious change in the 6 years of coverage. At the measured distance, the projected separation is 6.0 AU and implies an orbital period of ∼30 yr, assuming masses of 0.13 $M_\odot$ for each component. No perturbation can yet be identified in the right ascension and declination residuals, consistent with the long orbital period.

GJ 300: This star has a trigonometric parallax in YPC of 169.9 ± 15.0 mas (5.9 ± 0.5 pc). The large error excluded the star from the RECONS sample until the present study. Reid et al. (2004) reported a photometric distance of 6.3 pc. We measure a distance of 7.96 ± 0.06 pc, which is inconsistent with the previous trigonometric measurement and indicates that the uncertainty was optimistic. The star is mildly variable, with a standard deviation of 0.016 mag in the *V* band during 31 nights of observation, with a full variability range of 0.06 mag.

G041−014 ABC: This system is a triple system in which A and B form a close spectroscopic binary, and C is more distant. Reid & Gizis (1997) reported a separation of 1 AU for AB, while Delfosse et al. (1999) reported an orbital period of 7.6 days. For component masses of 0.19 and 0.17 $M_\odot$ for A and B (estimated after deconvolving the C component, then using the ratio of the spectroscopic K_1 and K_2 values and assigning masses via the mass-luminosity relation of Henry et al. [1999]), the separation would be only 0.05 AU. Nonetheless, the system is photometrically steady, with a standard deviation of only 0.009 mag in the *V* band during 22 nights of observation, indicating no obvious interaction between the components.

Delfosse et al. (1999) imaged component C at a separation of 0″.62 at P.A. ∼ 90° in 1997. The stars cannot be resolved in CTIOPI frames, so the photometry is for the combined light of all three stars. In fact, no elongation is seen even in frames with images having a FWHM of 1″.0. At the measured distance, the projected separation of AB-C is 4.2 AU, implying an orbital period of 11.5 yr, assuming an additional mass of 0.17 $M_\odot$ for component C. A hint of a perturbation at a level of 10 mas over 6 yr can be seen in the right ascension residuals, but more data are needed to confirm it. This perturbation is consistent with an orbital period that might be much longer than that derived from the projected separation.

The system was reported to have photometric distances of 4.5 ± 0.7 pc in CNS, 4.6 pc in Weis (1991b), and 5.3 pc in Henry et al. (1994), all of whom assumed it to be a single star. The distance is 6.77 ± 0.09 pc; the distance estimates were too low because the system is a close triple.

LHS 2090: This star was reported to have photometric distances of 6.0 ± 1.1 pc by Scholz et al. (2001), 5.2 ± 1.0 by Reid & Cruz (2002), and 5.7 ± 0.9 pc by Henry et al. (2004). The distance is 6.37 ± 0.11 pc, consistent with previous estimates.

LHS 2206: This star was reported to have a photometric distance of 10.2 ± 1.6 pc in CNS. The distance is 9.23 ± 0.20 pc, consistent with the previous estimate and firmly placing the star in the RECONS sample.

LHS 288: This is a well-known nearby star in a very crowded field with a trigonometric parallax in YPC of 222.5 ± 11.3 mas (4.5 ± 0.2 pc). The large error excludes the star from the RECONS sample until the present study. However, the original result by Ianna & Bessell (1986), 221 ± 8 mas (4.5 ± 0.2 pc), has an error small enough to include the star in the RECONS sample. Fortunately, P. Ianna is an author on this paper, as well as the original parallax paper, so he can be credited with the discovery of LHS 288 as a RECONS system, whether the date is 1986 or at time of this paper. Henry et al. (2004) reported the star to have a photometric distance of 6.9 ± 1.7 pc. We measure a distance of 4.79 ± 0.06 pc, consistent with previous measurements.

SCR 1138−7721: This star was first reported in Hambly et al. (2004) to be a potential nearby star with an estimated photometric distance based on plate and 2MASS magnitudes of 8.8 ± 2.7 pc (when both internal and external errors are included). Henry et al. (2004) provided a distance estimate of 9.4 ± 1.7 pc using CCD and 2MASS magnitudes. The distance is 8.18 ± 0.20 pc, consistent with the previous estimates.

LHS 337: This star was reported to have photometric distances of 7.2 ± 1.5 pc in CNS and 9 pc by Patterson et al. (1998). The distance is 6.38 ± 0.08 pc.

WT 460: This star was reported to have a photometric distance of 11 pc by Patterson et al. (1998). The distance is 9.31 ± 0.13 pc, firmly placing the star in the RECONS sample.

The star is corrupted by two sources within 6″ in the northeast quadrant, neither of which is a common proper-motion companion. Astrometric residuals with rms values of 24 mas in right ascension and 32 mas in declination are roughly 3 times typical residuals, but the large number of frames and strong reference-star configuration allow an accurate parallax to be determined. This star will not be followed in ASPENS because of the corrupting background sources.

GJ 1207: This star has a trigonometric parallax in YPC of 104.4 ± 13.6 mas (9.6 ± 1.3 pc). The large error excluded the star from the RECONS sample until the present study. We measure a distance of 8.67 ± 0.11 pc, which is consistent with the previous measurement.

GJ 1207 has the largest photometric standard deviation (0.263 mag in the *V* band during 27 nights of observation) of any star reported here, primarily because of one extreme flare event. On UT 2002 June 17, the star's brightness was normal relative to reference stars in the first frame, then increased by a factor of 4.6 (1.7 mag) by the second frame, and subsequently faded to a factor of 2.5 (1.0 mag) higher than normal by the sixth frame. The entire sequence spanned only 15 minutes.

SCR 1845−6357 AB: This system was first reported in Hambly et al. (2004) to be a very red, potential nearby star with an estimated photometric distance based on plate and 2MASS magnitudes of 3.5 ± 1.2 pc (when both internal and external errors are included). A spectral type of M8.5 V and distance estimate of 4.6 ± 0.8 pc were presented using CCD and 2MASS magnitudes in Henry et al. (2004). Deacon et al. (2005) measured a preliminary trigonometric parallax, 282 ± 23 mas (3.5 ± 0.3 pc), based on eight SuperCOSMOS photographic plates, illustrating that reasonable parallaxes can be derived with only a few archival plates. We measure a parallax of 259.45 ± 1.11 mas (3.85 ± 0.02 pc), consistent with all previous estimates. This distance makes SCR 1845−6357 AB the 24th nearest system to the Sun.

Biller et al. (2006) reported a T dwarf companion separated by 1″17 at a P.A. of 170° in 2005. We find a very low error in the parallax because of intense coverage and a rich, well-balanced set of reference stars. We do not yet see any curvature in the astrometric centroids due to the companion, but the residuals do show a larger scatter than for most stars, possibly due to the pull of the companion. Assuming masses of 0.10 and 0.05 $M_\odot$ and a 4 AU separation, we derive a 21 yr orbital period. The photocentric semimajor axis is predicted to be ~350 mas, corresponding to a perturbation in the photocenter of ~34 mas yr^{-1}, although the rate depends on the true size, shape, and orientation of the orbit on the sky. Continued observations are planned to improve and monitor the position of the photocenter of the system.

LHS 3746: This star was reported to have photometric distances of 10.0 ± 2.7 pc in CNS and 10 pc in Patterson et al. (1998). The distance is 7.45 ± 0.07 pc. The relative photometry shows a long-term trend possibly indicative of a stellar activity cycle.

6.3. *Known RECONS Systems*

GJ 54 AB: This system is a fast-orbiting pair of red dwarfs that Rodgers & Eggen (1974) reported as a "suspected very close binary in the 40 inch reflector. The components are assumed to be of equal magnitude." No separation, P.A., or epoch were given, and the separation must have been near the diffraction limit of the Siding Spring Observatory 40 inch (1.0 m) telescope. Golimowski et al. (2004) provided details of the system, including clear resolution of the pair using the *HST* NICMOS. The system has been followed since 2000 in our continuing *HST* FGS effort to measure accurate masses for low-mass stars (Henry 2004). The *HST* FGS measurements indicate that $\Delta V = 1.04$, and a preliminary orbital analysis yields an orbital period of ~1.1 yr and semimajor axis of 0.9 AU.

As can be seen in Figure 1, the perturbation affects the astrometric residuals in both right ascension and declination (9.1 and 13.6 mas rms, respectively) after solving for proper motion and parallax. For comparison, the "well-behaved" GJ 300 right ascension and declination residuals (3.6 mas rms in each axis) are shown. For GJ 54 AB, beating of the 1.0 yr parallax motion and 1.1 yr orbital motion makes deconvolution of the two motions problematic, and a high parallax error (3.38 mas) results (and is not helped by a faint set of reference stars, which also cause the variability measurement to be artificially high). In fact, this is nearly a worst-case scenario because of the confluence of the two perturbations on the star's straight-line proper-motion path coupled with the small semimajor axis of the photocenter's orbital motion, only 16 mas. The system has trigonometric parallax measurements listed in YPC and HIP of 120.5 ± 10.1 mas (8.30 ± 0.70 pc) and 122.86 ± 7.53 mas (8.14 ± 0.50 pc), respectively. Our data yield a better parallax, but the weighted mean of the three independent parallax measurements, 136.62 ± 2.95 mas (7.32 ± 0.16 pc), still has a relatively high error. The system will be observed in ASPENS to improve the parallax, monitor the motion of the photocenter, and facilitate the derivation of accurate masses.

GJ 1061: This star was reported to have a photometric distance of 4.3 ± 1.1 pc in CNS. Henry et al. (1997) discovered the star to be the 20th nearest stellar system, with a trigonometric parallax of 273.4 ± 5.2 mas (3.66 ± 0.07 pc) from photographic plates. Three other stars of similar nearby pedigree reported in that work turned out to be distant giants, providing classic illustrations of how photometry and spectroscopy can be used to fine-tune astrometry observing lists before spending observing time on stars that have negligible parallax. Here we provide a CCD parallax of 271.92 ± 1.34 (3.68 ± 0.02 pc) for GJ 1061, which has an error 4 times smaller than the previous value and is completely consistent. GJ 1061 remains the 20th nearest system.

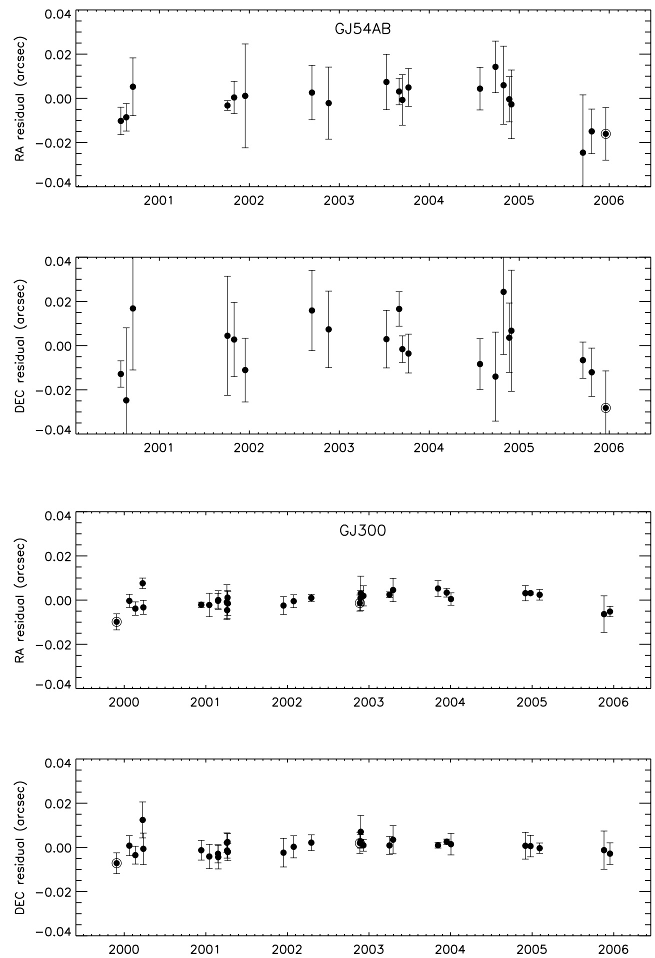

FIG. 1.—Nightly astrometric residuals in right ascension and declination for the binary star system GJ 54 AB in the top two panels after fitting for parallax and proper motion. The 1.1 yr orbital perturbation in the photocenter makes it difficult to fit the 1.0 yr period of the parallactic motion, resulting in relatively high rms residuals of 9.1 and 13.6 mas in right ascension and declination, respectively. Some seasonal trends are seen in the data. The much lower residuals for the presumed single star GJ 300 are shown in the bottom two panels, with rms values of only 3.6 mas in both right ascension and declination. For GJ 300, a $10M_{\rm Jup}$ planet in a face-on circular orbit with a period of 6 yr would cause the photocenter to trace a circle with a semimajor axis of 12 mas, clearly ruled out by the data. The semimajor axis expands to 19 mas for the same object in a 12 yr orbit, which is twice the time coverage of the astrometric series currently available. For both systems, points with circles around them indicate nights on which only one frame was taken, and representative errors have been assigned.

6.4. *Not RECONS Systems*

GJ 1001 ABC: This system is a triple system with separations of 18″2 at P.A. = 259° for A-BC and a changing separation always less than 0″1 for B-C (Golimowski et al. 2004). The initial L dwarf companion was reported by the EROS Collaboration (Goldman et al. 1999) and was resolved by Golimowski et al. (2004) using *HST* NICMOS into two nearly equal magnitude L dwarfs. The BC pair is evident in the parallax frames as a very faint source, but no $\pi_{\rm trig}$ measurement was attempted.

GJ 1001 A has a trigonometric parallax in YPC of 104.7 ± 11.4 mas (9.6 ± 1.1 pc). The distance determined here is 13.01 ± 0.67 pc, clearly pushing the system beyond the horizon of the RECONS sample. So far, the improvement in the parallax error is only a factor of 3 because of a set of faint reference stars and

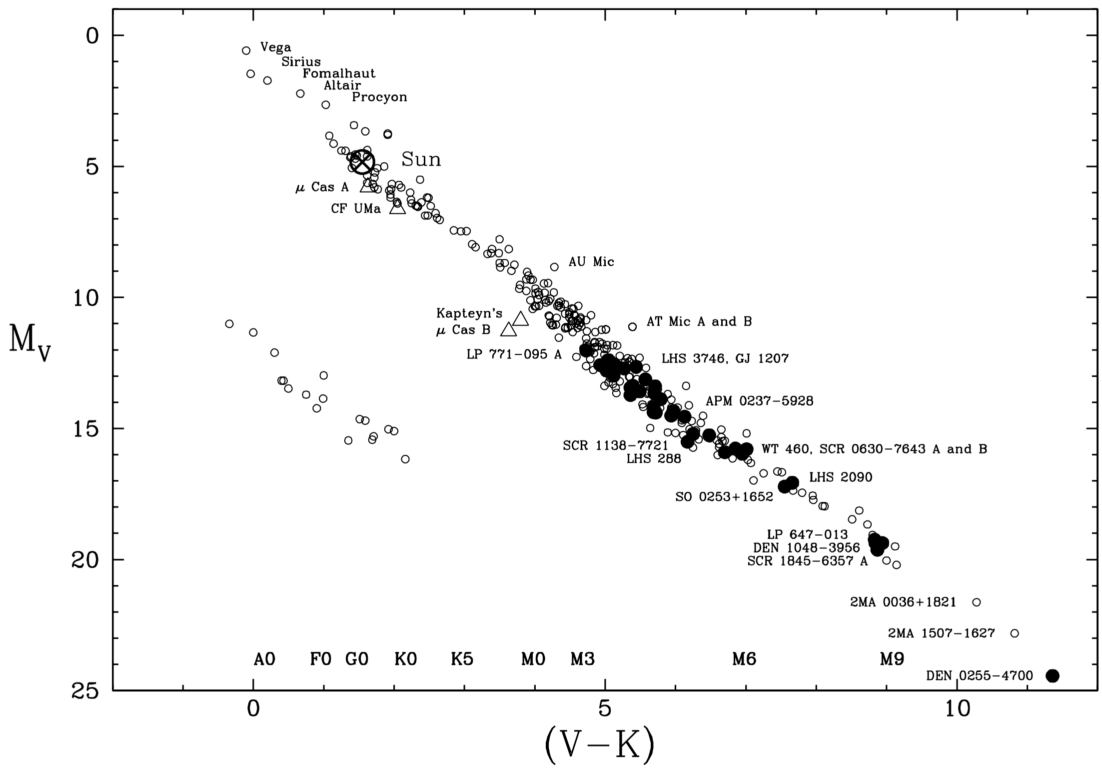

FIG. 2.—RECONS sample of objects in systems with trigonometric parallaxes larger than 100 mas and errors less than 10 mas plotted on an H-R diagram, using M_V vs. $V - K$. Noteworthy stars are labeled, including the four known subdwarfs (*triangles*), the three ~10 Myr old objects AU Mic and AT Mic A and B, and some of the recently discovered members of the 10 pc sample. Open circles represent objects known in 2000 or discovered recently by other groups, and filled circles represent RECONS discoveries. The three L dwarfs redder than $V - K = 10$ have all had distances measured since 2000.

poor observational coverage. The primary will remain a CTIOPI target because an accurate parallax for the system offers the opportunity to determine crucial masses for the brown dwarfs, B and C, which continuing observations show have an orbital period of ~4 yr (D. A. Golimowski et al. 2006, in preparation).

GJ 633: This star has a trigonometric parallax in YPC of 104.0 ± 13.7 mas (9.6 ± 1.3 pc). The distance determined here is 22.48 ± 0.93 pc, well beyond the 10 pc limit of the RECONS sample. A photocenter perturbation of ~60 mas is seen in the right ascension residuals, which may be real or could be due to a background star 7″ to the east that corrupts centroid measurements. The distance derived using the suite of relations in Henry et al. (2004) is 19.7 ± 3.0 pc, which is consistent with the trigonometric distance. The target will remain on the program to determine the veracity of the perturbation and the existence of a possible companion that would contribute minimal light to the system.

GJ 2130 ABC: This system is a triple system with a separation of 21.″23 at P.A. = 88° for A-BC (Jao et al. [2003] incorrectly noted as AC and B). BC is reported to be a double-lined spectroscopic binary by Delfosse et al. (1999). The duplicity of BC is not evident in frames with images having a FWHM of 1.″0.

Gliese & Jahreiss (1979) provided distance estimates of 14.5 pc for A and 19.1 pc for B (C was not known at the time). Reid et al. (2004) provided distances of 13.5 pc for A and 6.2 pc for BC (adopted from HIP). The distance estimates for the presumed single star, A, are good matches to our consistent measurements of parallaxes for A and BC, corresponding to 14.00 ± 0.52 and 14.24 ± 0.42 pc, respectively. The weighted mean of the two parallaxes for the system is 70.69 ± 1.62 mas (14.15 ± 0.32 pc), which is a factor of 14 improvement in the value measured by *Hipparcos*, 161.77 ± 11.29 mas (6.2 ± 0.4 pc), and a factor of 5 improvement in the value of 68.5 ± 7.9 mas (14.6 ± 1.7 pc) found by Fabricius & Makarov (2000), who used *Hipparcos* transit data to improve the result.

7. DISCUSSION

7.1. *The Solar Neighborhood Population*

After the publication of the YPC in 1995 and the *Hipparcos* results in 1997, there were 215 systems in the RECONS sample. Between the time of those publications and the first parallax results from CTIOPI (2005), only eight new systems had reliable trigonometric parallaxes measured that placed them within 10 pc (see Table 1), and the nearest, GJ 1061, was by our group (Henry et al. 1997). CTIOPI has already reported eight additional new 10 pc systems meeting the RECONS criteria: five in Jao et al. (2005), two in Costa et al. (2005), and one in Costa et al. (2006). In this paper we add an additional 20 systems to the sample of stars within 10 pc with high-quality parallaxes. Counting the additions in this paper, since the publication of the YPC and HIP results the total number of new RECONS systems stands at 36. The 34 systems added since 2000 constitute a 16% increase in the number of systems within 10 pc in 6 years.

Figure 2 shows an H-R diagram of the RECONS sample, plotting M_V versus $V - K$ for all systems with parallaxes meeting the RECONS criteria (see § 6.1). All multiples have been deconvolved into individual components as well as can currently be done at both the V and K bandpasses. Open circles indicate objects known to be within 10 pc after publication of the YPC and HIP catalogs, as well as new discoveries by other groups. Filled circles represent RECONS discoveries.

Labels are given for prominent or unusual stars. Triangles mark the four known subdwarfs within 10 pc. AU Mic and AT Mic AB

(GJ 803 and GJ 799 AB, respectively) form a wide triple system that is apparently quite young. The system appears to be comoving with the β Pic group and has an age of only $\sim$20 Myr. The position of all three stars above the main sequence supports the hypothesis that the system is young and the stars have not yet descended onto the main sequence. Further support came recently, when AU Mic was found to be the nearest (9.9 pc) star with a dust disk directly observed at optical and near-infrared wavelengths (Kalas et al. 2004). The three known L dwarfs within 10 pc (2MASS 0036+1821, 2MASS 1507−1627, and DENIS 0255−4700) are shown, but none of the eight known T dwarfs or five extrasolar planets are plotted.

All of the systems reported in this paper are mid- to late-type M dwarfs (spectral types listed in Table 2). The three brightest new stars are labeled (LP 771−095 A, LHS 3746, and GJ 1207), as well as many of the fainter discoveries from the RECONS group and others. Note in particular the M_V of 24.4 for DENIS 0255−4700, for which a parallax and photometry were determined during our CTIOPI 1.5 m program (Costa et al. 2006). We believe that this is the faintest object outside the solar system for which M_V has been determined.

The dominance of the nearby stellar population by red dwarfs is obvious from Figure 2. For objects in the refereed literature, including this paper, the complete count of current objects meeting the RECONS criteria is 18 white dwarfs, 4 A types, 6 F, 21 G, 44 K, 239 M, 3 L, 8 T, and 5 extrasolar planet candidates. Counts include the Sun and the adoption of a dividing line between spectral types K and M at $M_V = 9.00$. Thus, of the 348 total objects, the 239 M dwarfs comprise 69% of the nearby population. Elimination of the presumably nonstellar L, T, and extrasolar planet portions brings the fraction to 72% of all stars, and this fraction will continue to grow as more nearby red dwarfs are revealed.

7.2. *Hidden Multiples*

To confirm or reveal unresolved multiple systems, we make a comparison between the accurate trigonometric distances presented here and in previous CTIOPI papers and the photometric distances estimated via the suite of M_K-color relations described in Henry et al. (2004). This technique provides distance estimates good to 15%, measured by running RECONS stars with accurate trigonometric parallaxes back through the suite of relations under the assumption that the stars are single. Photometric distance estimates for the systems discussed in detail in this paper are given in column (14) of Table 2, and the numbers of relations used for each target (maximum of 12) are given in column (15).

Figure 3 compares the photometric distances with trigonometric distances for objects within 20 pc, as reported by CTIOPI in the four papers with parallaxes to date. The distance cutoff of 20 pc has been selected because that is the distance limit of our 20-20-20 sample (within 20 pc, orbital periods less than 20 yr, at least one component with a mass less than 20% of the Sun's; for details, see Henry et al. [1999]), which includes red dwarf binaries observed to measure high-quality masses. Presumed single main-sequence stars are shown as open circles, and known close multiples with combined photometry are shown as filled squares.

The solid line represents identical photometric and trigonometric distances. Dotted lines trace distances differing by 20%; stars above the outlined region are often subdwarfs; stars below are often unresolved multiples because they are predicted photometrically to be closer than they actually are. In two cases, SCR 1845−6357 AB and LP 771−095 BC, the multiples are within the 20% region, as is expected because of the relatively large magnitude differences between the components. Additional close multiples in which secondaries contribute minimal light to the system would not be revealed with this method. From left to right in Figure 3 (increasing trigonometric distance), the known close multiples recovered below the 20% region are G041−014 ABC, GJ 54 AB, GJ 2005 ABC, G089−032 AB, SCR 0630−7643 AB, and GJ 2130 BC. The three best candidates for previously unnoticed multiples are shown as thick open squares; from left to right, GJ 555, ER 2, and LTT 6933. GJ 555 is a marginal case, while the latter two are almost certainly close multiples with small flux ratios.

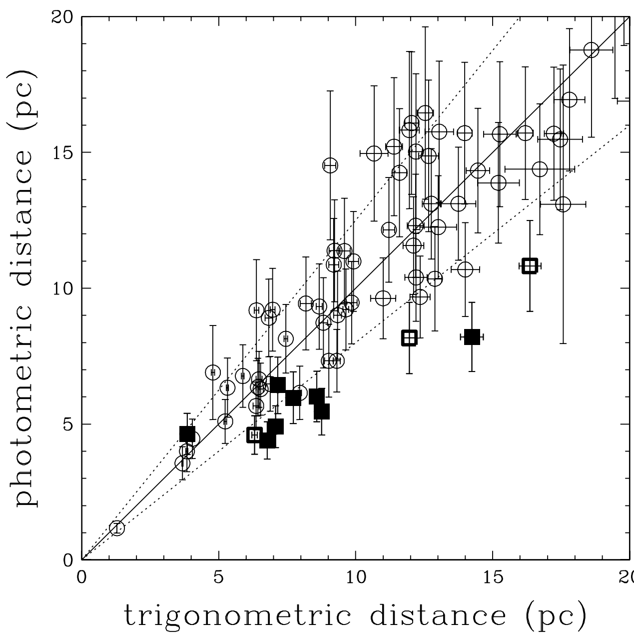

FIG. 3.—Comparison of photometric distances and trigonometric distances for objects within 20 pc with parallaxes published in the four CTIOPI papers reporting parallaxes to date. Open circles represent presumed single main-sequence stars. Filled squares represent known multiple stars with combined photometry. Three possible unnoticed doubles are shown with open squares; from left to right, GJ 555, ER 2, and LTT 6933, all from Jao et al. (2005), and LTT 6933 confirmed in Costa et al. (2005). The solid line represents equal photometric and trigonometric distances, and the dotted lines trace the region with distances differing by more than 20%.

7.3. *The Big Picture*

To date, we have observed more than 400 stars for parallax during CTIOPI. This paper is the fifth in our series that provides accurate parallaxes for nearby stellar systems—one from P. Ianna's plate-parallax effort at Siding Spring Observatory and four from the ongoing CCD effort at CTIO. With the 20 new systems described here, we have now reported high-quality parallaxes for a total of 29 new RECONS systems. We anticipate that future papers will yield additional nearby systems because the pool of stars nearer than 10 pc without accurate parallaxes is by no means drained.

We emphasize that the stellar companions discussed here are not at CTIOPI's detection threshold; the ASPENS program will search for substellar and possibly planetary-mass companions. Red and white dwarf systems within 10 pc and south of $\delta = 0^\circ$, including all but one (WT 460) of the new RECONS members discussed here, are being observed intensely to reveal any possible long-term astrometric perturbations. Initial results imply that we can detect companions with masses as low as 10 $M_{\rm Jup}$ for stars with good observational coverage and strong reference star sets.

Each new system found within 10 pc is a member of the fundamental sample of objects that is used to (1) determine accurate luminosity and mass functions in the solar neighborhood, (2) evaluate the multiplicity of stellar populations, and (3) calculate the total amount of mass found in stars and substellar objects. Because of their proximity, each system is a promising target for detailed astrophysical studies such as astroseismology, variability investigations, direct radii measurements, and metal abundance evaluations. Aside from astrophysical efforts, these systems have great astrobiological potential because of their proximity. They are prime targets to be scrutinized as possible planetary hosts, and any planets found can be explored as nearby harbors of life.

We would like to thank the Georgia State University (GSU) students who have assisted in many facets of the RECONS effort to discover nearby stars, including Jacob Bean, Misty Brown, Charlie Finch, Stephanie Ramos, and Jennifer Winters. We also gratefully acknowledge assistance in the early stages of the CTIOPI effort from Claudio Anguita, Rafael Pujals, Maria Teresa Ruiz, and Pat Seitzer. Nigel Hambly has been vital to our SuperCOSMOS search, which revealed the three SCR stars here for which we report parallaxes. We also thank Hartmut Jahreiss, a referee without peer for this paper, for his review.

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