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THE SOLAR NEIGHBORHOOD. IV. DISCOVERY OF THE TWENTIETH NEAREST STAR SYSTEM

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ABSTRACT

As part of a RECONS (Research Consortium on Nearby Stars) effort to discover stars nearer than 10 pc, LHS 1565 (GJ 1061; V=13.03; M5.5 V) has been found to be only 3.7 pc from the Sun using a combination of photometric, spectroscopic, and trigonometric parallax work. It ranks as the twentieth closest stellar system and underscores the incompleteness of the nearby star sample, particularly for objects near the end of the main sequence. Ironically, this unassuming red dwarf provides a shocking reminder of how much we have yet to learn about even our nearest stellar neighbors. © *1997 American Astronomical Society.* [S0004-6256(97)01107-2]

1. INTRODUCTION

The nearest stars provide astronomers with much of our understanding of stellar astronomy and hold a special fascination for the general public. Astronomers study the Sun's neighbors because they are the nearest, and therefore brightest, examples of their types. For many kinds of stars, the fundamental framework of stellar astronomy is built upon direct measurements of luminosities, colors, temperatures, and masses for nearby stars. As a population, we can determine the nature of the Galaxy's components via stellar luminosity and mass functions and studies of stellar multiplicity. The more complete our reconnaissance of the solar neighborhood — defined here to be a volume of space 10 pc in radius — the better we will understand the nature of the stars that make up the Galaxy, and our Sun's place among them.

The public has a keen interest in the nearest stars because they constitute the first step beyond our own solar system. Several of the stars in the 10 pc sample are visible to the naked eye and are quite familiar — the most famous include α Centauri, Sirius, Procyon, Vega, Altair, and Fomalhaut. The literary and film media of the past several decades have popularized others, such as τ Ceti and ϵ Eridani, as outposts of future human colonization, or even as realms of other civilizations.

Yet, in many ways the population of stars even this close to the Sun is not well understood. A formal census of stars within 10 pc reveals that a large portion of the population is made up of small, faint, red dwarfs. These M dwarfs dominate the solar neighborhood, accounting for at least 70% of all stars, and comprise nearly half of the Galaxy's total stellar mass. However, the M dwarfs are inherently faint, only 10^{-4} to 10^{-2} the luminosity of the Sun, and many lurk unrecognized in the solar neighborhood due to their low luminosity.

As shown in Fig. 1, the sample of stars known to be within 10 pc of the Sun is woefully incomplete. The list of nearby stars (closing date 1997.0) used to develop Fig. 1 is taken from the Yale Catalog of Stellar Parallaxes (van Altena *et al.* 1995) and supplemented with information from the Third Catalog of Nearby Stars (CNS3, Jahreiss 1997). Stellar systems are included only if they have trigonometric parallaxes determined to be $\geqslant 0\farcs1000$. A recent nearby addition since the closure date of the catalogs, LP 944-20 ($\pi_{\rm trig}$=0.2014±0.0042, Tinney 1996), is also included. Each of the 229 known systems, whether made up of one or several stars, is represented by a single point to prevent overem-

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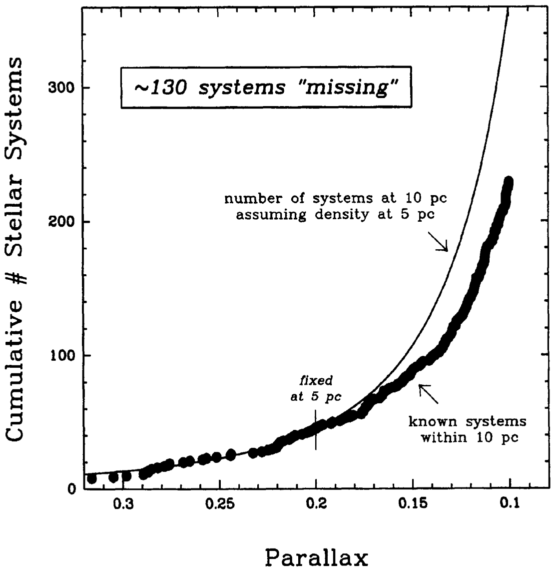

FIG. 1. The cumulative number of stellar systems known within 10 pc is shown with points. Assuming the density of stars within 5 pc carries to 10 pc, 130 systems are anticipated to be missing from present catalogs.

phasizing multiple systems in the distance distribution.

Assuming the density of stellar systems within 5 pc carries to 10 pc, we estimate that 130 systems are missing from the census. Although it is possible that stellar density drops dramatically just past 5 pc, it is far more likely that the subsamples of faint M dwarfs and white dwarfs are underrepresented. This is supported by the fact that the density of more luminous G and K dwarfs with $M_V \leq 7$ does not drop within the CNS3 distance limit of 25 pc (Jahreiss 1994). Moreover, even the sample of early type M dwarfs (types M1 to M3) with $M_V = 10$ to 11 does not show evidence of incompleteness until 12 pc. The dearth of M dwarfs is particularly evident in the southern sky where few follow-up observations of candidates have been done.

In order to focus effort on nearby star research, we have formed a team known as the Research Consortium on Nearby Stars, or RECONS. The purpose of RECONS is to understand the nature of the Sun's nearest stellar neighbors, both individually and as a population. Our goals for the primary sample — all stars within 10 pc — are (1) to improve the completeness of the stellar census and (2) to characterize (photometry, spectroscopy, multiplicity) all stars in the sample. New members are found via follow-up observations of proper motion candidates and targets selected using color-magnitude relations. Companions are revealed using both high-resolution and wide field imaging searches. Characterization includes photometry and spectroscopy at both optical and infrared wavelengths for individual members, as well as determinations of the luminosity function, mass function, and multiplicity fraction for the entire sample. Three papers in *The Solar Neighborhood* series, all part of the RECONS effort, have already been published in this journal, and are listed in Table 1 for reference. In this, the fourth paper in the series, we describe the observing programs used to reveal new nearby stars and discuss the discovery of the twentieth nearest star system, LHS 1565 (GJ 1061).

2. TARGET SELECTION AND OBSERVING PROGRAMS

New nearby stars are added to the 10 pc sample using a combination of optical and infrared photometry, red spectroscopy, and trigonometric parallax work. In order to identify and confirm nearby stars, the RECONS program uses a three stage process outlined below to advance stars from *potential* nearby stars to *probable* ones, and finally, to *proven* new members of the solar neighborhood. In the following sections, we discuss how targets are selected and outline the observing programs underway in the RECONS effort.

2.1 Target Selection — Potential Nearby Stars

Potential nearby stars are selected based upon preliminary photometric or spectroscopic distance estimates and/or high proper motion. The distance estimates are typically made using optical photometry in the *BVRI* bandpasses, often from the extensive work of Eggen (1987, and references therein) and Weis (1996, and references therein). Spectroscopic surveys such as those done by Stephenson & Sanduleak (1975) and Stephenson (1986) sometimes reveal a few potential nearby candidates, although spectroscopic distance estimates are typically not as accurate as those determined by photometric methods.

Generally, nearby stars exhibit relatively large proper motions, so motions are used when distance estimates are not possible. Targets with high proper motions, ($\geq 1''.0$/yr) are selected from the proper motion surveys of Luyten (The NLTT Catalog, 1979, 1980) and Giclas *et al.* (1971, 1978), as well as the more recent southern programs of Wroblewski & Torres (1995, and references therein) and Ruiz & Takamiya (1995, and references therein). The NLTT Catalog alone includes nearly 60,000 stars with proper motions exceeding $0''.18$/yr, 528 of which have motions of $1''.0$/yr or more. The recent work of Wroblewski and Torres includes more than a thousand additional proper motion stars south of $-40°$ with motions of at least $0''.15$/yr, supplementing the sample of potential nearby stars in the southern hemisphere.

TABLE 1. Previous papers in *The Solar Neighborhood* series.

	Authors	Reference	Subject
TSN1	Henry, Kirkpatrick, & Simons 1994	AJ, 108, 1437	standard spectral types
TSN2	Kirkpatrick, Henry, & Simons 1995	AJ, 109, 797	ultra-cool dwarfs
TSN3	Simons, Henry, & Kirkpatrick 1996	AJ, 112, 2238	wide binaries

TABLE 2. Previously cataloged information for the four target stars.

Name	RA (1950) DEC	Sp Type	V	$(B-V)$	$(V-R)$	$(V-I)$	π_{phot}
LHS 1565 (GJ 1061)	03 34 16−44 40 18	M4.5[a]	13.03[b]	1.90[b]	1.99[b]	3.59[b]	0″.233±0″.057
CD −52°6295 (GJ 2110)	14 43 20−53 08 18	dM1[c]	10.86[d]	1.84[d]			0″.461±0″.211
Stephenson 1440	17 06 45+11 31 18	dM6[e]	11.5 [f]				0″.317±0″.059
GJ 2129	17 17 17−47 59 48	dM2[c]	11.87[d]	1.88[d]			0″.340±0″.170

[a] Bidelman (1985); no luminosity class given.
[b] Rodgers & Eggen (1974).
[c] Stephenson & Sanduleak (1975).
[d] Turon *et al.* (1992).
[e] Stephenson (1986).
[f] Weis (1991); variable.

2.2 Photometric and Spectroscopic Programs — Probable Nearby Stars

The first step in advancing stars from potential to *probable* nearby status is to acquire optical (*VRI*) *and* infrared (*JHK*) photometry. The *VRI* data are taken from the literature, often from Weis' extensive program (Weis 1996), or are supplemented with data obtained during the parallax program of the University of Virginia (UVa) at Siding Spring Observatories (SSO). The parallax program uses the SSO 1 m with a front-illuminated EEV 2K×1K CCD at a scale of 0″.58/pixel with a Bessell *VRI* filter set. Aperture photometry is carried out on the bias subtracted, flatfielded CCD frames with FIGARO and local least-squares routines that find extinction and transformation coefficients from 20–30 standard stars observed during a night when photometry is planned.

Few of the potential nearby stars have near-infrared photometry, so we have initiated programs in both hemispheres to obtain *JHK* photometry. Northern targets are observed at the Steward Observatory 2.3 m telescope on Kitt Peak, using the 2D Infrared Speckle Camera designed and operated by Don McCarthy. The camera is equipped with a NICMOS 256^2 array and photometric observations are made using the 0″.10/pixel or 0″.20/pixel scales. In the southern hemisphere, we use CIRIM at the CTIO 1.5 m telescope. This camera also contains a NICMOS 256^2 array and is used with a plate scale of 0″.64/pixel. Typically, a target star is rastered around the array to several locations and multiple frames are recorded at each. Integration times range from 0.5 to 5.0 seconds. Frames are dark subtracted, flatfielded, and sky subtracted within IRAF, and the results calibrated using standard stars observed throughout each night at various airmasses. Resulting photometry is on the CIT system. Sometimes, multiples with separations as small as 1″ can be seen during the photometric observations, and distance estimates must be adjusted depending on the brightness ratio of the components. Of course, there may still be unresolved multiples that are included in the probable category, and if the flux contribution from the secondary is sufficiently large, the photometric parallax will be incorrect, as ultimately shown by the trigonometric parallax.

Follow-up spectroscopy provides a check by verifying an object's metallicity and luminosity class, i.e., the target is confirmed to be a nearby dwarf, or a subdwarf or reddened giant mimicking the colors of a nearby dwarf. Red spectra are obtained in the region ~5000–9500 Å at a resolution of 6–18 Å, and compared to the standard spectral sequence of Kirkpatrick *et al.* (1991). This system has now been calibrated using seven different telescope/instrument combinations — at the MMT on Mt. Hopkins in Arizona, the 107-inch at McDonald Observatory in Texas, the Palomar 5 m in California, and on the CTIO 1.5 m and 4 m in Chile. Integration times range from less than a second to three hours.

If a potential nearby star has a derived photometric distance within 12 pc and is not eliminated because it is a subdwarf or giant, it is advanced to the probable nearby category. The adopted distance cutoff is 12 pc in order to prevent dropping objects with true distances within 10 pc — the photometric distance estimates will be shown in Sec. *4.2* to have associated errors of 15%–20%.

2.3 Trigonometric Parallax Program — Proven Nearby Stars

Once a star is advanced to the probable category, it is placed on a trigonometric parallax program to determine a definitive distance. Northern targets are included in the UVa parallax program at the Fan Mountain station of McCormick Observatory. The 1 m astrometric reflector there is equipped with a back-illuminated SITe 2K×2K having a scale of 0″.36/pixel. Southern targets are placed on the CCD program at SSO near Coonabarabran, Australia, using the instrumentation described in Sec. *2.2*. Astrometric observations are continued for a minimum of 2.0 years to decouple the parallax and proper motion. The precision of the resulting relative parallax is typically better than two milliseconds of arc for stars with $V=15$ and good reference star configurations. The colors and magnitudes of the reference stars are used to estimate the reduction to absolute parallax. If the parallax is found to be ⩾0″.1000, then a star is formally added to the 10 pc sample and is considered to be a *proven* member.

3. SAMPLE — FOUR TARGET STARS

The four specific target stars discussed here — LHS 1565, CD −52°6295, Stephenson 1440, and GJ 2129 — were selected because they were potentially *very* nearby, within 5 pc, based upon photometric or spectroscopic distance estimates. Table 2 lists the data available before observations by the RECONS program began, including the π_{phot} estimates which have errors of 18%–50%. The SIMBAD database was queried to gather additional information, although very little

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TABLE 3. New data for the four target stars.[a]

Name	J	H	K	Sp Type
LHS 1565	7.50	6.97	6.63	M5.5 V
CD −52°6295	7.38	6.57	6.37	M1 III+[b]
Stephenson 1440	6.41	5.53	5.27	M5 III+[b]
GJ 2129	8.09	7.24	7.01	M1 III+[b]

[a] Photometry on CIT system; errors ±0.02 mag.
[b] Star is a giant or higher luminosity class.

was forthcoming (there were no references for CD −52 °6295 and GJ 2129). A brief history for each of the four stars is given here.

LHS 1565: Rodgers & Eggen (1974) provided the only available photometry, *UBVRI*, for this star (BVRI given in Table 2). Based upon these data, the star entered the supplement (CNS2sup, Gliese & Jahreiss 1979) to the Second Catalog of Nearby Stars (CNS2, Gliese 1969) as GJ 1061. Rodgers and Eggen stated that for LHS 1565, "the parallax could be as large as 0.″2" but assigned a value of 0.″130, which is the value listed in CNS2sup. While compiling CNS3, Jahreiss derived a value of 0.″233 using the $(R-I)$ color. A spectral type of M4.5 was reported by Bidelman (1985) based upon Kuiper's extensive work, although no luminosity class was given.

CD −52°6295: This star became a potential nearby target through the spectroscopic survey of Stephenson & Sanduleak (1975), who listed a spectral type of M1 in their table of dwarf stars. Gliese first derived a coarse distance estimate of 14 pc based upon the spectral type alone, and because no further information was available by 1979, the star was included in the list of "Suspected Nearby Stars" in Table 2 of CNS2sup as GJ 2110. Before the current study only *BV* photometry was obtained, as part of the Hipparcos effort (Hipparcos Input Catalog, Turon *et al.* 1992). Based upon the $(B-V)$ color and V magnitude, a rough distance estimate of 2.2 pc was made by Jahreiss with the understanding that the star's color of $(B-V)=1.84$ is much redder than the $(B-V)=1.30$ cutoff for which such distance estimates are reliable.

Stephenson 1440: Stephenson (1986) described his star number 1440 as "a real rarity" and assigned a type of M6 in his table of dwarf stars. Weis (1991) noted that the star varied from V = 11.47 to 11.93 using 18 observations between 1986 and 1989. Although likely to be a variable giant, the coarse spectral type did not reveal the star's luminosity class, so the possibility remained that it could be a nearby dwarf.

GJ 2129: This star has a similar history to that of CD −52°6295; it was revealed to be a potential nearby star through the spectroscopic survey of Stephenson & Sanduleak (1975), and assigned a type of M2 in their list of dwarf stars. Gliese's distance estimate, based solely upon the spectral type, was 17 pc, and the star was included in CNS2sup as GJ 2129. Jahreiss estimated a distance of 2.9 pc using *BV* photometry from the Hipparcos effort, although again with the caveat that its red color, $(B-V)=1.88$, was beyond the reliable distance estimate cutoff of $(B-V)$ =1.30.

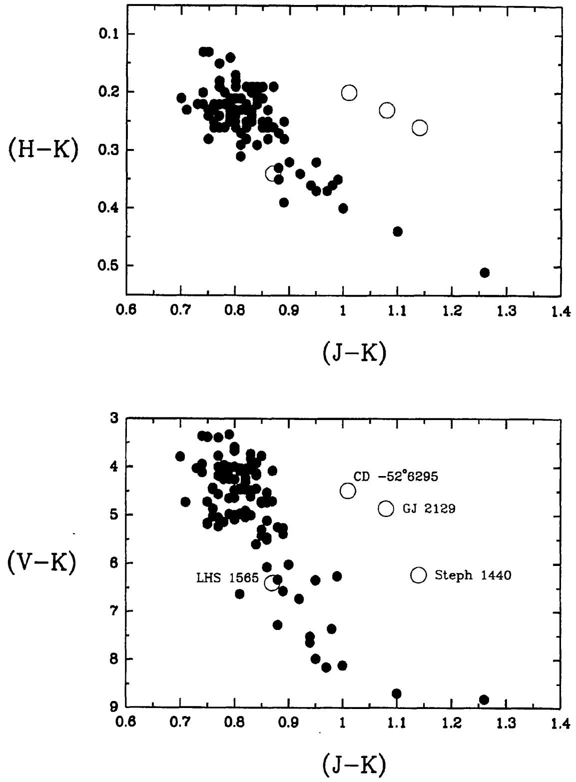

FIG. 2. Color-color diagrams using *VJHK* photometry illustrating that three of the four targets observed (open points) are not dwarfs. Solid points are known red dwarfs within 10 pc. Note the spread of six full magnitudes in $(V-K)$ color in the bottom panel, as compared to only 0.4 mag in $(H-K)$ in the top panel.

4. RESULTS

4.1 Photometry and Spectroscopy

On UT 1995 August 6, *JHK* photometry for the four stars was obtained at the CTIO 1.5 m telescope. For each filter, five integrations of 0.5 seconds were made at nine different locations on the NICMOS array. The integrated fluxes at *JHK* were compared to standard stars from Elias *et al.* (1982) and the fainter UKIRT standards of Casali & Hawarden (1994, suitably adjusted to the CIT system during data reduction using the transformations given in Leggett 1992) taken throughout the night, and through a wide range of airmasses. Bright stars were defocused to prevent saturation on the array, so a rather large 12″ radius photometric aperture was required to include all of a source's signal. GJ 2129 required a 10″ aperture to eliminate a faint source nearby. A 5″ annulus outside the aperture was used to determine the level of sky subtraction required.

JHK photometry on the CIT system is given in Table 3 for the four stars. Errors have been determined to be only 0.02 mag, and include random errors for each set of nine measurements at a given wavelength as well as systematic errors in the extinction corrections. Figure 2 illustrates the colors of the four stars (open circles) and known dwarfs in the 10 pc sample (solid points). The top panel shows that the infrared colors alone allow us to flag three of the four stars as

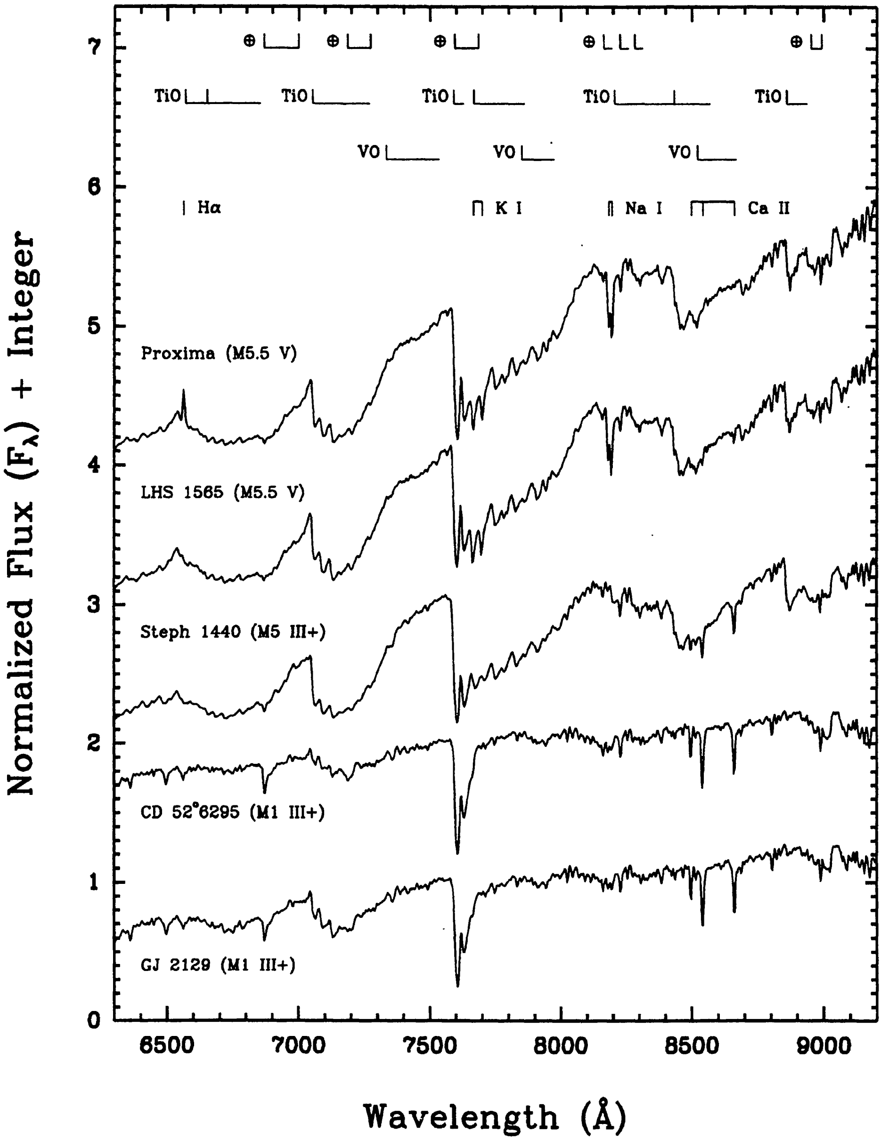

FIG. 3. Spectra of the four program stars and the nearest star, Proxima Centauri. Note the strong K I and Na I features in the dwarfs, and the presence of Ca II in the giants. Resolution is 9 Å. The spectra are normalized to 1.0 at 7500 Å and offset by unit values.

likely non-dwarfs. However, the $(V-K)$ vs $(J-K)$ diagram shown in the bottom panel is an even better separator of the three non-dwarfs. The color spread is six full magnitudes in $(V-K)$ for red stars, whereas it is only 0.4 mag in $(H-K)$. In the latter case, the photometric errors can be significant relative to the color measured, while the additional "leverage" provided by $(V-K)$ is much greater than any error in the color.

Follow-up red spectroscopy a few nights later (UT 1995 August 12 for the four program stars, and UT 1995 August 13 for Proxima Cen) on the CTIO 4 m telescope was accomplished using the R-C Spectrograph + Folded Schmidt +Tek 1K CCD, with grating #510 and order blocking filter GG495 (resulting resolution, 9 Å). The spectra of the four stars and Proxima Cen are illustrated in Fig. 3, and the new spectral types are listed in Table 3. As anticipated, the presence of strong Ca II triplets (8498, 8542, and 8662 Å) and the lack of strong K I doublets (7665 and 7699 Å) or Na I doublets (8183 and 8195 Å) confirm that the three likely non-dwarfs are actually higher luminosity class objects. However, we cannot tell in this spectral region at this resolution whether the stars are giants or supergiants because of the lack of suitable luminosity class diagnostics. Regardless, they are not nearby stars. LHS 1565, on the other hand, proves to be a normal dwarf of spectral type M5.5 V, nearly a twin to Proxima Cen, and is a member of the immediate solar neighborhood.

4.2 Distance Estimate for LHS 1565

To estimate distances to red dwarfs like LHS 1565, various colors have been utilized to produce empirical fits of

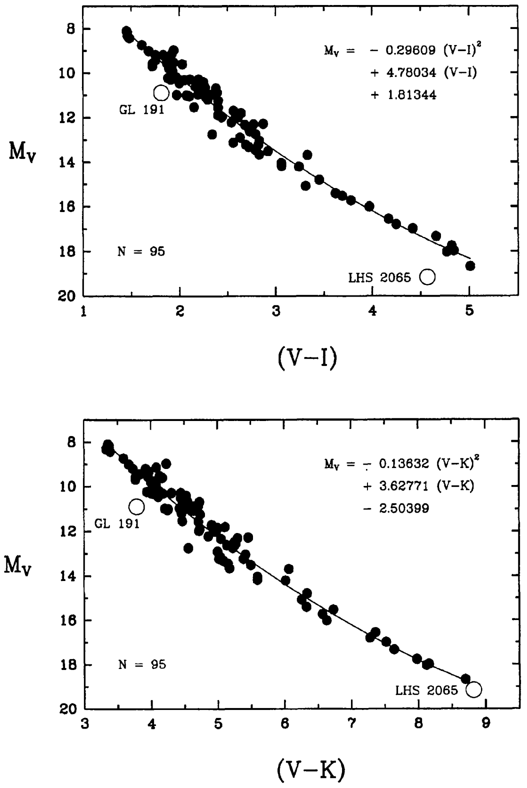

FIG. 4. Top panel: the M_V vs $(V-I)$ diagram. Bottom panel: the M_V vs $(V-K)$ diagram. See text for discussion.

M_V vs color. The V passband has been chosen because it is generally the magnitude most likely to be measured for a target star, particularly in cases of those selected for their high proper motion via photographic plates. The colors explored here include the three optical colors derivable from *VRI* photometry, $(V-R)$, $(V-I)$, and $(R-I)$, and the optical/infrared colors $(V-J)$, $(V-H)$, and $(V-K)$.

Stars used to generate the fits were carefully selected to meet the following criteria: (1) members of the 10 pc sample (thereby having high-quality distance determinations), (2) *VRI* photometry in Weis (1996) or Leggett (1992, R and I band photometry on the Cousins system has been converted to the Kron system of Weis using ~150 stars in common to both studies), (3) *JHK* photometry in Leggett (1992), (4) uncorrupted photometry (no known close companions). Significant effort has gone into satisfying the final criterion. Known close multiples with separations < 4″ have not been used in the fits because accurate individual magnitudes are not available. Some of these stars have been searched for close companions from 0–1 AU with radial velocity techniques (see Henry & McCarthy 1993, and references therein), and many from 1–10 AU using infrared speckle techniques (Henry 1991). For those stars that have been searched, substellar companions cannot always be ruled out, but such companions will not contribute significantly to the visible or infrared flux of the system and will therefore not significantly affect the relation derived.

The two panels of Fig. 4 illustrate the M_V vs $(V-I)$ and M_V vs $(V-K)$ diagrams. $(V-I)$ is shown because it is often used to estimate distances when only optical photometry is available. Ninety-seven stars meet the four criteria listed above, but two were removed because of available spectral information. GL 191 is the only known subdwarf in the sample (Gizis 1997) and was excluded from all fits. In addition, LHS 2065 (spectral type M9 V) was excluded because for the latest-type dwarfs the optical color relations fold back toward blue colors. Weis (1991) has pointed out that dwarfs and giants can only be reliably discriminated for types K4 to M4 using optical photometry alone. For example, his Fig. 1 illustrates that dwarfs and giants are separated only in the restricted range $0.4 \leqslant (R-I) \leqslant 1.3$, whereas late-type dwarfs extend to $(R-I)=2.1$ before the relation turns back toward blue colors. The top panel of Fig. 4 shows that the $(V-I)$ relation is two-valued for M dwarfs redder than $(V-I)=4.5$, corresponding to types later than M6 V, e.g., LHS 2065 (M9 V, $V-I=4.57$) has a similar color to LHS 292 (M6.5 V, $V-I=4.66$). Distance estimates are therefore ambiguous for the reddest dwarfs if only optical photometry is used.

Least-squares solutions yield the third-order polynomial fits shown in Fig. 4. For comparison, one purely optical color, $(V-I)$, and one broader baseline color using both optical and infrared photometry, $(V-K)$, are shown. The curves for the optical colors (*RI* on the Kron system) are described by

$$M_V = -1.78783(V-R)^2 + 11.46118(V-R) - 0.30562 \quad [0.89 \leqslant (V-R) \leqslant 2.72], \tag{1}$$

$$M_V = -0.29609(V-I)^2 + 4.78034(V-I) + 1.81344 \quad [1.45 \leqslant (V-I) \leqslant 5.01], \tag{2}$$

$$M_V = +0.06400(R-I)^2 + 6.44409(R-I) + 4.37624 \quad [0.56 \leqslant (R-I) \leqslant 2.12], \tag{3}$$

where the range over which each fit is valid is given after the equation in square brackets. The red limit assumes that the observer knows the target does not have ''saturated'' colors, such as LHS 2065. For these three relations, the derived distance estimates are accurate to 18.0%, 15.8%, and 17.8%, respectively. These values represent the mean absolute percentage differences found when comparing the estimated distances determined from the equations above to the true distances of the 95 stars used to define the relations. These relations can be used to estimate M_V for red dwarfs with unknown distances, provided they are not subdwarfs, not later than M6 V, and fall in the color ranges given.

Of course, in some cases a target will prove to be a multiple system upon further investigation and the distance estimate will have to be revised. For example, three targets listed in TSN1, Table 2, as possibly being within 10 pc were found to have at least two components during infrared speckle work in 1996 April: LP 476-207 [separation 1.0″ at position angle 165° with ΔK ~ 1 mag], LHS 1885 [2.0″ at 220° with ΔK ~ 2 mag], and G 89-32 [0.7″ at 270° with ΔK ~ 0 mag]. LHS 1885, which was estimated to lie at 9.9 pc when assumed to be a single star, must be beyond 10 pc,

TABLE 4. The 25 nearest star systems.

1997 Rank	Name	CNS Name	# Stars	Distance (pc)	1969 Rank
1	α Cen + Proxima	GL 559 AB + GL 551	3	1.33	1
2	Barnard's Star	GL 699	1	1.83	2
3	Wolf 359	GL 406	1	2.39	3
4	Lalande 21185	GL 411	1	2.53	4
5	Sirius	GL 244 AB	2	2.62	5
6	LHS 9 + 10	GL 65 AB	2	2.68	6
7	Ross 154	GL 729	1	2.90	7
8	Ross 248	GL 905	1	3.16	8
9	ϵ Eridani	GL 144	1	3.28	10
10	Ross 128	GL 447	1	3.35	11
11	LHS 68	GL 866 ABC	3	3.45	9
12	ϵ Indi	GL 845	1	3.46	13
13	61 Cygni	GL 820 AB	2	3.49	12
14	Procyon	GL 280 AB	2	3.49	14
15	BD +59°1915	GL 725 AB	2	3.51	16
16	BD +43°44	GL 15 AB	2	3.55	15
17	CD −36°15693	GL 887	1	3.59	17
18	τ Ceti	GL 71	1	3.62	18
19	LHS 248	GJ 1111	1	3.63	—
20	**LHS 1565**	**GJ 1061**	**1**	**3.66**	**—**
21	LHS 138	GL 54.1	1	3.72	—
22	BD +5°1668	GL 273	1	3.77	19
23	CD −39°14192	GL 825	1	3.86	20
24	Kapteyn's Star	GL 191	1	3.90	21
25	Krüger 60	GL 860 AB	2	3.98	22

as is confirmed by the recent parallax measurement of 0."0874 ± 0."0023 (van Altena *et al.* 1995). Even though the original targets LP 476-207 and G 89-32 are now known to be made up of more than one source (whether the companions are optical or physical), at least the primaries are still probable new members of the 10 pc sample.

Of the 95 stars used in the fits, 82 have parallax errors less than 5%, and the mean parallax error for all 95 is only 3.1%. This value corresponds to only 0.07 mag in absolute magnitude, much larger than the rms in M_V from the resulting fits, 0.43 to 0.51 mag. Systematic errors due to Lutz-Kelker and Malmquist-type biases are insignificant, with a combined effect <0.05 mag (see discussion in Gliese 1982) due to the brightness of the stars used in the relations and the very high quality of the parallaxes (which in the present case are even better than those used in Gliese 1982). Thus, it is clear that these photometric distance relations are limited by real differences in the low mass stars (age, metallicity) rather than by the accuracy of the parallaxes.

In the lower panel of Fig. 4, a similar plot illustrates the dependence of M_V on $(V-K)$. The $(V-K)$ color is as good as the more commonly used $(V-I)$ at estimating distances and separates the subdwarf from the normal dwarfs better. Furthermore, $(V-K)$ can also be used for stars later than M6 V because $(V-K)$ does not saturate for the latest dwarfs. The formal fits for the three optical/infrared colors are

$$M_V=-0.13606(V-J)^2+3.48565(V-J)+0.04399 \quad [2.54\leqslant(V-J)\leqslant7.60], \tag{4}$$

$$M_V=-0.15576(V-H)^2+3.86302(V-H)-2.59771 \quad [3.19\leqslant(V-H)\leqslant8.26], \tag{5}$$

$$M_V=-0.13632(V-K)^2+3.62771(V-K)-2.50399 \quad [3.33\leqslant(V-K)\leqslant8.70]. \tag{6}$$

These three relations yield distances accurate to 16.0%, 18.1%, and 17.5%, respectively.

We derive the following distance estimates for LHS 1565 using the six equations above — $(V-R)$: 3.23 pc, $(V-I)$: 3.75 pc, $(R-I)$: 4.32 pc, $(V-J)$: 3.75 pc, $(V-H)$: 3.87 pc, $(V-K)$: 3.80 pc, yielding a mean photometric distance estimate of 3.79±0.35 pc. Infrared speckle imaging has not revealed any stellar companions to LHS 1565 from 1–10 AU (Leinert *et al.* 1997), so its photometry is unlikely to be affected by a close companion. Given the small estimated distance, the confirmation that it is a normal dwarf, and the evidence that it is likely a single star, efforts are underway to determine the trigonometric parallax.

4.3 Trigonometric Parallax for LHS 1565

A preliminary trigonometric parallax is available from the UVa southern photographic parallax program carried out on the Yale-Columbia 66 cm refractor at Mount Stromlo Observatory. Sixty-three images on unfiltered IIa-O plates at a scale of 18."85/mm are currently available in the time period 1976.7 to 1990.0. The laser-encoded PDS 1010GM microdensitometer in Charlottesville was used to determine an absolute trigonometric parallax of 0."2734 ± 0."0052 using a reference frame of 15 stars (Ianna 1997). The parallax is considered preliminary owing to the small number of images in the solution, many of which are somewhat underexposed. LHS 1565 now has been placed on the Virginia southern CCD program in order to acquire a more precise parallax. Nonetheless, the preliminary trigonometric distance of 3.66

± 0.07 pc is quite consistent with the photometric distance estimated above, 3.79 ± 0.35 pc. This makes LHS 1565 the twentieth nearest star, and less than three times as far away as the α Centauri system.

5. CONCLUSIONS

Listed in Table 4 are the nearest 25 star systems, ranked in order of distance from the Sun based upon parallaxes in the Yale Catalog of Stellar Parallaxes (van Altena *et al.* 1995). The fourth column lists the number of stars in each system, including 36 stars in all, and the final column gives the rank the system had in 1969 (CNS2). Three of the 25 systems were not known to be among the Sun's nearest neighbors a quarter century ago. Additional nearby stars are sure to be revealed in the future, some of which may prove to be as close, or even closer than LHS 1565.

Continuing efforts of the RECONS team include searching for new solar neighbors in the field (a few dozen candidates have already been advanced to the probable category via infrared photometry and red spectroscopy) and searching for companions to stars known to lie within 10 pc. This work will allow us to define more accurately the census and character of the nearby star sample. Ultimately, our goal is to provide *VRIJHK* photometry for all members, and spectral types on a standard system for the subset of red dwarfs with $M_V \geqslant 8.00$. Once this comprehensive database is established, we will be able to determine the luminosity and mass functions for the nearby stars to unprecedented accuracy, and understand where our Sun fits into the realm of the nearest stars.

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