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# THE SOLAR NEIGHBORHOOD. X. NEW NEARBY STARS IN THE SOUTHERN SKY AND ACCURATE PHOTOMETRIC DISTANCE ESTIMATES FOR RED DWARFS

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## ABSTRACT

Photometric ($V_J R_C I_C$) and spectroscopic (6000–9500 Å) observations of high–proper-motion stars discovered during the first phase of the SuperCOSMOS RECONS (SCR) search are used to estimate accurate distances to eight new nearby red dwarfs, including probable 10 pc sample members SCR 1845−6357 (M8.5 V at 4.6 pc), the binary SCR 0630−7643AB (M6.0 V J at 7.0 pc), and SCR 1138−7721 (M5.0 V at 9.4 pc). Distance estimates are determined using a suite of new photometric color-$M_{K_s}$ relations defined using a robust set of nearby stars with accurate *VRIJHK*$_s$ photometry and trigonometric parallaxes. These relations are used with optical and infrared photometry to estimate distances on a uniform system (generally good to 15%) for two additional samples of red nearby star candidates: several recently discovered members of the solar neighborhood and known faint stars with proper motions in excess of 1$''$.0 yr$^{-1}$ south of decl. = $-57^\circ.5$. Of those without accurate trigonometric parallax measurements, there are five stars in the first sample and three in the second that are likely to be within 10 pc. The two nearest are SO 0253+1652 (M7.0 V at 3.7 pc) and DENIS 1048−3956 (M8.5 V at 4.5 pc). When combined with SCR 1845−6357, these three stars together represent the largest increase in the 5 pc sample in several decades. Red spectra are presented for the red dwarfs, and types are given on the RECONS standard spectral system. Red spectra are also given for two new nearby white dwarfs for which we estimate distances from the photometry of less than 20 pc: WD 0141−675 (LHS 145; 9.3 pc) and SCR 2012−5956 (17.4 pc). WD 0141−675 brings the total number of systems nearer than 10 pc discussed in this paper to 12.

*Key words:* solar neighborhood — stars: distances — stars: statistics

## 1. INTRODUCTION

Large plate digitization efforts such as the Digitized Sky Survey and SuperCOSMOS, as well as sky surveys such as the Two Micron All Sky Survey (2MASS) and the Sloan Digital Sky Survey, have led to a renaissance in the search for faint objects lying undiscovered in the solar neighborhood. In particular, the census of the nearest stars (Henry et al. 1997) is gradually being filled in to the end of the stellar main sequence. Many of the new discoveries are the latest M dwarfs (spectral types M6.0 V to M9.5 V), some of which are among the nearest few dozen stellar systems. Each of the recent discoveries has been made via high–proper-motion and/or color surveys, some relying on the classic work of Luyten (Scholz et al. 2001; Reid & Cruz 2002), while others are entirely original efforts (Delfosse et al. 2001; Lepine et al. 2002; Teegarden et al. 2003; Cruz et al. 2003; this work).

Here we report optical photometry and spectroscopy for nine new nearby star candidates from the first phase of the SuperCOSMOS RECONS (SCR) search (Hambly et al. 2004) that have proper motions in excess of 1$''$.0 yr$^{-1}$ or have types of M6.0 V or later. One object in particular, SCR 1845−6357, is remarkable, having $V_J = 17.40$, $R_C = 15.00$, $I_C = 12.47$, and spectral type M8.5 V. We predict that it lies only 4.6 pc from the Sun, making it the third new stellar system found within 5 pc in the last few years. This jump in the 5 pc census from 44 to 47 systems represents a 7% increase. Two of the three new neighbors are found south of decl. = $-30^\circ$, where searches for nearby stars are less complete than in the north.

We also provide a suite of new, robust relations using *VRIJHK*$_s$ photometry to estimate distances for nearby stars. These relations hinge on the $M_{K_s}$ magnitudes of single stars within 10 pc with high-quality parallaxes, supplemented with recent results for very red stars, many of which now have reliable parallaxes placing them within 25 pc (e.g., Dahn et al. 2002). When used as an ensemble, these relations allow photometric distance estimates to be more accurate than ever before, generally good to 15%. We give distance estimates for the new SCR discoveries, several red dwarfs advertised to be nearby, and for the sample of known faint stars with $\mu >$ 1$''$.0 yr$^{-1}$ south of decl. = $-57^\circ.5$. We also provide a detailed check of the technique by applying it to the sample of very red dwarfs with parallaxes.

## 2. SAMPLES

Four samples are included in the current effort. Details are given in Tables 1 and 2. The initial phase of the SCR search provides a large number of new proper-motion stars south of decl. = $-57^\circ.5$ that have $R_2$ = 10.0–16.5 (the value $R_2$ represents the photographic $R_{59F}$ band). Details of the search are given in Hambly et al. (2004). In this paper, we discuss the five SCR stars with $\mu \geq 1''.0$ yr$^{-1}$ and four others with

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TABLE 1

Trigonometric Parallaxes, Photometry, and Spectral Types for SCR Stars, Recently Discovered Nearby Red Dwarfs, and Stars with $\mu \geq 1''.0$ yr$^{-1}$ Recovered in the SCR Search

| Name (1) | LHS (2) | R.A. (J2000.0) (3) | Decl. (J2000.0) (4) | Mean $\pi_{\rm trig}$ (5) | Ref. (6) | $V_{\rm J}$ (7) | $R_{\rm C}$ (8) | $I_{\rm C}$ (9) | Ref. (10) | $J$ (11) | $H$ (12) | $K_s$ (13) | SpT (14) | Ref. (15) | Notes (16) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| New SCR Discoveries | | | | | | | | | | | | | | | |
| SCR 0342−6407 | ... | 03 42 57.4 | −64 07 56 | ... | | 15.99 | 14.62 | 12.92 | 4 | 11.32 | 10.89 | 10.58 | M4.5 V | 4 | a |
| SCR 0420−7005 | ... | 04 20 12.6 | −70 05 59 | ... | | 17.17 | 15.56 | 13.49 | 4 | 11.19 | 10.59 | 10.25 | M6.0 V | 4 | |
| SCR 0630−7643AB | ... | 06 30 46.6 | −76 43 09 | ... | | 14.91 | 13.32 | 11.24 | 4 | 8.89 | 8.28 | 7.92 | M6.0 V J | 4 | b |
| SCR 0702−6102 | ... | 07 02 50.3 | −61 02 48 | ... | | 16.61 | 14.75 | 12.48 | 4 | 10.36 | 9.85 | 9.52 | M6.5 V | 4 | |
| SCR 0723−8015 | ... | 07 23 59.7 | −80 15 18 | ... | | 17.41 | 15.60 | 13.41 | 4 | 11.30 | 10.82 | 10.44 | M6.0 V | 4 | |
| SCR 1138−7721 | ... | 11 38 16.8 | −77 21 49 | ... | | 14.78 | 13.20 | 11.25 | 4 | 9.40 | 8.89 | 8.52 | M5.0 V | 4 | a, c |
| SCR 1845−6357 | ... | 18 45 05.3 | −63 57 48 | ... | | 17.40 | 15.00 | 12.47 | 4 | 9.54 | 8.97 | 8.51 | M8.5 V | 4 | a, d |
| SCR 1848−6855 | ... | 18 48 21.0 | −68 55 34 | ... | | 16.87 | 15.67 | 13.82 | 4 | 11.89 | 11.40 | 11.10 | M5.0 V | 4 | a |
| SCR 2012−5956 | ... | 20 12 31.8 | −59 56 52 | ... | | 15.82 | 15.39 | 15.00 | 4 | 14.93 | 15.23 | 15.41 | DC/DQ | 4 | a, e |
| Recently Discovered Nearby Late-Type M Dwarfs | | | | | | | | | | | | | | | |
| SO 0253+1652 | ... | 02 53 00.9 | +16 52 53 | ... | | 15.20 | 13.30 | 10.96 | 4 | 8.39 | 7.88 | 7.59 | M7.0 V | 4 | f |
| LP 775-31 | ... | 04 35 16.1 | −16 06 57 | ... | | 17.82 | 15.78 | 13.36 | 4 | 10.41 | 9.78 | 9.35 | M7.0 V | 4 | g |
| LP 655-48 | ... | 04 40 23.3 | −05 30 08 | ... | | 17.86 | 15.95 | 13.63 | 4 | 10.66 | 9.99 | 9.55 | M7.0 V | 4 | h |
| LHS 2021 | 2021 | 08 30 32.6 | +09 47 16 | ... | | 19.38 | 17.22 | 14.97 | 4 | 11.89 | 11.17 | 10.76 | M7.5 V | 4 | i |
| LHS 2090 | 2090 | 09 00 23.6 | +21 50 05 | ... | | 16.10 | 14.09 | 11.85 | 4 | 9.44 | 8.84 | 8.44 | M6.0 V | 4 | j |
| DENIS 1048−3956 | ... | 10 48 14.6 | −39 56 07 | ... | | 17.33 | 14.97 | 12.46 | 4 | 9.54 | 8.91 | 8.45 | M8.5 V | 4 | k |
| LHS 325a | 325a | 12 23 56.2 | −27 57 46 | ... | | 18.39 | 16.42 | 14.20 | 4 | 11.98 | 11.40 | 11.07 | M6.0 V | 4 | l |
| LSR 1826+3014 | ... | 18 26 11.0 | +30 14 19 | ... | | 19.36 | 17.40 | 14.35 | 5 | 11.66 | 11.18 | 10.81 | M8.5 V | 5 | m |
| Stars with $\mu \geq 1''.0$ yr$^{-1}$ in Region decl. $=-57^{\circ}.5$ to $-90^{\circ}$ Fainter than $m_R$ = 10 | | | | | | | | | | | | | | | |
| GJ 1022 | 124 | 00 49 29.1 | −61 02 33 | ... | | 12.18 | 11.19 | 9.93 | 4 | 8.63 | 8.09 | 7.84 | M2.5 V | 6 | |
| GJ 45 | 128 | 00 57 19.7 | −62 14 44 | 0.05175 ± 0.00106 | 1, 2 | 9.47 | 8.68 | 7.98 | 7 | 7.08 | 6.49 | 6.28 | K5.0 V | 6 | |
| WD 0141−675 | 145 | 01 43 01.0 | −67 18 30 | ... | | 13.83 | 13.54 | 13.24 | 4 | 12.87 | 12.66 | 12.58 | DA | 4 | n |
| GJ 85 | 150 | 02 07 23.3 | −66 34 12 | 0.06460 ± 0.01780 | 1 | 11.50 | 10.49 | 9.32 | 7 | 8.13 | 7.61 | 7.36 | M1.5 V | 6 | |
| GJ 118 | 160 | 02 52 22.2 | −63 40 48 | 0.08682 ± 0.00188 | 1, 2 | 11.38 | 10.32 | 8.99 | 7 | 7.67 | 7.12 | 6.83 | M2.5 V | 6 | |
| GJ 181.1 | 199 | 04 55 58.0 | −61 09 47 | 0.04440 ± 0.01080 | 1 | 12.05 | 11.14 | 10.15 | 7 | 9.04 | 8.51 | 8.31 | K7.0 V | 6 | |
| GJ 1077 | 205 | 05 17 00.0 | −78 17 20 | 0.07750 ± 0.01100 | 1 | 11.90 | 10.87 | 9.49 | 8 | 8.07 | 7.44 | 7.20 | M2.0 V | 6 | |
| GJ 293 | 34 | 07 53 08.2 | −67 47 32 | 0.14120 ± 0.00840 | 1 | 13.60 | 13.21 | 12.85 | 7 | 12.73 | 12.48 | 12.36 | DQ9 | 9 | o |
| GJ 1123 | 263 | 09 17 05.3 | −77 49 23 | ... | | 13.14 | 11.80 | 10.10 | 4 | 8.33 | 7.77 | 7.45 | M4.5 V | 10 | |
| GJ 345 | 268 | 09 24 21.0 | −80 31 21 | 0.01653 ± 0.00098 | 1, 2 | 10.15 | 9.80 | 9.42 | 7 | 8.89 | 8.53 | 8.46 | F–G | 11 | |
| GJ 1128 | 271 | 09 42 46.4 | −68 53 06 | ... | | 12.72 | 11.35 | 9.61 | 4 | 7.95 | 7.39 | 7.04 | M4.5 V | 10 | |
| LHS 288 | 288 | 10 44 21.2 | −61 12 36 | 0.22250 ± 0.01130 | 1 | 13.90 | 12.31 | 10.27 | 4 | 8.49 | 8.05 | 7.73 | M5.5 V | 4 | p |
| GJ 422 | 40 | 11 16 00.2 | −57 32 52 | 0.07954 ± 0.00267 | 1, 2 | 11.64 | 10.57 | 9.17 | 7 | 7.81 | 7.30 | 7.04 | M3.5 V | 6 | q |
| GJ 440 | 43 | 11 45 42.9 | −64 50 30 | 0.21657 ± 0.00201 | 1, 2 | 11.47 | 11.30 | 11.15 | 4 | 11.19 | 11.13 | 11.10 | DC/DQ | 4 | r |
| GJ 467 A | 328 | 12 28 40.0 | −71 27 52 | 0.02150 ± 0.01910 | 1 | 13.65 | 12.55 | 11.15 | 7 | 9.81 | 9.30 | 9.05 | M3.0 V | 4 | |
| GJ 467 B | 329 | 12 28 43.1 | −71 27 57 | 0.02150 ± 0.01910 | 1 | 15.75 | 14.38 | 12.66 | 7 | 10.98 | 10.50 | 10.18 | M4.5 V | 4 | |
| GJ 551 | 49 | 14 29 43.0 | −62 40 47 | 0.76876 ± 0.00030 | 1, 2, 3 | 11.09 | 9.42 | 7.37 | 4 | 5.36 | 4.84 | 4.38 | M5.5 V | 12 | s |
| LHS 475 | 475 | 19 20 54.3 | −82 33 16 | ... | | 12.68 | 11.50 | 10.00 | 4 | 8.56 | 8.00 | 7.69 | M3.0 V | 6 | |
| GJ 1251 | 493 | 20 28 03.7 | −76 40 16 | ... | | 13.83 | 12.67 | 11.11 | 4 | 9.36 | 8.88 | 8.60 | M4.5 V | 6 | |
| GJ 808 | 499 | 20 51 41.6 | −79 18 40 | 0.06300 ± 0.01170 | 1 | 11.83 | 10.83 | 9.65 | 7 | 8.46 | 7.91 | 7.66 | M1.5 V | 6 | |

TABLE 1—*Continued*

| Name (1) | LHS (2) | R.A. (J2000.0) (3) | Decl. (J2000.0) (4) | Mean $\pi_{\rm trig}$ (5) | Ref. (6) | $V_{\rm J}$ (7) | $R_{\rm C}$ (8) | $I_{\rm C}$ (9) | Ref. (10) | $J$ (11) | $H$ (12) | $K_s$ (13) | SpT (14) | Ref. (15) | Notes (16) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PJH 2115−7541 | ... | 21 15 15.1 | −75 41 52 | ... | | 14.46 | 13.24 | 11.66 | 4 | 10.14 | 9.60 | 9.33 | M3.0 V | 4 | t |
| SSPM J2231−7515 | ... | 22 30 33.6 | −75 15 24 | ... | | 16.90 | 16.19 | 15.56 | 4 | 14.86 | 14.82 | 14.72 | DX14 | 9 | u |
| SSPM J2231−7514 | ... | 22 30 40.0 | −75 13 55 | ... | | 16.59 | 15.95 | 15.36 | 4 | 14.66 | 14.66 | 14.44 | DX12 | 9 | v |
| GJ 877 | 531 | 22 55 45.5 | −75 27 31 | 0.11610 ± 0.00132 | 1, 2 | 10.38 | 9.31 | 7.95 | 7 | 6.62 | 6.08 | 5.81 | M2.5 V | 4 | w |
| GJ 1277 | 532 | 22 56 24.7 | −60 03 49 | ... | | 14.01 | 12.60 | 10.81 | 13 | 8.98 | 8.36 | 8.11 | M5.0 V | 4 | x |

Note.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

[a] Also in Hambly et al. (2004).
[b] Binary with separation 1".0; "J" indicates a joint spectrum.
[c] Found twice in SCR search.
[d] Possibly variable in spectral type.
[e] White dwarf; $K_s$ unreliable.
[f] M6.5 V in Teegarden et al. (2003).
[g] M8.0 V in McCaughrean et al. (2002); M6.0 V in Cruz & Reid (2002); M7.0 V in Cruz et al. (2003).
[h] M7.5 V in McCaughrean et al. (2002); M6.0 V in Cruz & Reid (2002); M7.0 V in Cruz et al. (2003).
[i] Error in $V = 0.4$ mag.
[j] M6.5 V in Scholz et al. (2001).
[k] M9.0 V in Delfosse et al. (2001); M8.0 V in Gizis (2002); possibly variable in spectral type.
[l] M6.0 V in Bessell (1991) (listed as LHS 325 instead of LHS 325a).
[m] Northern target not observed by RECONS from Chile.
[n] White dwarf; DA7 in McCook & Sion (1999).
[o] White dwarf.
[p] Missed in SCR search; $V = 13.92$, $R = 12.33$, and $I = 10.31$ in Bessell (1991); blended in 2MASS.
[q] Missed in SCR search.
[r] White dwarf; missed in SCR search; DQ6 in McCook & Sion (1999).
[s] Proxima; missed in SCR search; $V = 11.05$, $R = 9.43$, and $I = 7.43$ in Bessell (1990).
[t] Also SCR 2115−7541.
[u] Also SCR 2230−7515; white dwarf; $V = 16.87$ in Scholz et al. (2002).
[v] Also SCR 2230−7513; white dwarf; $V = 16.60$ in Scholz et al. (2002).
[w] M2.5 V in Hawley et al. (1996).
[x] M4.5 V in Hawley et al. (1996).

References.—(1) van Altena et al. 1995; (2) ESA 1997; (3) Benedict et al. 1999; (4) this paper; (5) Lepine et al. 2002; (6) Hawley et al. 1996; (7) Bessell 1990; (8) Leggett 1992; (9) McCook & Sion 1999; (10) Henry et al. 2002; (11) Gliese 1969; (12) Henry et al. 1997; (13) Patterson et al. 1998.

TABLE 2

Trigonometric Parallaxes, Photometry, and Spectral Types for the Supplemental Sample of Late-Type M Dwarfs within 25 pc

| Name (1) | LHS (2) | R.A. (J2000.0) (3) | Decl. (J2000.0) (4) | Mean $\pi_{\rm trig}$ (5) | Ref. (6) | $V_{\rm J}$ (7) | $R_{\rm C}$ (8) | $I_{\rm C}$ (9) | Ref. (10) | $J$ (11) | $H$ (12) | $K_s$ (13) | SpT (14) | Ref. (15) | Notes (16) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BRI 0021−0214 | ... | 00 24 24.6 | −01 58 20 | 0.08660 ± 0.00400 | 1 | ... | 17.42 | 15.16 | 4 | 11.99 | 11.08 | 10.54 | M9.0 V | 17 | a |
| RG 0050−2722 | ... | 00 52 54.7 | −27 06 00 | 0.04171 ± 0.00372 | 2, 3 | 21.50 | ... | 16.82 | 3, 9 | 13.61 | 12.98 | 12.54 | M8.0 V | 18 | |
| 2MASS 0149+2956 | ... | 01 49 09.0 | +29 56 12 | 0.04440 ± 0.00070 | 4 | 21.25 | 18.94 | 16.81 | 4 | 13.45 | 12.58 | 11.98 | M9.5 V | 19 | |
| LHS 1375 | 1375 | 02 16 29.9 | +13 35 13 | 0.11770 ± 0.00400 | 2 | 15.79 | ... | ... | 10 | 9.87 | 9.31 | 8.98 | M6.0 V | 17 | b |
| LP 771-21 | ... | 02 48 41.0 | −16 51 22 | 0.06160 ± 0.00543 | 3 | ... | ... | 15.42 | 3 | 12.55 | 11.87 | 11.42 | M8.0 V | 20 | |
| LP 412-31 | ... | 03 20 59.7 | +18 54 23 | 0.06890 ± 0.00060 | 4 | 19.21 | 16.98 | 14.70 | 4 | 11.76 | 11.07 | 10.64 | M8.0 V | 21 | c |
| LP 944-20 | ... | 03 39 35.3 | −35 25 44 | 0.20140 ± 0.00421 | 3 | ... | ... | 14.16 | 3 | 10.73 | 10.02 | 9.55 | M9.0 V | 17 | d |
| LHS 1604 | 1604 | 03 51 00.0 | −00 52 45 | 0.06810 ± 0.00180 | 2 | 18.02 | ... | 13.80 | 11 | 11.30 | 10.61 | 10.23 | M6.0 V | 22 | e |
| LHS 191 | 191 | 04 26 19.9 | +03 36 36 | 0.05840 ± 0.00180 | 2 | 18.51 | 16.24 | 13.96 | 12 | 11.62 | 11.07 | 10.69 | M6.5 V | 23 | |
| ESO 207-61 | ... | 07 07 53.3 | −49 00 50 | 0.05129 ± 0.00226 | 3, 5 | 20.39 | 18.63 | 16.23 | 13 | 13.23 | 12.54 | 12.11 | M9.0 V: | 13 | f |
| GJ 283B | 234 | 07 40 19.4 | −17 24 46 | 0.11240 ± 0.00270 | 2 | 16.54 | 14.68 | 12.43 | 14 | 10.16 | 9.63 | 9.29 | M6.5 V | 17 | g |
| GJ 1111 | 248 | 08 29 49.3 | +26 46 34 | 0.27580 ± 0.00300 | 2 | 14.90 | 12.90 | 10.64 | 14 | 8.24 | 7.62 | 7.26 | M6.5 V | 17 | h |
| LHS 2026 | 2026 | 08 32 30.5 | −01 34 39 | 0.05080 ± 0.00050 | 2 | 18.94 | 16.69 | 14.32 | 12 | 12.04 | 11.48 | 11.14 | M6.0 V | 12 | |
| GJ 316.1 | 2034 | 08 40 29.7 | +18 24 09 | 0.07110 ± 0.00100 | 2 | 17.59 | ... | 13.45 | 15 | 11.05 | 10.42 | 10.05 | M6.0 V | 22 | i |
| LHS 2065 | 2065 | 08 53 36.2 | −03 29 32 | 0.11730 ± 0.00150 | 2 | 18.74 | 16.74 | 14.54 | 12 | 11.21 | 10.47 | 9.94 | M9.0 V | 17 | j |
| LHS 292 | 292 | 10 48 12.6 | −11 20 10 | 0.22030 ± 0.00360 | 2 | 15.73 | 13.67 | 11.33 | 12 | 8.86 | 8.26 | 7.93 | M7.0 V | 17 | k |
| LHS 2314 | 2314 | 10 49 03.4 | +05 02 23 | 0.04110 ± 0.00230 | 2 | 19.11 | ... | 14.91 | 11 | 12.54 | 11.97 | 11.60 | M6.0 V | 22 | |
| GJ 406 | 36 | 10 56 28.9 | +07 00 53 | 0.41910 ± 0.00210 | 2 | 13.53 | 11.67 | 9.50 | 14 | 7.09 | 6.48 | 6.08 | M6.0 V | 17 | l |
| LHS 2351 | 2351 | 11 06 19.0 | +04 28 33 | 0.04810 ± 0.00314 | 3 | 19.56 | 17.25 | 14.91 | 12 | 12.33 | 11.72 | 11.33 | M6.5 V | 12 | |
| LHS 2471 | 2471 | 11 53 52.7 | +06 59 56 | 0.07030 ± 0.00260 | 2 | 18.11 | ... | 13.66 | 12 | 11.26 | 10.66 | 10.26 | M6.0 V | 22 | m |
| BRI 1222−1222 | ... | 12 24 52.2 | −12 38 36 | 0.05860 ± 0.00380 | 3 | ... | ... | 15.74 | 3 | 12.57 | 11.82 | 11.35 | M9.0 V | 21 | |
| LHS 2924 | 2924 | 14 28 43.2 | +33 10 39 | 0.09267 ± 0.00128 | 1, 2 | 19.58 | ... | 15.21 | 15 | 11.99 | 11.23 | 10.74 | M9.0 V | 21 | |
| LHS 2930 | 2930 | 14 30 37.8 | +59 43 25 | 0.10380 ± 0.00130 | 2 | 17.88 | ... | 13.31 | 15 | 10.79 | 10.14 | 9.79 | M6.5 V | 18 | n |
| LHS 3003 | 3003 | 14 56 38.3 | −28 09 49 | 0.15705 ± 0.00259 | 2, 3 | 17.05 | 14.88 | 12.53 | 12 | 9.97 | 9.32 | 8.93 | M7.0 V | 17 | o |
| TVLM 513-46546 | ... | 15 01 08.2 | +22 50 02 | 0.09450 ± 0.00060 | 1, 4 | 19.87 | 17.53 | 15.16 | 4 | 11.87 | 11.18 | 10.71 | M9.0 V | 17 | p |
| TVLM 868-110639 | ... | 15 10 16.8 | −02 41 08 | 0.06120 ± 0.00470 | 1 | ... | ... | 15.79 | 1 | 12.61 | 11.84 | 11.35 | M9.0 V | 21 | |

TABLE 2—*Continued*

| Name (1) | LHS (2) | R.A. (J2000.0) (3) | Decl. (J2000.0) (4) | Mean $\pi_{trig}$ (5) | Ref. (6) | $V_J$ (7) | $R_C$ (8) | $I_C$ (9) | Ref. (10) | $J$ (11) | $H$ (12) | $K_s$ (13) | SpT (14) | Ref. (15) | Notes (16) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GJ 644C | 429 | 16 55 35.3 | −08 23 41 | 0.15497 ± 0.00056 | 2, 6, 7 | 16.78 | 14.60 | 12.18 | 14 | 9.78 | 9.20 | 8.82 | M7.0 V | 17 | q |
| 2MASS 1835+3259 | ... | 18 35 37.9 | +32 59 53 | 0.17650 ± 0.00050 | 8 | 18.27 | ... | 13.46 | 8 | 10.27 | 9.62 | 9.17 | M8.5 V | 8 | |
| GJ 752B | 474 | 19 16 57.6 | +05 09 02 | 0.17079 ± 0.00061 | 1, 2, 3, 6 | 17.50 | 15.10 | 12.84 | 12, 15 | 9.91 | 9.23 | 8.77 | M8.0 V | 17 | r |
| GJ 1245B | 3495 | 19 53 55.2 | +44 24 54 | 0.22020 ± 0.00100 | 2 | 14.01 | 12.36 | 10.27 | 16 | 8.28 | 7.73 | 7.39 | M6.0 V | 23 | s |
| LHS 523 | 523 | 22 28 54.4 | −13 25 19 | 0.08880 ± 0.00490 | 2 | 16.90 | 14.90 | 12.56 | 14 | 10.77 | 10.22 | 9.84 | M6.5 V | 23 | t |

[a] Parallax in van Altena et al. (1995) is superseded by Tinney et al. (1995) value; ≥M9.5 V: in Kirkpatrick et al. (1995); M9.5 V in Kirkpatrick et al. (2000).
[b] M5.5 V in Reid et al. (1995).
[c] M9.0 V in Gizis et al. (2000) and Cruz & Reid (2002); M8.0 V in Cruz et al. (2003).
[d] M9.0 V in Kirkpatrick et al. (2000); M9.5 V in McCaughrean et al. (2002); ≥M9.0 V in Kirkpatrick et al. (1997).
[e] M6.0 V in Cruz & Reid (2002); M7.5 V in Cruz et al. (2003).
[f] Parallax in van Altena et al. (1995) is superseded by Ianna & Fredrick (1995) value; photometry is quoted as being "Kron-Cousins" but filter set likely matches Cousins; spectral type determined by comparison of printed published spectrum to standards by our group.
[g] M6.0 V in Henry et al. (1994); M6.0 V in Reid et al. (1995).
[h] M6.5 V in Kirkpatrick et al. (1991); M6.0 V in Reid et al. (1995).
[i] M6.0 V in Bessell (1991).
[j] M9.0 V in Kirkpatrick et al. (1991).
[k] M6.5 V in Henry et al. (1994).
[l] M6.0 V in Kirkpatrick et al. (1991); M5.5 V in Reid et al. (1995).
[m] M6.5 V in Bessell (1991).
[n] M5.5 V in Reid et al. (1995).
[o] M6.5 V in Bessell (1991); M7.0 V in Kirkpatrick et al. (1995).
[p] M8.5 V in Kirkpatrick et al. (1995).
[q] VB 8; several parallaxes for GJ 644ABD and GJ 643, members of the same system, included; M7.0 V in Kirkpatrick et al. (1991).
[r] VB 10; several parallaxes for GJ 752A included; parallax in van Altena et al. (1995) was recalculated without value superseded by Tinney et al. (1995); M8.0 V in Kirkpatrick et al. (1991).
[s] M5.5 V in Reid et al. (1995).
[t] M6.0 V in Bessell (1991); M6.5 V in Cruz & Reid (2002).

References.—(1) Tinney et al. 1995; (2) van Altena et al. 1995; (3) Tinney 1996; (4) Dahn et al. 2002; (5) Ianna & Fredrick 1995; (6) ESA 1997; (7) Söderhjelm 1999; (8) Reid et al. 2003; (9) Reid & Gilmore 1984; (10) Dahn et al. 1988; (11) Monet et al. 1992; (12) Bessell 1991; (13) Ruiz et al. 1991; (14) Bessell 1990; (15) Leggett 1992; (16) Weis 1996; (17) this paper; (18) Kirkpatrick et al. 1993; (19) Kirkpatrick et al. 1999; (20) Kirkpatrick et al. 1997; (21) Kirkpatrick et al. 1995; (22) Reid et al. 1995; (23) Kirkpatrick et al. 1991.

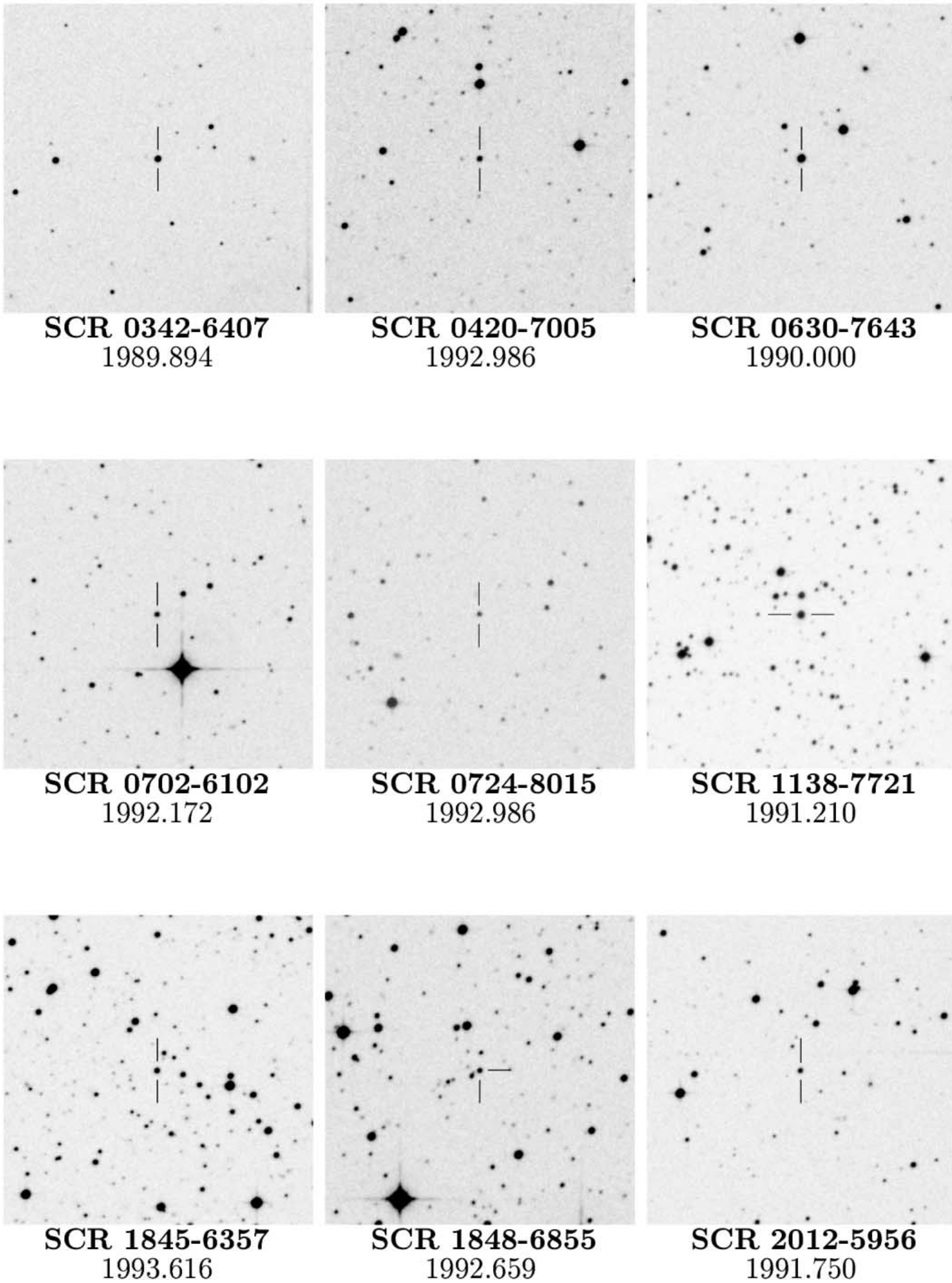


Fig. 1.—Finder charts for the nine SCR stars from the SuperCOSMOS red UK Schmidt images (photographic passband $R_{59F}$). Each chart is 5′ on a side, with north up and east to the left, and the epoch of the image is given.

$\mu = 0\farcs4$–$1\farcs0$ yr$^{-1}$ that have spectral types of M6.0 V or later. Finder charts are given in Figure 1.

The second sample includes eight red dwarfs with spectral types M6.0 V to M8.5 V that have photometric or spectroscopic distance estimates bringing them into the sample of the nearest few hundred stellar systems. Various distance estimates have been made for these stars using many techniques, sometimes yielding highly discordant estimates. Here we provide *VRIJHK*$_s$ photometry and optical spectroscopy so that they can be compared on uniform photometric and spectroscopic systems.

The third sample includes previously known stars with $\mu \geq 1\farcs0$ yr$^{-1}$ south of decl. $= -57\fdg5$, the region investigated in the first phase of the SCR search. The LHS Catalogue (Luyten 1979, hereafter LHS) includes a total of 37 stars meeting these criteria, 22 of which are fainter than $m_R = 10$ by Luyten's estimate. Also meeting these criteria are an additional white dwarf pair found recently by Scholz et al. (2001) and a red dwarf found by Pokorny et al. (2003), bringing the total sample to 25 objects. The SCR search recovered 21 of these; four were missed because of image blending.

The fourth sample includes 31 M dwarfs with spectral types M6.0 V to M9.5 V within 25 pc that are combined with the RECONS sample of stars within 10 pc to develop high-quality color-$M_{K_s}$ relations. We refer to these stars as the ''supplemental sample.''

## 3. OBSERVATIONS

### 3.1. *Photometry*

The primary sources for red dwarf photometry in the $V_J R_C I_C$ system are the comprehensive efforts reported in Bessell (1990, 1991), Leggett (1992), Weis (1996), and Dahn et al. (2002). Once those sources were exhausted, additional references were used as listed in Tables 1 and 2, in particular for the reddest M dwarfs.

Optical photometry for the SCR stars and additional objects listed in Table 1 was obtained in the $V_J R_C I_C$ bands using the Cerro Tololo Inter-American Observatory (CTIO) 0.9 m telescope during several observing runs from 2000 to 2004 as part of the NOAO Surveys Program and the SMARTS (Small and Moderate Aperture Research Telescope System) Consortium. The $2048 \times 2046$ Tektronix CCD camera was used with the Tek 2 *VRI* filter set. Standard stars from Graham (1982), Bessell (1990), and Landolt (1992) were observed through a range of air masses each night to place measured fluxes on the $V_J R_C I_C$ system and to calculate extinction corrections.

Data were reduced using IRAF via typical bias subtraction and dome flat-fielding, using calibration frames taken at the beginning of each night. In general, a circular aperture 14″ in diameter was used to determine stellar fluxes in order to match the aperture used by Landolt (1992) for the standard stars. In cases of crowded fields, an appropriate aperture 6″–12″ in diameter was used to eliminate stray light from close sources and aperture corrections were applied. Program stars were typically observed on multiple nights, yielding a measure of the internal, night-to-night errors of $\pm 0.031$, 0.021, and 0.025 mag at the $V_J$, $R_C$, and $I_C$ bands, respectively, for stars with three or more nights of data (which are usually the faintest targets). From the fits of the standard stars, external errors are estimated to be $\pm 0.017$, 0.015, and 0.020 mag for the $V_J$, $R_C$, and $I_C$ bands, respectively. From these two error estimates, we adopt a total error of $\pm 0.03$ mag in each band. The final magnitudes are given in Table 1.

Infrared photometry in the $JHK_s$ system has been extracted from 2MASS and is also given in Tables 1 and 2. The errors are the *x*_msigcom errors (where *x* is "j," "h," or "k"), which give a measure of the total photometric uncertainty, including global and systematic terms. The errors are almost always less than 0.05 mag and are typically 0.02–0.03 mag. Notable exceptions are the three white dwarfs SCR 2012−5956 (errors of 0.05, 0.11, and null at the $J$, $H$, and $K_s$ bands, respectively; at $K_s > 15.4$, the star is too faint for a reliable measurement of the magnitude and error), SSPM J2231−7515 (0.04, 0.06, and 0.12 mag), and SSPM J2231−7514 (0.04, 0.06, and 0.08 mag).

### 3.2. *Spectroscopy*

There are two large, reliable bodies of spectroscopic work for M dwarfs that use modern CCDs: that of the RECONS group (e.g., Kirkpatrick et al. 1991; Henry et al. 2002) and the Palomar/MSU (PMSU) survey (Reid et al. 1995; Hawley et al. 1996). The PMSU types are based on comparisons with objects observed by the RECONS group but employ a restricted range in wavelength coverage, ~6300–7200 Å (for the CTIO setup, which is the one most relevant for the southern stars discussed here). Spectral types from other authors given in Tables 1 and 2 are often the result of comparison to RECONS spectral types.

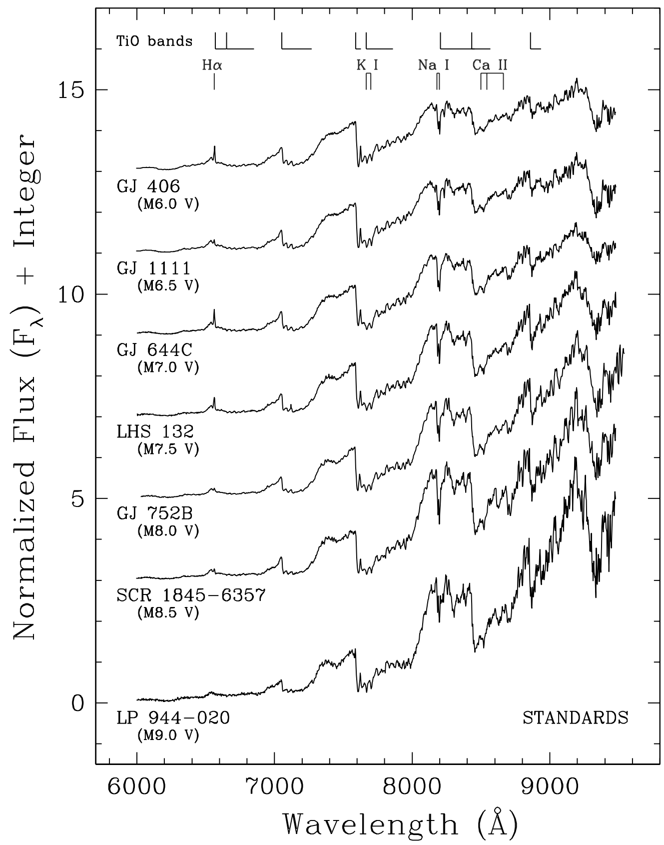


Fig. 2.—Spectra of standard late-type red dwarfs, defining each 0.5 subtype from M6.0 V to M9.0 V. Important spectral features are labeled at the top. The absorption complex at 9300 Å and redward is due in part to $H_2O$ in the Earth's atmosphere.

In one case (Bessell 1991), spectral types are on a different system altogether, but a representative spectral type is better than none.

New spectra were obtained during observing runs in 2003 July, October, and December and 2004 March at the CTIO 1.5 m telescope as part of the SMARTS Consortium. The Ritchey-Chrétien Spectrograph and Loral $1200 \times 800$ CCD detector were used with grating 32, which provided 8.6 Å resolution and wavelength coverage from 6000 to 9500 Å. In a few cases, spectra are included from previous CTIO 4.0 m telescope runs that used the Ritchey-Chrétien Spectrograph and Loral $3K \times 1K$ CCD detector with grating 181, which provided 5.7 Å resolution and wavelength coverage from 5000 to 10000 Å. In all cases, data were reduced using IRAF via typical bias subtraction and dome and/or sky flat-fielding, using calibration frames taken at the beginning of each night. Fringing at red wavelengths in the 4.0 m telescope data was removed by fitting the fringes and subtracting them via a tailored IDL program. Fringing was effectively removed from the 1.5 m telescope data in a more straightforward manner using a combination of dome and sky flats.

Spectral types were assigned using the ALLSTAR program as described in Henry et al. (2002), which currently contains a library of ~500 K5.0 V to M9.0 V spectra. RECONS types in Tables 1 and 2 have been assigned using a new finely tuned set of M6.0 V to M9.0 V standards, illustrated in Figure 2, thereby placing all stars on a uniform system. In a few cases, spectral types have shifted from those previously published by RECONS and others (given in the notes). These updates are

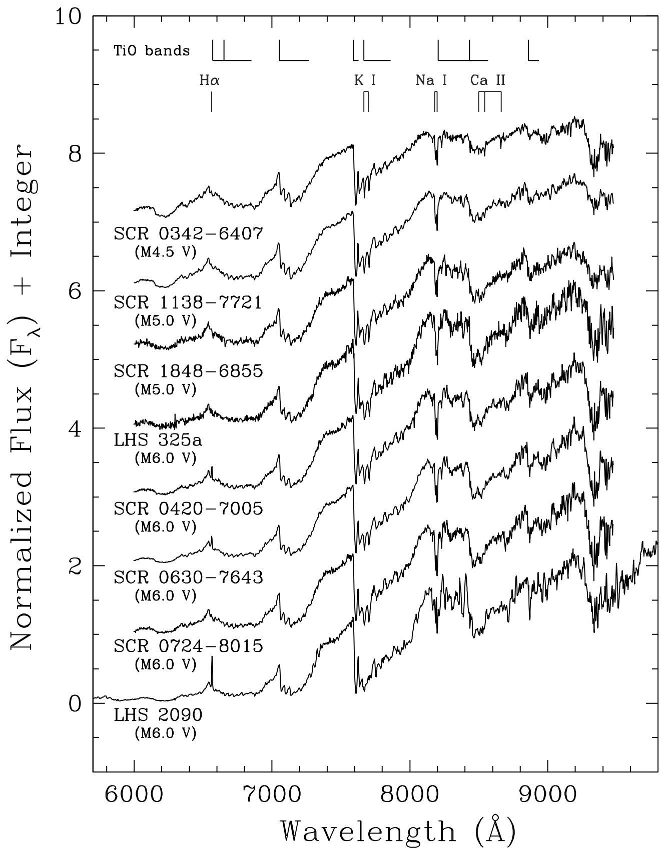


FIG. 3.—Spectra of new SCR discoveries and recently found nearby late-M dwarfs with spectral types from M4.5 V to M6.0 V.

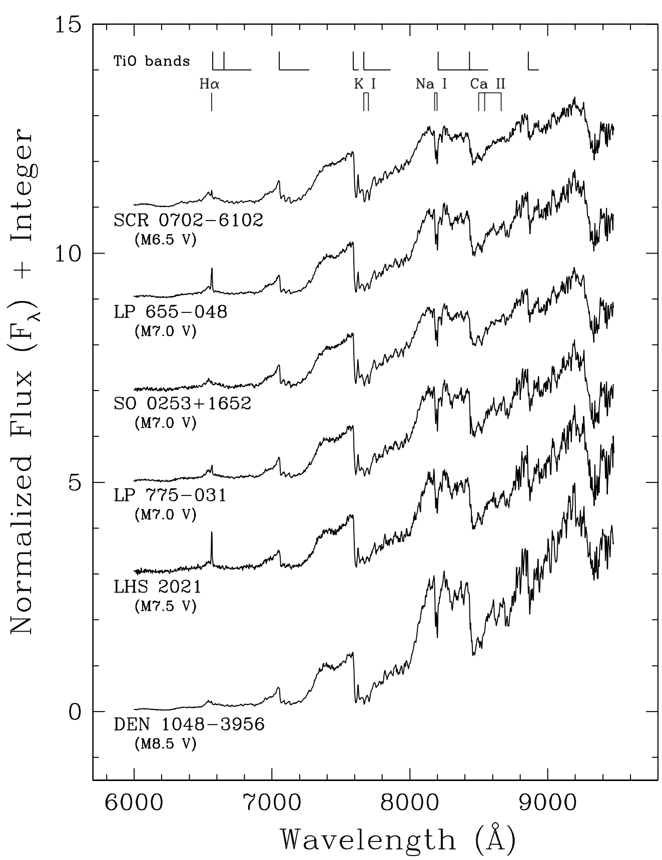


FIG. 4.—Spectra of new SCR discoveries and recently found nearby late-M dwarfs with spectral types from M6.5 V to M8.5 V.

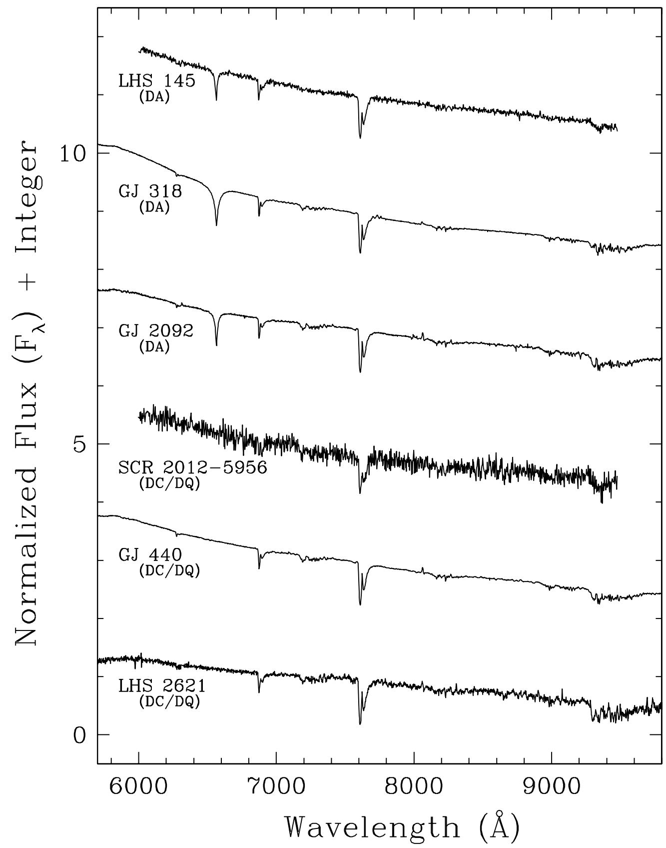


FIG. 5.—Spectra of the nearby white dwarfs LHS 145 (type DA; note the H$\alpha$ feature at 6563 Å) and SCR 2012−5956 (type DC or DQ). Also shown for comparison are spectra for white dwarfs of similar types. The DC/DQ types are virtually featureless in this wavelength region; the "features" seen are all telluric.

warranted, because the new spectra reported generally have higher resolution and broader wavelength coverage than previous spectra and were taken on only two telescopes, thereby reducing instrumental inconsistencies. Spectra of the eight new SCR red dwarfs and seven of the eight new very red solar neighbors are shown in Figures 2–4, ranked from bluest to reddest in each panel.

As predicted by the photometry and the reduced proper-motion diagram, the spectrum of SCR 2012−5956 indicates that it is a white dwarf. For comparison, shown in Figure 5 are its spectrum and the similar spectrum of the white dwarf GJ 440. An additional white dwarf, LHS 2621, also has a similar spectrum, and to our knowledge this is the first report that it is a white dwarf. The lack of any obvious spectral features indicates that the type could be DC or DQ (because no strong carbon features typical of DQ white dwarfs are included in the spectral range shown here; the "features" in all three are telluric). Also shown is the spectrum of WD 0141−675 (LHS 145), a new nearby DA white dwarf for which we have determined a parallax within 10 pc (the subject of a future paper), and spectra for two similar DA white dwarfs (note the defining H$\alpha$ absorption features at 6563 Å in each of the DA white dwarfs).

## 4. ANALYSIS

### 4.1. *Photometric Distances*

To estimate distances to red dwarfs in the three target samples, we take advantage of recent photometry and trigonometric parallax determinations and combine optical *UBVRI* and near-infrared $JHK_s$ photometry to form an extended baseline over which subtle colors are evident and additional color ''leverage'' is available. Using all eight filter bands provides 28 possible color-$M_{K_s}$ relations. The $M_{K_s}$ band has been selected because $K_s$ magnitudes are now available from 2MASS for nearly every red dwarf considered in nearby star studies. These relations can be used in combination to reduce errors in photometric distance estimates caused by photometric outliers in the fits and to overcome photometric errors in one or more filters for the target stars.

The new color-$M_{K_s}$ relations have been developed for red dwarfs with $M_{K_s} \sim 4$–11, corresponding to spectral types K0.0 V to M9.5 V. This broad range encompasses eight of the nine SCR stars, all eight of the recent nearby star candidates, and 19 of the 25 stars in the known high–proper-motion sample (the exceptions are generally white dwarfs). Two samples of stars—stars within 10 pc (the RECONS sample) and the supplemental sample of late-type M dwarfs within 25 pc—have been combined to develop reliable relations. Complete details for the RECONS sample, including all of the photometric values, will be presented in a future 10 pc summary paper in this series. In short, only photometrically single, main-sequence stars within 10 pc are used. Subdwarfs, close multiple systems, and stars with parallax errors greater than 5 mas (i.e., 5% errors at most at 10 pc) have been removed. To bolster the red end of the relations, the RECONS sample has been supplemented with the stars listed in Table 2. These stars are nearer than 25 pc, have $M_{K_s} = 9$–11 (spectral types M6.0 V to M9.5 V), have trigonometric parallaxes with errors less than 10 mas, are not subdwarfs, and are not known to be in close multiple systems. There are few objects of types M7.0 V to M9.5 V missing from this list that have published trigonometric parallaxes larger than 40 mas.

Trigonometric parallaxes have been collected from the two fundamental parallax references, the Yale Parallax Catalog (van Altena et al. 1995) and The Hipparcos Catalogue (ESA 1997). Additional parallaxes have been determined for many objects with spectral types from M6.0 V to M9.5 V during the last decade, primarily through the efforts of Tinney et al. (1995), Tinney (1996), and Dahn et al. (2002). *Hipparcos* parallaxes are available in only a few cases in which bright primary stars could be observed, because all of the stars in Table 2 were too faint for *Hipparcos*. In stellar systems in which the late-type M dwarf is a companion, parallaxes are included for all components in the system, thereby taking advantage of many determinations that may be more accurate than those for the faint component alone. In one case, GJ 644C, Söderhjelm (1999) provides an updated *Hipparcos* parallax for the primary, GJ 644 ABD, which is actually a close triple. When there is more than one parallax determination, the weighted mean of all available parallaxes for the stellar system has been adopted, as listed in column (5) of Tables 1 and 2 and column (2) of Table 4.

Of the 28 possible color-$M_{K_s}$ relations derivable from $UBVRIJHK_s$, only 12 were deemed useful. Currently, there is insufficient reliable $U$ and $B$ photometry for red dwarfs (particularly past M6.0 V), so the 13 relations employing $U$ and $B$ are not used. In addition, the three colors derived from $JHK_s$ alone do not have sufficient baselines to provide reliable distance estimates. Fits to each set of color-$M_{K_s}$ data were made for second through eighth orders. Overall, fifth-order fits proved reliable for all 12 colors used, and higher orders did not improve the fits in any meaningful way.

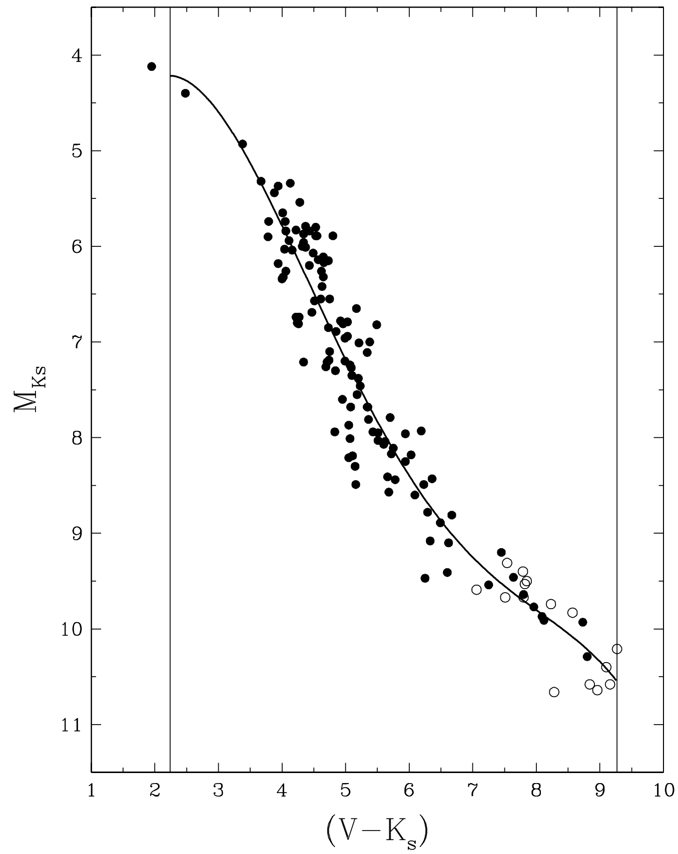


FIG. 6.—Example color-$M_{K_s}$ fit of stars in the RECONS and supplemental samples, illustrating the $V - K_s$ relation. Filled circles represent RECONS stars within 10 pc. Open circles represent stars in the supplemental sample of objects with spectral types of M6.0 V and later. Vertical lines indicate the valid limits of the relation at $V - K_s = 2.24$–9.27.

A sample fit for $M_{K_s}$ versus $(V - K_s)$ is shown in Figure 6. For each of the 12 relations adopted, the applicable color range, the numbers of stars used from the RECONS and very red samples, the fit coefficients, and the rms values of the fits are given in Table 3. Equations for the relations have the following format:

$$M_{K_s} = +0.00959(V - K_s)^4 - 0.23953(V - K_s)^3 + 2.05071(V - K_s)^2 - 5.98231(V - K_s) + 9.77683.$$

Of course, trigonometric parallaxes for additional objects (including many of those investigated here) and photometry would allow the improvement of the photometric relation matrix, in particular for the stars with types later than M7.0 V. We note that Dahn et al. (2002), who include accurate data for many stars of this type, provide an $M_J$ relation for $2.8 < I - J < 4.2$ (spectral types M6.5 V to L8.0 V).

The photometric distance estimates for stars in the four samples are given in Table 4, where the number of color-$M_{K_s}$ relations used to generate each mean distance is listed. To determine the reliability of these distance estimates, we have run the complete sample of 140 stars used to generate the fits back through the relations. (Not all stars have all colors, so 140 exceeds the total number of stars used in each fit, as listed in Table 3.) The resulting average error of the suite of relations technique is 15.3%. The final errors listed for the distance estimates throughout this paper include this 15.3% error (the

TABLE 3
Details for Photometric Distance Relations

| Color | Applicable Range | RECONS Stars | Very Red Stars | Coeff. 1 (× color$^4$) | Coeff. 2 (× color$^3$) | Coeff. 3 (× color$^2$) | Coeff. 4 (× color) | Coeff. 5 (constant) | rms (mag) |
|---|---|---|---|---|---|---|---|---|---|
| $V-R$ | 0.53–2.40 | 117 | 8 | +2.79703 | −17.48617 | +36.67711 | −25.90589 | +9.96960 | 0.40 |
| $V-I$ | 0.88–4.81 | 119 | 15 | +0.02853 | −0.49504 | +2.64479 | −3.51296 | +5.62135 | 0.40 |
| $V-J$ | 2.51–8.00 | 115 | 15 | +0.02447 | −0.52310 | +3.91317 | −10.94674 | +15.31851 | 0.39 |
| $V-H$ | 3.59–8.69 | 100 | 15 | +0.03207 | −0.77797 | +6.74382 | −23.61879 | +34.23360 | 0.42 |
| $V-K$ | 2.24–9.27 | 119 | 15 | +0.00959 | −0.23953 | +2.05071 | −5.98231 | +9.77683 | 0.42 |
| $R-I$ | 0.43–2.42 | 117 | 9 | −1.08390 | +5.68997 | −9.78999 | +9.22596 | +1.54462 | 0.41 |
| $R-J$ | 1.64–5.66 | 114 | 9 | +0.07380 | −1.15011 | +6.26647 | −12.52051 | +13.44932 | 0.41 |
| $R-H$ | 2.68–6.36 | 99 | 9 | +0.10427 | −1.91432 | +12.58352 | −33.56316 | +36.76955 | 0.45 |
| $R-K$ | 1.63–6.97 | 117 | 9 | +0.01785 | −0.37226 | +2.59680 | −5.75029 | +8.19804 | 0.45 |
| $I-J$ | 0.88–3.43 | 116 | 19 | +0.58092 | −4.69507 | +12.35365 | −9.20851 | +6.22309 | 0.45 |
| $I-H$ | 1.67–4.23 | 101 | 19 | +0.14094 | −1.31052 | +3.12906 | +2.68748 | −2.62035 | 0.54 |
| $I-K$ | 1.07–4.83 | 120 | 19 | +0.19771 | −2.44679 | +10.18426 | −14.30638 | +10.38741 | 0.52 |

"external" error from the fits) and the standard deviation of the up to 12 different distance estimates for an individual star (the "internal" error for each star).

For the supplemental sample, which represents the reddest dwarfs focused on in this paper, the differences between the photometric and trigonometric distances shown in Table 4 are remarkably good, with a mean difference of only 9.3%. This is rather better than the 15.3% value obtained when considering the entire range of colors covered by the suite of relations. There are at least two possible causes: either the very red dwarfs are better constrained in $M_{K_s}$ than their earlier type counterparts, or the lack of data for the reddest dwarfs currently provides a poorer measure of the spread in $M_{K_s}$ values. Additional data on the reddest dwarfs (trigonometric parallaxes in particular) should determine which is the true cause.

Illustrated in Figure 7 is a comparison between the two distance determinations for the 31 stars in the supplemental sample. Note that nearly every point is within 1 $\sigma$ of the equal-distance line, indicating the strength of the photometric distance technique. Either the photometry or trigonometric parallax (or both) is suspect for the single clear outlier, ESO 207-61, which has an offset of 37.1% between the estimated and true distances. The remaining 30 stars (97%) have distances estimated to better than 30.6% (2 times the adopted error for the technique for the full ranges of the relations), and 25 stars (81%) have distance estimates better than 15.3%, thereby indicating that the mean difference is a conservative representation of a 1 $\sigma$ "error" for these stars. As mentioned, we have vetted the sample for known close multiple systems, but additional companions may yet be found to some of the stars included.

For the white dwarfs, we have used equation (7) of Salim et al. (2004), which relates $M_V$ and $V-I$ for white dwarfs from Bergeron et al. (2001). A trial run of 11 white dwarfs in the RECONS sample with reliable parallaxes and $V_J R_C I_C$ photometry through that single relation yields an average difference between the photometric and trigonometric distances of 13.2%. However, there is significantly more scatter than for results from the red dwarfs' photometric relation matrix: three of the 11 white dwarf distance estimates are discordant by more than 20%. Because we do not have multiple relations to use to determine an individual error for each white dwarf distance, we conservatively adopt a generic 20% error for each estimate. (Eight of 11, or 73% of the white dwarfs, are within 20%, corresponding roughly to a 1 $\sigma$ "error" for roughly two-thirds of the stars.) We plan to create a white dwarf photometric relation matrix and report the results in a future paper in this series.

## 5. DISCUSSION

Typically, distance estimates are made for the most compelling new nearby star candidates, but comparing one discovery to another is difficult because different methods are used in each publication. The methods used to estimate distances include nearly any permutation involving optical photometry, infrared photometry, optical spectroscopy, and trigonometric parallaxes. Often, only a few reference stars are used to establish the distance to a newly discovered star. In addition, as is evident from the need for 23 different references in Table 2, there is a general lack of homogeneity in basic information for the reddest stars.

Here we remedy some of these problems by estimating distances to stars in all three target samples using the suite of relations in a uniform way that allows accurate distance estimates and, perhaps more importantly, allows the target stars to be compared directly. This effort can overcome some of the differences in photometry and spectroscopy inherent to different observers and their techniques. Distance estimates are given in Table 4. We highlight results for noteworthy stars here.

### 5.1. *Comments on the SCR Discoveries*

**SCR 0342−6407** ($\mu = 1''.071$ yr$^{-1}$ at 141°.4) is the most distant of the five SCR discoveries with $\mu > 1''.0$ yr$^{-1}$ at $38.1 \pm 7.8$ pc and has the earliest spectral type, M4.5 V.

**SCR 0630−7643AB** ($\mu = 0''.483$ yr$^{-1}$ at 356°.8) is a close binary. Images indicate two sources with a constant separation of 1''.0 over 5 months and brightness ratio of 0.8 at $I$. The combined photometry yields a distance estimate of $5.2 \pm 0.9$ pc. Assuming a brightness difference of 0.25 mag at all wavelengths (no color information is currently available), the distance estimate is $7.0 \pm 1.2$ pc. By either estimate, the system is almost certainly a new member of the RECONS sample and a promising target for future mass determinations.

**SCR 1138−7721** ($\mu = 2''.141$ yr$^{-1}$ at 286°.8) is a possible new member of the RECONS sample, falling just within the 10 pc horizon at $9.4 \pm 1.7$ pc.

**SCR 1845−6357** ($\mu = 2''.558$ yr$^{-1}$ at 74°.8) is the third recent discovery of a late-M dwarf that is probably within 5 pc, with a distance estimate of $4.6 \pm 0.8$ pc. At 2''.6 yr$^{-1}$, it has the highest proper motion of the 120 new SCR stars discovered south of decl. $= -57°.5$ that have $\mu \geq 0''.4$ yr$^{-1}$.

TABLE 4
Distance Estimates from New Photometric Parallax Relations

| Name (1) | Mean $\pi_{trig}$ (2) | $M_{K_s}$ (3) | Colors (4) | Est. Dist. (pc) (5) | True Dist. (pc) (6) | % Diff. (7) | Notes (8) |
|---|---|---|---|---|---|---|---|
| **New SCR Discoveries** | | | | | | | |
| SCR 0342−6407 | ... | ... | 12 | 38.08 ± 7.79 | ... | ... | 39.3 ± 11.7 pc in Hambly et al. (2004) |
| SCR 0420−7005 | ... | ... | 12 | 15.41 ± 2.57 | ... | ... | |
| SCR 0630−7643AB | ... | ... | 12 | 6.95 ± 1.21 | ... | ... | Assuming Δmag = 0.25 in all filters |
| SCR 0702−6102 | ... | ... | 12 | 10.84 ± 2.06 | ... | ... | |
| SCR 0724−8015 | ... | ... | 12 | 17.16 ± 3.10 | ... | ... | |
| SCR 1138−7721 | ... | ... | 12 | 9.43 ± 1.68 | ... | ... | 8.8 ± 1.7 pc in Hambly et al. (2004) |
| SCR 1845−6357 | ... | ... | 10 | 4.63 ± 0.75 | ... | ... | 3.5 ± 0.7 pc in Hambly et al. (2004) |
| SCR 1848−6855 | ... | ... | 12 | 37.03 ± 9.43 | ... | ... | 34.8 ± 9.8 pc in Hambly et al. (2004) |
| SCR 2012−5956 | ... | ... | 1 | 17.37 ± 3.47 | ... | ... | White dwarf distance estimate |
| **Recently Discovered Nearby Late-Type M Dwarfs** | | | | | | | |
| SO 0253+1652 | ... | ... | 12 | 3.73 ± 0.59 | ... | ... | [a] |
| LP 775-31 | ... | ... | 12 | 7.33 ± 1.19 | ... | ... | [b] |
| LP 655-48 | ... | ... | 12 | 8.24 ± 1.40 | ... | ... | [c] |
| LHS 2021 | ... | ... | 12 | 13.80 ± 2.34 | ... | ... | |
| LHS 2090 | ... | ... | 12 | 5.67 ± 0.88 | ... | ... | [d] |
| DENIS 1048−3956 | ... | ... | 10 | 4.53 ± 0.73 | ... | ... | [e] |
| LHS 325a | ... | ... | 12 | 20.74 ± 3.43 | ... | ... | |
| LSR 1826+3014 | ... | ... | 10 | 14.48 ± 2.52 | ... | ... | [f] |
| **Stars with $\mu \geq 1''.0$ yr$^{-1}$ in Region decl. $=-57^{\circ}.5$ to $-90^{\circ}$ Fainter than $m_R = 10$** | | | | | | | |
| GJ 1022 | ... | ... | 12 | 20.49 ± 3.35 | ... | ... | [g] |
| GJ 45 | 0.05175 ± 0.00106 | 4.85 | 7 | 19.18 ± 3.11 | 19.32 ± 0.40 | − 0.7 | |
| WD 0141−675 | ... | ... | 1 | 9.27 ± 1.85 | ... | ... | White dwarf distance estimate |
| GJ 85 | 0.06460 ± 0.01780 | 6.42 | 12 | 19.01 ± 3.00 | 15.48 ± 4.62 | +22.8 | Poor parallax |
| GJ 118 | 0.08682 ± 0.00188 | 6.52 | 12 | 11.57 ± 1.80 | 11.52 ± 0.25 | +0.5 | |
| GJ 181.1 | 0.04440 ± 0.01080 | 6.55 | 9 | 36.03 ± 5.65 | 22.52 ± 5.82 | +60.0 | Poor parallax |
| GJ 1077 | 0.07750 ± 0.01100 | 6.65 | 12 | 12.14 ± 2.38 | 12.90 ± 1.87 | − 5.9 | Poor parallax |
| GJ 293 | 0.14120 ± 0.00840 | 13.11 | 1 | 6.82 ± 1.36 | 7.08 ± 0.42 | ... | White dwarf distance estimate |
| GJ 1123 | ... | ... | 12 | 7.47 ± 1.22 | ... | ... | [h] |
| GJ 345 | 0.01653 ± 0.00098 | 4.56 | 0 | ... | 60.50 ± 3.60 | ... | Too blue for relations |
| GJ 1128 | ... | ... | 12 | 6.41 ± 1.01 | ... | ... | [i] |
| LHS 288 | 0.22250 ± 0.01130 | 9.46 | 12 | 6.90 ± 1.74 | 4.49 ± 0.23 | +53.5 | Poor parallax |
| GJ 422 | 0.07954 ± 0.00267 | 6.54 | 12 | 12.12 ± 1.92 | 12.57 ± 0.42 | − 3.6 | |
| GJ 440 | 0.21657 ± 0.00201 | 12.78 | 1 | 4.38 ± 0.88 | 4.62 ± 0.04 | ... | White dwarf distance estimate |
| GJ 467 A | 0.02150 ± 0.01910 | 5.71 | 12 | 30.87 ± 4.98 | 46.51 ± huge | −33.6 | Poor parallax |
| GJ 467 B | 0.02150 ± 0.01910 | 6.84 | 12 | 28.48 ± 4.79 | 46.51 ± huge | −38.8 | Poor parallax |
| GJ 551 | 0.76876 ± 0.00030 | 8.81 | 12 | 1.17 ± 0.19 | 1.30 ± 0.01 | −10.2 | Proxima |
| LHS 475 | ... | ... | 12 | 13.07 ± 2.03 | ... | ... | |
| GJ 1251 | ... | ... | 12 | 16.05 ± 3.40 | ... | ... | |
| GJ 808 | 0.06300 ± 0.01170 | 6.66 | 12 | 21.41 ± 7.43 | 15.87 ± 3.05 | +34.9 | Poor parallax |
| PJH 2115−7541 | ... | ... | 12 | 24.84 ± 3.84 | ... | ... | |
| SSSPM J2231−7515 | ... | ... | 1 | 14.89 ± 2.98 | ... | ... | White dwarf distance estimate |
| SSSPM J2231−7514 | ... | ... | 1 | 14.82 ± 2.96 | ... | ... | White dwarf distance estimate |
| GJ 877 | 0.11610 ± 0.00132 | 6.14 | 12 | 7.10 ± 1.10 | 8.61 ± 0.10 | −17.5 | |
| GJ 1277 | ... | ... | 12 | 8.89 ± 1.42 | ... | ... | |
| **Late-Type M Dwarfs within 25 pc** | | | | | | | |
| BRI 0021−0214 | 0.08660 ± 0.00400 | 10.23 | 7 | 11.31 ± 2.16 | 11.55 ± 0.53 | − 2.1 | |
| RG 0050−2722 | 0.04171 ± 0.00372 | 10.64 | 7 | 28.21 ± 4.63 | 23.98 ± 2.16 | +17.7 | |
| 2MASS 0149+2956 | 0.04440 ± 0.00070 | 10.21 | 12 | 21.59 ± 5.35 | 22.52 ± 0.36 | − 4.2 | |
| LHS 1375 | 0.11770 ± 0.00400 | 9.33 | 3 | 9.16 ± 1.41 | 8.50 ± 0.29 | +7.8 | |
| LP 771-21 | 0.06160 ± 0.00543 | 10.37 | 3 | 18.65 ± 2.94 | 16.23 ± 1.44 | +14.9 | |
| LP 412-31 | 0.06890 ± 0.00060 | 9.83 | 12 | 13.31 ± 2.13 | 14.51 ± 0.13 | − 8.3 | [j] |
| LP 944-20 | 0.20140 ± 0.00421 | 11.07 | 3 | 6.05 ± 1.15 | 4.97 ± 0.10 | +21.9 | |
| LHS 1604 | 0.06810 ± 0.00180 | 9.40 | 7 | 12.51 ± 1.99 | 14.68 ± 0.39 | −14.8 | [k] |
| LHS 191 | 0.05840 ± 0.00180 | 9.53 | 12 | 16.02 ± 2.70 | 17.12 ± 0.53 | − 6.5 | |
| ESO 207-61 | 0.05129 ± 0.00226 | 10.66 | 12 | 26.74 ± 5.01 | 19.50 ± 0.86 | +37.1 | |
| GJ 283B | 0.11240 ± 0.00270 | 9.54 | 12 | 9.13 ± 1.49 | 8.90 ± 0.21 | +2.6 | |
| GJ 1111 | 0.27580 ± 0.00300 | 9.46 | 12 | 3.30 ± 0.51 | 3.63 ± 0.04 | − 9.1 | |

TABLE 4—*Continued*

| Name (1) | Mean $\pi_{trig}$ (2) | $M_{K_s}$ (3) | Colors (4) | Est. Dist. (pc) (5) | True Dist. (pc) (6) | % Diff. (7) | Notes (8) |
|---|---|---|---|---|---|---|---|
| LHS 2026 | 0.05080 ± 0.00050 | 9.67 | 12 | 19.77 ± 3.51 | 19.69 ± 0.19 | +0.5 | |
| GJ 316.1 | 0.07110 ± 0.00100 | 9.31 | 7 | 12.12 ± 1.89 | 14.06 ± 0.20 | −13.9 | |
| LHS 2065 | 0.11730 ± 0.00150 | 10.29 | 12 | 9.10 ± 1.95 | 8.53 ± 0.11 | +6.7 | l |
| LHS 292 | 0.22030 ± 0.00360 | 9.64 | 12 | 4.32 ± 0.68 | 4.54 ± 0.07 | − 4.9 | |
| LHS 2314 | 0.04110 ± 0.00230 | 9.67 | 7 | 25.08 ± 3.89 | 24.33 ± 1.37 | +3.1 | |
| GJ 406 | 0.41910 ± 0.00210 | 9.20 | 12 | 1.99 ± 0.31 | 2.39 ± 0.01 | −16.5 | |
| LHS 2351 | 0.04810 ± 0.00314 | 9.74 | 12 | 19.53 ± 3.05 | 20.79 ± 1.36 | − 6.1 | |
| LHS 2471 | 0.07030 ± 0.00260 | 9.50 | 7 | 12.84 ± 2.04 | 14.22 ± 0.53 | − 9.8 | |
| BRI 1222−1222 | 0.05860 ± 0.00380 | 10.19 | 3 | 16.29 ± 2.50 | 17.06 ± 1.11 | − 4.6 | |
| LHS 2924 | 0.09267 ± 0.00128 | 10.58 | 7 | 12.77 ± 2.23 | 10.79 ± 0.15 | +18.4 | |
| LHS 2930 | 0.10380 ± 0.00130 | 9.87 | 7 | 9.75 ± 1.52 | 9.63 ± 0.12 | +1.2 | |
| LHS 3003 | 0.15705 ± 0.00259 | 9.91 | 12 | 6.53 ± 1.02 | 6.37 ± 0.11 | +2.6 | m |
| TVLM 513-46546 | 0.09450 ± 0.00060 | 10.58 | 12 | 11.85 ± 2.21 | 10.58 ± 0.07 | +12.0 | |
| TVLM 868-110639 | 0.06120 ± 0.00470 | 10.28 | 3 | 16.07 ± 2.47 | 16.34 ± 1.26 | − 1.6 | |
| GJ 644C | 0.15497 ± 0.00056 | 9.77 | 12 | 6.45 ± 1.05 | 6.45 ± 0.02 | +0.0 | |
| 2MASS 1835+3259 | 0.17650 ± 0.00050 | 10.40 | 7 | 5.82 ± 1.01 | 5.67 ± 0.02 | +2.7 | |
| GJ 752B | 0.17079 ± 0.00061 | 9.93 | 12 | 5.50 ± 0.89 | 5.86 ± 0.02 | − 6.1 | |
| GJ 1245B | 0.22020 ± 0.00100 | 9.10 | 12 | 4.69 ± 0.79 | 4.54 ± 0.02 | +3.4 | |
| LHS 523 | 0.08880 ± 0.00490 | 9.59 | 12 | 14.25 ± 4.41 | 11.26 ± 0.62 | +26.5 | n |

[a] 2.4 ± 0.5 pc from astrometry and 3.6 ± 0.4 pc from photometry in Teegarden et al. (2003).
[b] 6.2–6.5 pc in McCaughrean et al. (2002); 7.4 ± 1.5 pc in Reid & Cruz (2002); 11.3 ± 1.3 pc in Cruz & Reid (2002); 8.6 ± 1.0 pc in Cruz et al. (2003).
[c] 7.9–8.2 pc in McCaughrean et al. (2002); 7.7 ± 1.5 pc in Reid & Cruz (2002); 15.3 ± 2.6 pc in Cruz & Reid (2002); 9.8 ± 1.1 pc in Cruz et al. (2003).
[d] 6.0 ± 1.1 pc in Scholz et al. (2001); 5.2 ± 1.0 pc in Reid & Cruz (2002).
[e] 4.1 ± 0.6 pc in Delfosse et al. (2001).
[f] 13.9 ± 3.5 pc in Lepine et al. (2002).
[g] 7.2 and 29.5 pc in Reyle et al. (2002).
[h] 7.6 pc in Henry et al. (2002).
[i] 6.6 pc in Henry et al. (2002).
[j] 11.9 ± 1.9 pc in Cruz & Reid (2002); 13.1 ± 1.1 pc in Cruz et al. (2003).
[k] 10.9 ± 2.2 pc in Reid & Cruz (2002); 14.7 ± 0.4 pc in Cruz & Reid (2002); 11.5 ± 1.1 pc in Cruz et al. (2003).
[l] 8.5 ± 1.7 pc in Reid & Cruz (2002).
[m] 6.3 ± 1.3 pc in Reid & Cruz (2002).
[n] 10.9 ± 0.6 pc in Cruz & Reid (2002).

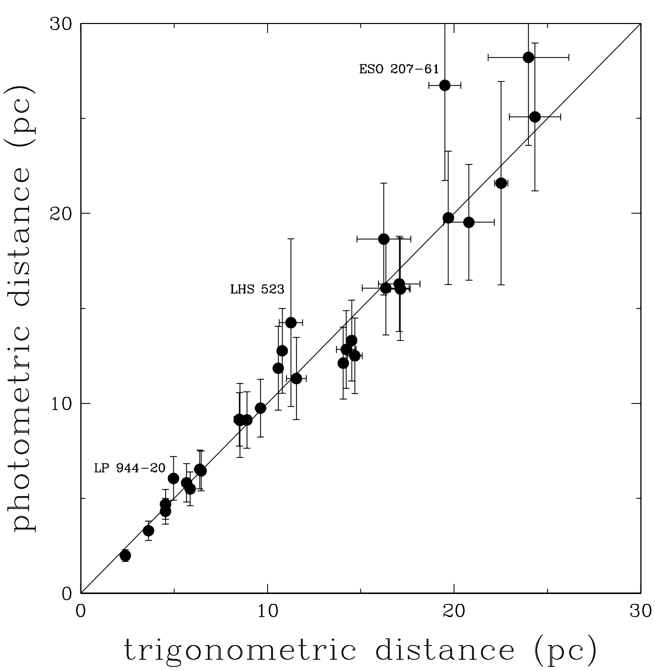


FIG. 7.—Comparison of true trigonometric and derived photometric distances for the 31 late-M dwarfs with accurate trigonometric parallaxes listed in Tables 2 and 4. The three labeled stars are discussed in the text.

**SCR 1848−6855** ($\mu = 1''.287$ yr$^{-1}$ at 194°.4) appears to be a normal M5.0 V star with no obvious subdwarf features. Given its estimated distance of 37.0 ± 9.4 pc and high proper motion, it has a relatively high tangential velocity of 225 km s$^{-1}$.

**SCR 2012−5956** ($\mu = 1''.440$ yr$^{-1}$ at 165°.6) is a new nearby white dwarf with an estimated distance of 17.4 pc, using equation (7) of Salim et al. (2004).

### 5.2. *Comments on the Recently Discovered Nearby Late-M Dwarfs*

**SO 0253+1652** has been claimed to be the third nearest star at a distance of only 2.4 ± 0.5 pc on the basis of a crude trigonometric parallax and 3.6 ± 0.4 pc photometrically using $V = 15.40$, $R = 13.26$, and $I = 10.66$ (Teegarden et al. 2003). Our photometry from three nights gives $V - I = 4.24$ rather than their $V - I = 4.74$, and the relations place it farther away, at 3.7 ± 0.6 pc, than their trigonometric distance. This would rank it as the 22nd-nearest system, rather than as the third nearest system indicated by the poorly determined trigonometric value.

**LP 775-31 and LP 655-48** are M7.0 V "twins" reported by McCaughrean et al. (2002) to be 6.2–6.5 and 7.9–8.2 pc from the Sun, respectively, using a combination of spectroscopy and infrared photometry, although they reported types of M8.0 V and M7.5 V. Reid & Cruz (2002) estimated distances of 7.4 ± 1.5 and 7.7 ± 1.5 pc from infrared photometry. Cruz & Reid (2002) gave types of M6.0 V for both and estimated distances of $11.3 \pm 1.3$ and $15.3 \pm 2.6$ pc. Cruz et al. (2003) revised both types to M7.0 V and estimated distances of $8.6 \pm 1.0$ and $9.8 \pm 1.1$ pc. We confirm that they are probable new members of the RECONS sample and provide distance estimates of $7.3 \pm 1.2$ and $8.2 \pm 1.4$ pc, respectively.

**LHS 2021** is an M7.5 V star that had, to our knowledge, no distance estimate until that given here. At $13.8 \pm 2.3$ pc, it is just beyond the RECONS sample horizon.

**LHS 2090** was reported in Scholz et al. (2001) to have spectral type M6.5 V and was estimated to be $6.0 \pm 1.1$ pc distant on the basis of its 2MASS $JHK_s$ photometry and that of a similar star, GJ 1111. Reid & Cruz (2002) report a distance estimate of $5.2 \pm 1.0$ pc on the basis of an ($M_{K_s}$, $J - K_s$) relation. We derive a distance of $5.7 \pm 0.9$ pc.

**DENIS 1048−3956** was reported in Delfosse et al. (2001) to have spectral type M9.0 V and magnitudes $B = 19.0$ and $R = 15.7$ from Schmidt plates and $I = 12.67$, $J = 9.59$, and $K = 8.58$ from the DENIS survey. Gizis (2002) determined a spectral type of M8.0 V. Delfosse et al.'s comparison to four M dwarfs with type M9.0 V yielded a distance estimate of $4.1 \pm 0.6$ pc. Preliminary trigonometric parallaxes have been reported by Deacon & Hambly (2001; $5.2 \pm 1.0$ pc) and Neuhäuser et al. (2002; $4.6 \pm 0.3$ pc), although the latter used a faint set of reference stars, assumed a proper motion rather than solving for it, and utilized only three frames. Our photometric distance estimate is $4.5 \pm 0.7$ pc.

**LHS 325a** was reported as LHS 325 in Bessell (1991), but it must be in fact LHS 325a, an insertion in the LHS catalog between LHS 325 and 326 because of its right ascension. We have found it to be rather brighter in *VRI* than Bessell (1991), who gives $V = 18.67$, $R = 16.60$, and $I = 14.36$.

**LSR 1826+3014** is an M8.5 V object found by Lepine et al. (2002) and noted to be the faintest ($V = 19.36$) red dwarf discovered to have a proper motion larger than $2'' \text{ yr}^{-1}$. Their distance estimate of $13.9 \pm 3.5$ pc is based on three photometric/spectroscopic estimates. Given the northern declination, we have not observed this object from CTIO. Nonetheless, our distance estimate from published data and 10 relations is $14.5 \pm 2.5$ pc, which is certainly consistent with theirs.

### 5.3. *Comments on Additional Objects*

Among the known high–proper-motion stars, the true distances to GJ 85 (LHS 150), GJ 181.1 (LHS 199), GJ 1077 (LHS 205), LHS 288, GJ 467AB (LHS 328 and 329), and GJ 808 (LHS 499) are poorly known, given that their parallaxes have errors larger than 10 mas. Not surprisingly, all but GJ 1077 have photometric distances differing from the trigonometric distances by more than 20%.

**WD 0141−675** (LHS 145) is a nearby white dwarf with no trigonometric parallax. We estimate a distance of $9.3 \pm 1.9$ pc using equation (7) of Salim et al. (2004). This is a probable new member of the RECONS sample and among the 20 nearest known white dwarfs.

**GJ 1123** (LHS 263) has a photometric distance estimate of $7.5 \pm 1.2$ pc, which matches the spectroscopic estimate of 7.6 pc by Henry et al. (2002). It is a likely new member of the RECONS 10 pc sample.

**GJ 1128** (LHS 271) has a photometric distance estimate of $6.4 \pm 1.0$ pc, which matches the spectroscopic estimate of 6.6 pc by Henry et al. (2002). It is a likely new member of the RECONS 10 pc sample.

**GJ 1277** (LHS 532) is another probable new member of the RECONS sample, at a distance of $8.9 \pm 1.4$ pc.

**LP 944-20** is an important nearby red dwarf (or brown dwarf) at the end of the M spectral sequence. The first parallax was reported by Tinney (1996), placing it at a distance of slightly less than 5 pc and making it the most recent addition to the 5 pc sample other than GJ 1061 (Henry et al. 1997). The 22% difference in the photometric and trigonometric distances occurs because there are only three colors available and all lie near the very limit of each relation.

**ESO 207-61** has the poorest match between the photometric and trigonometric parallaxes, which differ by 37%. Ruiz et al. (1991) indicate that the *VRI* photometry is on the Kron-Cousins system, but the observations were made at the CTIO 0.9 m telescope (where our observations are made) and likely used the same filter set, as well as similar standards. Nonetheless, the photometry may not be on the Cousins system as we have assumed (and reported in Table 2), thereby causing the discordant distances.

**LHS 523** is the final star of the three in the red dwarf supplemental sample having a mismatch between photometric and trigonometric distances greater than 20%, in this case 27%. The 12 distance estimates are the least consistent of all of the stars in the supplemental sample. In particular, distances from colors including the *I* band range from 9.6 to 20.9 pc, indicating a possible problem with the *I* photometry.

## 6. CONCLUSIONS

The 12 new color-$M_{K_s}$ relations given here can be used to estimate distances accurately to stars falling in the color ranges given (generally, K0.0 V to M9.5 V in spectral type) in any combination. As an ensemble, they provide a powerful means to estimate distances to nearby star candidates on a uniform system.

We predict that the three most compelling targets, SO 0253+1652, DENIS 1048−3956, and SCR 1845−6357, all lie within 5 pc. These three late-M dwarfs compose the largest surge in the nearby star population in several decades.

With $\mu = 2''\!.6 \text{ yr}^{-1}$, SCR 1845−6357 ranks as the 41st fastest proper-motion system known, so it is not surprising that it is probably nearer than 5 pc. Of the 22 other red dwarfs discussed here that have no accurate trigonometric parallaxes, we find that 10 are likely to be closer than 10 pc. In addition, the white dwarf WD 0141−675 is also probably nearer than 10 pc, bringing the total number of new 10 pc systems discussed here to 12. This sample is currently being observed in the RECONS Cerro Tololo Inter-American Observatory Parallax Investigation carried out at the CTIO 0.9 m telescope, which should yield parallaxes for these high-priority targets in the near future.

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