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# THE SOLAR NEIGHBORHOOD. I. STANDARD SPECTRAL TYPES (K5–M8) FOR NORTHERN DWARFS WITHIN EIGHT PARSECS[1]

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## ABSTRACT

Spectral types on a standard system are presented for late-type dwarfs within 8 pc. All known main-sequence stars north of $-25°$ and with $M_V \geqslant 8.00$ have been observed, resulting in 92 spectra. Based upon the stellar system density to 5 pc, we estimate that ~35 systems in the 8 pc sample are "missing." In an effort to reveal these systems, we use an empirical spectral type–$M_V$ relation to estimate distances to additional stars that may lie within 8 pc.

## 1. INTRODUCTION

Due to their proximity, the nearby stars provide the only sample that allows us to study intrinsically faint stars in detail. As a result, our understanding of stellar luminosities, temperatures, and masses near the lower end of the main sequence is based almost entirely upon our knowledge of stars in the solar neighborhood. In order to establish basic stellar properties—fluxes, colors, spectral types, multiplicities, and masses—we are engaged in a systematic, multifaceted project to characterize this important stellar population. This paper is the first in a series of papers that will describe these properties for the nearest stars, including a detailed characterization of the targets at red and near-infrared wavelengths (6500 Å–2.2 μm) and a comprehensive study of multiplicity at spatial scales <1 to 1000 AU.

The nearby star sample is perhaps the toughest of all stellar samples to define because its members are typically very faint and scattered over the entire sky. The difficulty in studying any complete, distance-limited subset of the nearest stars is further compounded by the fact that the targets span a large range in brightness. For stars within 8 pc, for example, 19 mag at $V$ separate the brightest, Sirius, from the faintest, VB 10. Despite these difficulties, a compendium of information about the nearest stars has been produced through the painstaking work of researchers in Germany (Gliese 1969; Gliese & Jahreiss 1979, 1991). Even for stars within 8 pc, however, many of the available spectral types stem from antiquated or nonstandard systems, or have only been crudely estimated.

With the advent of high quantum efficiency CCD arrays, it is now possible to examine a large sample of faint stars in a modest amount of telescope time. Using these sensitive detectors, we have been able to concentrate on the most common stars, the red dwarfs, at wavelengths just short of their peak flux at ~1 μm. It is important to study these objects because they make up no less than three-quarters of all stars in the solar neighborhood, and therefore comprise the dominant stellar component of the Galaxy. In an effort to provide a fundamental reference for the nearby stars, and low mass stars in general, we have determined spectral types on a standard system for all northern dwarfs to 8 pc with types K5 or later.

## 2. SAMPLE AND OBSERVATIONS

### *2.1 Sample*

Targets with trigonometric parallaxes greater than or equal to 0.125″ have been chosen from the most recent version of the Catalog of Nearby Stars (Gliese & Jahreiss 1991, hereafter referred to as GJ91). We have further restricted this sample to red dwarfs with $M_V \geqslant 8.00$, corresponding to a spectral type of ~K5, and north of $\delta = -25°$ (spectroscopic observations of southern objects are planned). We have concentrated on the red dwarfs because these are the objects with nonstandard or, in some cases, unknown spectral types.

The resulting sample of 92 targets is listed in order of R.A. in Table 1. Columns (1) and (2) identify the objects by Gliese (GL—Gliese 1969; GJ—Gliese & Jahreiss 1979, 1991), Giclas (G—Giclas *et al.* 1971, 1978), and/or LHS number (Luyten 1979). Column (3) gives the trigonometric parallax and its error as listed in GJ91. Column (4) lists the absolute $V$ magnitude, where the photometry was taken from the source listed in column (5). Columns (6)–(12) are dis-

[1]Observations reported here were obtained at the Multiple Mirror Telescope Observatory, a facility operated jointly by the Smithsonian Institution and the University of Arizona.

  

TABLE 1. Spectral types for northern red dwarfs within 8 pc.

| Name (1) | LHS (2) | $\pi_{trig} \pm \sigma$ (3) | | $M_V$ (4) | Ref (5) | Obs (UT) (6) | Tel (7) | Spectral Types GJ91 (8) | Spectral Types this work (9) | emission Boe (10) | emission SH (11) | emission HM (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GJ 1002 | 2 | .2128 | .0033 | 15.40 | L | 1993 Oct 31 | McD | M5-5.5[a] | M5.5 V | n | | |
| GJ 1005 AB | 1047 | .1887 | .0084 | 13.41 | GJ | 1991 Nov 13 | MMT | M4 J | M4 V J | | | |
| GL 15 A | 3 | .2895 | .0049 | 10.39 | L | 1993 Oct 31 | McD | M2 V | M1.5 V | n | a | |
| GL 15 B | 4 | .2895 | .0049 | 13.38 | L | 1993 Oct 31 | McD | M6 Ve | M3.5 V | n | | |
| GL 34 B | 122 | .1684 | .0031 | 8.64 | GJ | 1993 Oct 31 | McD | K7 V | K7 V | n | | |
| GL 54.1 | 138 | .2674 | .0030 | 14.19 | L | 1993 Oct 31 | McD | dM5 e | M4.5 V | | | |
| GL 65 A | 9 | .3807 | .0043 | 15.09 | HM | 1990 Jan 20 | MMT | dM5.5 e | M5.5 V | e | | |
| GL 65 B | 10 | .3807 | .0043 | 15.95 | HM | 1990 Jan 20 | MMT | dM5.5 e | M6 V | e | | |
| GL 83.1 | 11 | .2238 | .0029 | 14.04 | L | 1991 Nov 13 | MMT | dM8 e | M4.5 V | e | | |
| GL 105 B | 16 | .1294 | .0043 | 12.22 | L | 1993 Oct 29 | McD | dM4.5 | M3.5 V | n | n[b] | |
| GL 109 | 1439 | .1256 | .0027 | 11.06 | SH | 1993 Oct 29 | McD | dM3.5 | M3 V | n | a | |
| GL 166 C | 25 | .2071 | .0025 | 12.77 | L | 1991 Nov 13 | MMT | dM4.5 e | M4.5 V | e | | |
| GL 169.1A | 26 | .1819 | .0011 | 12.38 | SH | 1991 Nov 13 | MMT | dM4 | M4 V | | | |
| GL 185 AB | | .1296 | .0075 | 9.02 | GJ | 1993 Mar 16 | McD | M0 V J | K7 V J | | | a |
| GL 205 | 30 | .1723 | .0031 | 9.13 | L | 1990 Jan 22 | MMT | M1.5 V | M1.5 V | n | a | |
| GL 213 | 31 | .1665 | .0039 | 12.64 | L | 1991 Nov 13 | MMT | M4 | M4 V | n | a | |
| G 192-13 | 1805 | .1322 | .0029 | 12.32 | GJ | 1993 Mar 14 | McD | m | M3.5 V | | | |
| G 99-49 | | .1863 | .0062 | 12.68 | GJ | 1993 Mar 14 | McD | M4 | M3.5 V | | | |
| GL 229 | 1827 | .1749 | .0067 | 9.33 | L | 1990 Jan 22 | MMT | M1 Ve | M1 V | n | | |
| GL 234 AB | 1849/50 | .2421 | .0017 | 13.00 | L | 1991 Nov 13 | MMT | M4.5 J | M4.5 V J | e | e | |
| GL 251 | 1879 | .1736 | .0022 | 11.21 | L | 1990 Jan 22 | MMT | dM4 | M3 V | n | a | |
| GJ 1093 | 223 | .1289 | .0035 | 15.07 | L | 1993 Mar 14 | McD | m | M5 V | | | |
| GL 268 AB | 226 | .1646 | .0031 | 12.57 | L | 1990 Jan 22 | MMT | M4.5 Ve J | M4.5 V J | e | e | |
| GL 273 | 33 | .2644 | .0020 | 11.97 | L | 1990 Jan 22 | MMT | M3.5 | M3.5 V | n | | a |
| GL 285 | 1943 | .1611 | .0041 | 12.19 | L | 1993 Mar 15 | McD | dM4.5 e | M4 V | e | e | e |
| GL 299 | 35 | .1480 | .0026 | 13.68 | L | 1993 Mar 15 | McD | dM5 | M4 V | n | | |
| GL 300 | 1989 | .1700 | .0102 | 13.22 | L | 1993 Mar 15 | McD | M4 | M3.5 V | | | |
| GJ 1111 | 248 | .2758 | .0030 | 16.99 | L | 1990 Jan 20 | MMT | M6.5 | M6.5 V | e | | |
| GJ 1116 AB | 2076/77 | .1913 | .0025 | 15.03 | L | 1990 Nov 23 | MMT | m + m | M5.5 V J | | | |
| GL 338 A | 260 | .1625 | .0020 | 8.67 | GJ | 1990 Jan 22 | MMT | M0 Ve | M0 V | | | a[c] |
| GL 338 B | 261 | .1625 | .0020 | 8.76 | GJ | 1990 Jan 22 | MMT | M0 Ve | K7 V | | | |
| GL 380 | 280 | .2132 | .0027 | 8.23 | L | 1990 Jan 22 | MMT | K2 Ve | K7 V | n | | a |
| GL 388 | 5167 | .2039 | .0028 | 10.87 | L | 1993 Mar 14 | McD | M4.5 Ve | M3 V | e | e | |
| GL 393 | 2272 | .1362 | .0041 | 10.32 | L | 1993 Mar 14 | McD | dM2.5 | M2 V | n | a | |
| | 292 | .2210 | .0036 | 17.32 | L | 1990 Nov 23 | MMT | M6.5 | M6.5 V | | | |
| GL 402 | 294 | .1451 | .0048 | 12.46 | L | 1990 Jan 22 | MMT | dM5 | M4 V | n | a | |
| GL 406 | 36 | .4183 | .0025 | 16.56 | L | 1990 Jan 20 | MMT | M6 | M6 V | e | | |
| GL 408 | | .1446 | .0044 | 10.82 | L | 1993 Mar 14 | McD | M3 | M2.5 V | n | a | |
| GL 411 | 37 | .3973 | .0018 | 10.47 | L | 1990 Jan 22 | MMT | M2 Ve | M2 V | n | a | |
| GL 412 A | 38 | .1888 | .0061 | 10.14 | L | 1993 Mar 14 | McD | M2 Ve | M1 V | n | a | |
| GL 412 B | 39 | .1888 | .0061 | 15.78 | L | 1993 Mar 14 | McD | M6 e | M5.5 V | | | |
| GL 445 | 2459 | .1915 | .0053 | 12.23 | L | 1993 Mar 15 | McD | sdM4 | M3.5 V | | a | |
| GL 447 | 315 | .3011 | .0019 | 13.51 | L | 1993 Mar 15 | McD | dM4.5 | M4 V | n | n | a |
| GJ 1156 | 324 | .1529 | .0030 | 14.73 | GJ | 1993 Mar 14 | McD | dM e | M5 V | | | |
| GL 473 AB | 333 | .2322 | .0043 | 14.29 | L | 1990 May 04 | MMT | dM5.5 e J | M5.5 V J | e | | |
| GL 514 | 352 | .1387 | .0029 | 9.76 | L | 1993 Mar 14 | McD | M1 V | M1 V | n | a | |
| GL 526 | 47 | .1840 | .0013 | 9.79 | L | 1993 Mar 14 | McD | M4 Ve | M1.5 V | n | a | |
| GL 555 | 2945 | .1590 | .0066 | 12.32 | L | 1993 Mar 14 | McD | M3 | M3.5 V | | | |
| GL 570 BC | 386 | .1742 | .0060 | 9.30 | L | 1993 Mar 14 | McD | M2 V J | M1 V J | | | |
| GL 581 | 394 | .1579 | .0065 | 11.55 | L | 1993 Mar 14 | McD | dM5 | M2.5 V | a | | |
| GL 623 AB | 417 | .1317 | .0039 | 10.86 | L | 1990 May 23 | MMT | dM3 J | M2.5 V J | a | | |
| GL 625 | | .1593 | .0046 | 11.11 | L | 1990 May 23 | MMT | dM2 | M1.5 V | a | | |
| GL 628 | 419 | .2447 | .0063 | 12.02 | L | 1993 Mar 15 | McD | M3.5 | M3 V | | | |
| GL 643 | 427 | .1719 | .0073 | 12.95 | L | 1989 Jul 10 | MMT | sdM4 | M3.5 V | | a | |
| GL 644 ABD | 428 | .1539 | .0026 | 9.96 | L | 1993 Mar 15 | McD | M3 J | M2.5 V J | | e | e |
| GL 644 C | 429 | .1539 | .0026 | 17.74 | L | 1993 Mar 15 | McD | M7 | M7 V | | | |
| G 203-47 | | .1318 | .0310 | 12.4 | GJ | 1993 Mar 16 | McD | M3 | M3.5 V | | | |
| GL 661 AB | 433/34 | .1595 | .0031 | 10.41 | L | 1990 May 04 | MMT | M3 J | M3 V J | | a | |
| GL 673 | 447 | .1289 | .0035 | 8.08 | L | 1993 Mar 16 | McD | K7 V | K7 V | | | a |
| GL 686 | 452 | .1289 | .0026 | 10.17 | L | 1993 Mar 16 | McD | dM1 | M0 V | | a | |
| GL 687 | 450 | .2127 | .0020 | 10.86 | L | 1993 Mar 16 | McD | M3.5 V | M3 V | | | |
| GL 699 | 57 | .5453 | .0010 | 13.23 | L | 1989 Jul 10 | MMT | M5 V | M4 V | | | |
| GL 701 | 3356 | .1259 | .0047 | 9.87 | L | 1993 Mar 16 | McD | dM2 | M0 V | | a | |
| GJ 1224[d] | 3359 | .1327 | .0037 | 14.24 | GJ | 1993 Nov 01 | McD | m | M4.5 V | | | |
| G 258-33 | 3376 | .1373 | .0053 | 14.17 | GJ | 1993 Mar 16 | McD | m | M4.5 V | | | |
| GJ 1230 A | 3405 | .1302 | .0283 | 13.0 | GJ | 1993 Nov 01 | McD | k-m | M4.5 V | | | |

TABLE 1. (continued)

| Name (1) | LHS (2) | $\pi_{trig} \pm \sigma$ (3) | $M_V$ (4) | Ref (5) | Obs (UT) (6) | Tel (7) | Spectral Types GJ91 (8) | Spectral Types this work (9) | emission Boe (10) | emission SH (11) | emission HM (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GJ 1230 B | 3404 | .1302 .0283 | 15. | GJ | 1993 Nov 01 | McD | m | M4.5 V | | | |
| GL 725 A | 58 | .2861 .0018 | 11.18 | L | 1991 Nov 13 | MMT | dM4 | M3 V | | a | |
| GL 725 B | 59 | .2861 .0018 | 11.96 | L | 1991 Nov 13 | MMT | dM5 | M3.5 V | | a | |
| GL 729 | 3414 | .3411 .0081 | 13.13 | L | 1993 Nov 01 | McD | dM4.5 e | M3.5 V | | | |
| GL 752 A | 473 | .1767 .0024 | 10.36 | L | 1989 Jul 10 | MMT | M3.5 Ve | M3 V | n | a | a |
| GL 752 B | 474 | .1767 .0024 | 18.74 | L | 1989 Jul 10 | MMT | dM5 e | M8 V | | | |
| GJ 1245 AC | 3494 | .2120 .0043 | 15.04 | L | 1989 Jul 13 | MMT | M5.5 Ve J | M5.5 V J | e | | |
| GJ 1245 B | 3495 | .2120 .0043 | 15.63 | L | 1989 Jul 13 | MMT | m | M6 V | | | |
| GL 809 | 3595 | .1335 .0026 | 9.13 | L | 1990 Nov 23 | MMT | M2 Ve | M0 V | | | a |
| GL 820 A[e] | 62 | .2887 .0019 | 7.51 | GJ | 1989 Jul 14 | MMT | K5 Ve | K5 V | | | a |
| GL 820 B | 63 | .2887 .0019 | 8.33 | L | 1989 Jul 14 | MMT | K7 Ve | K7 V | | | a |
| GL 829 | 508 | .1478 .0026 | 11.16 | L | 1990 Nov 23 | MMT | dM4 e | M3.5 V | | a | |
| GL 831 AB | 511 | .1256 .0045 | 12.50 | L | 1990 Nov 23 | MMT | dM4.5 e J | M4.5 V J | | e | |
| | 3799 | .1341 .0056 | 13.89 | GJ | 1993 Nov 01 | McD | M4 | M4.5 V | | | |
| GL 860 A | 3814 | .2519 .0023 | 11.81 | HM | 1990 Sep 13 | MMT | M2 V | M3 V | n[c] | n[c] | |
| GL 860 B | 3815 | .2519 .0023 | 13.83 | HM | 1990 Sep 13 | MMT | M6 V | M4 V | | | |
| GL 866 AB | 68 | .2943 .0035 | 14.67 | L | 1989 Jul 24 | MMT | M5 e J | M5 V J | e | | |
| GL 873 | 3853 | .1970 .0025 | 11.73 | L | 1991 Nov 13 | MMT | dM4.5 e | M3.5 V | e | e | e |
| GL 876 | 530 | .2113 .0048 | 11.80 | L | 1993 Oct 31 | McD | dM5 | M3.5 V | | | |
| GL 880 | 533 | .1482 .0025 | 9.51 | L | 1990 Nov 22 | MMT | dM2 e | M1.5 V | | a | a |
| GL 884 | 3885 | .1284 .0068 | 8.40 | L | 1993 Nov 01 | McD | K5/M0V[f] | <K5 V[f] | | | |
| GL 896 A | 3965 | .1519 .0037 | 11.29 | GJ | 1993 Oct 31 | McD | dM4 e | M3.5 V | e | e | e[c] |
| GL 896 B | 3966 | .1519 .0037 | 13.3 | GJ | 1993 Oct 31 | McD | dM6 e | M4.5 V | e | e | |
| GJ 1286 | 546 | .1386 .0035 | 15.40 | GJ | 1993 Oct 31 | McD | M5 | M5.5 V | | | |
| GL 905 | 549 | .3156 .0016 | 14.79 | L | 1993 Oct 31 | McD | dM6 e | M5.5 V | e | | |
| GL 908 | 550 | .1779 .0056 | 10.23 | L | 1993 Oct 31 | McD | M2 Ve | M1 V | n | a | a |

Notes to TABLE 1

[a] adopted M5.5 V for Figure 2a

[b] SH Table 6 lists as having no detectable Hα feature; SH Table 1 lists as having a slight absorption Hα feature

[c] observation is for both components

[d] wrong star is marked on finder chart in Luyten & Albers (1979); correct star is located 270″ east-southeast of object marked (or about 1 millimeter above the "5" in the "3359" label)

[e] spectral standard with $M_V < 8.00$

[f] adopted K7 for Figure 2a (plotted at −1.0) and <K5 for Figure 2b (plotted at −2.0 with arrow)

Photometry References, column (5):
GJ = Gliese & Jahriess (1991), HM = Henry & McCarthy (1993), L = Leggett (1992), SH = Stauffer & Hartmann (1986)

cussed in the following sections. Finder charts for most of these objects can be found in Luyten & Albers (1979). A second sample that includes objects that *may* lie within 8 pc is discussed in Sec. *4.2*.

### *2.2 Observations*

During the last five years, spectroscopic observations were obtained at the Multiple Mirror Telescope (MMT, effective aperture 4.5 m) on Mount Hopkins, AZ, and the McDonald Observatory 2.7 m telescope on Mount Locke, TX. Each spectrum was acquired on the date given in column (6) of Table 1 and at the telescope indicated in column (7). At the MMT, spectra were obtained with the Red Channel Spectrograph equipped with an 800×800 TI CCD. A 270 line $mm^{-1}$ grating with an LP-495 order-blocking filter was used to cover the range 6300–9000 Å at a resolution of 18 Å. At McDonald, spectra were obtained with the Large Cassegrain Spectrograph equipped with a 1024×1024 Craf/Cassini CCD. A 300 line $mm^{-1}$ grating with a GG475 order-blocking filter was used to cover the range 6400–9200 Å at a resolution of 12 Å. At both observatories a 2″-wide slit was used.

Many of the observations reported here are the result of a back-up program designed for periods of cloudy weather. Varying sky conditions make corrections for atmospheric absorption unreliable, and as a result, features such as the *A* and *B* bands of telluric $O_2$ at 7594–7685 and 6867–7000 Å, respectively, have not been removed. These telluric absorptions do not present a problem with spectral classification, as shown in Kirkpatrick *et al.* (1991, hereafter referred to as KHM).

## 3. RESULTS

### *3.1 New Spectral Types on the Standard System*

Spectral types have been assigned using the least-squares minimization technique described in KHM, which is an extension to red wavelengths of the system defined by Boeshaar (1976) and Boeshaar & Tyson (1985). In Table 1, spectral types given in GJ91 are listed in column (8) and the new types are presented in column (9). The letter "*J*" indicates a joint spectral type for multiple components in close systems. A generous estimate of the errors in the types is 0.5 subclasses, based upon the repeatability of classifications for objects observed in both Arizona and Texas. Sample spectra at each integral subclass between K5 V and M8 V are shown in the two panels of Fig. 1. The increasing redness of later

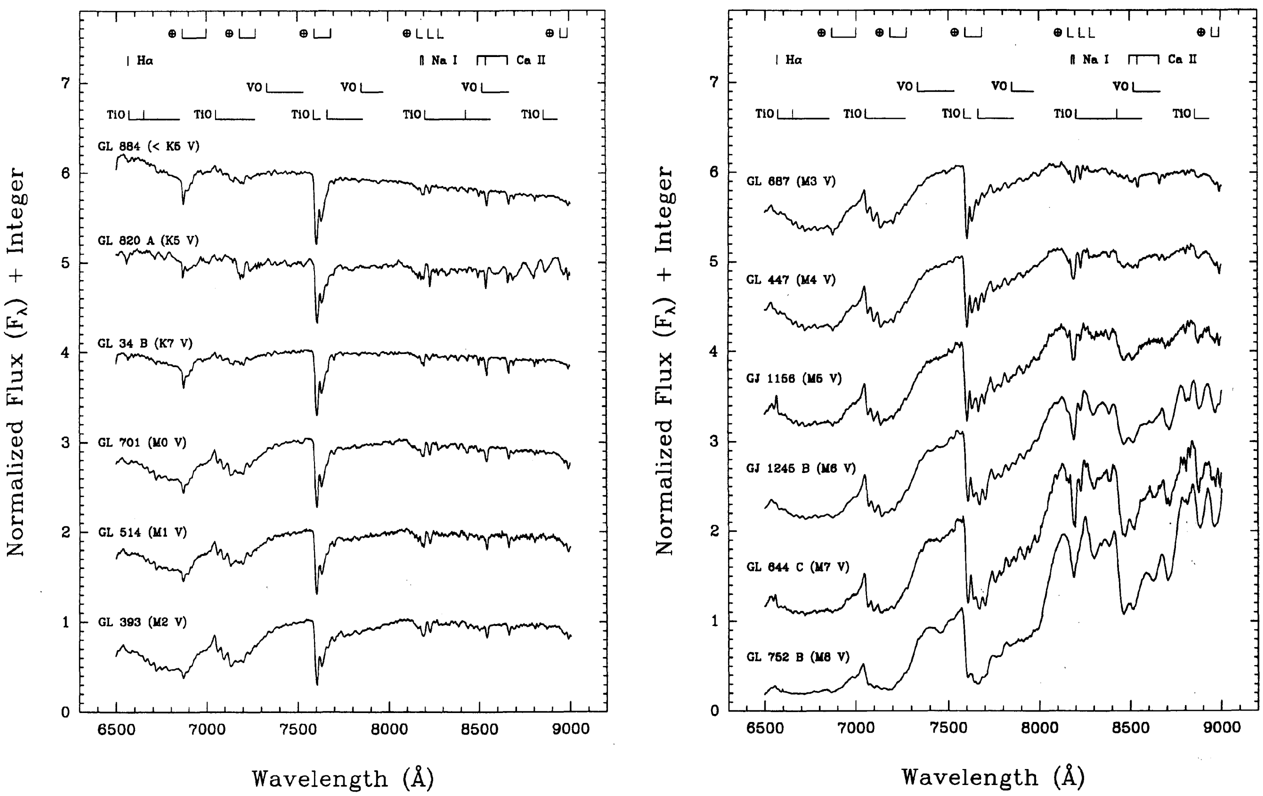


FIG. 1. Representative spectra of survey targets. The spectra are normalized to unity at 7500 Å, offset by unit amounts for clarity, and clipped at 6500 and 9000 Å. Spectra of GL 820A, GJ 1245B, and GL 644C were taken at the MMT at a resolution of 18 Å, and the remainder were taken at McDonald at a resolution of 12 Å. Also indicated are the TiO and VO bands, and several atomic features. Atmospheric absorption has not been removed—these telluric features are shown at the top of the figure.

types is apparent, as well as the change in TiO band absorption strength at 6550–6850, 7050–7250, 7650–7850, 8200–8550, and 8850–8950 Å along the sequence. At this spectral resolution, the VO bands at 7350–7550, 7850–7950, and 8500–8650 Å appear only in objects of type M7 or later. Specific line identifications can be found in KHM.

Examination of Table 1 shows that the most commonly observed stars in this survey are the mid-M dwarfs, with spectral types M3 V to M4 V. As discussed in Sec. *4.1*, this is undoubtedly a selection effect—the faintest targets are probably significantly under-represented. The reddest objects in the sample are the famous dwarfs VB 8 (GL 644C, M7 V) and VB 10 (GL 752B, M8 V), discovered as wide companions to known nearby stars by van Biesbroeck (1961). There are eight objects currently known with spectral types later than M8 V (Kirkpatrick *et al.* 1993; Kirkpatrick *et al.* 1993), but trigonometric/photometric parallaxes place these beyond the distance limit considered here.

Two double systems warrant special note. What is normally referred to as the fainter "$B$" component in the GL 338 system has, in fact, a slightly earlier type than the western "$A$" component. Care was taken at the telescope and during data reduction to assure that the two objects were not confused. Astrometric analysis of the wide binary indicates that the $B$ component may be overmassive (Chang 1972), possibly because of an unseen component, although the ~1000 yr orbit is poorly determined. No stellar companions have been found around either component between 1 and 10 AU via infrared speckle imaging (Henry 1991), or detected in the in-depth radial velocity study of Morbey & Griffin (1987), so no definitive explanation for the slightly disparate spectral types and fluxes can yet be achieved. Regardless, the two types and the brightnesses of the components are consistent within the 0.5 subclass accuracy of the classification system.

The GJ 1230 system is more puzzling. Again, care has been taken to assure that the two spectra were clearly separated on the chip and not confused during data reduction. The $V$ photometry given in GJ91 is of poor quality, but infrared photometry obtained by Henry (1991) indicates $B$ to be 1.9 mag fainter than $A$ in the $J$, $H$, and $K$ near-infrared bandpasses, yet both have the same M4.5 V spectral type. From the $M_K$ values for 1230 $A$ and $B$, and comparison to stars in the survey with similar $M_K$, we estimate that $A$ should have a type of M3.5–4.5 V and $B$ a type of M5.5–6 V. Apparently, the fainter component is the unusual star. Infrared speckle work reveals no stellar secondary to $A$ from 1 to 10 AU, but $B$ could not be searched independently due to its faintness and the proximity of $A$. If $B$ were a multiple, we would expect it to be brighter for its type, rather than fainter which is the case (see the discussion in Sec. *3.2*). Clearly, further investigative work should be done on this intriguing system.

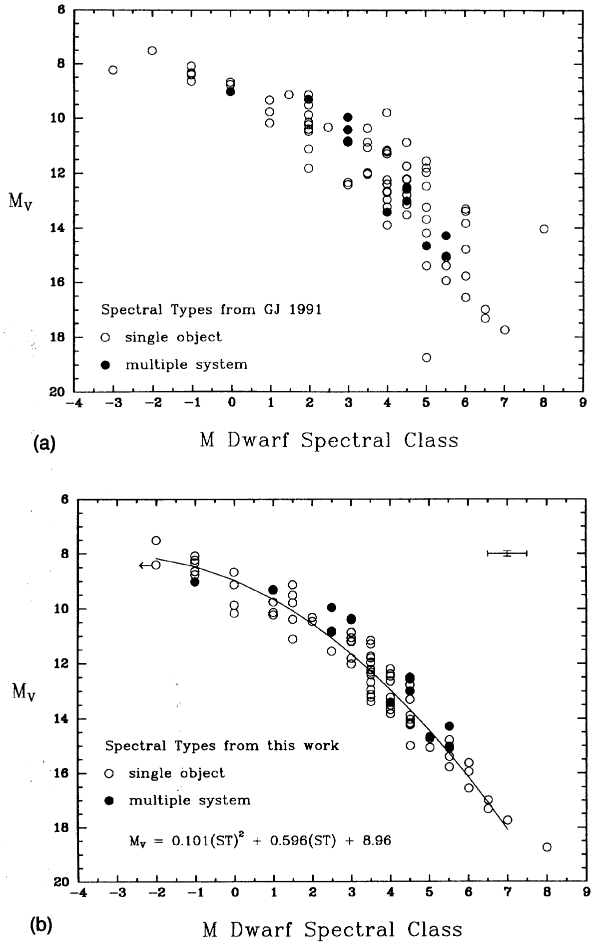


FIG. 2. Absolute visual magnitudes plotted vs spectral types for the survey targets using types from GJ91 [panel (a)] and from this work [panel (b)]. Note the reduced scatter in panel (b) due to the standardization of the spectral types. Typical error bars for points in panel (b) are shown in the upper right. The equation representing the fit is shown in the lower left.

### *3.2 Comparison to Previous Spectral Types*

It is instructive to compare the new spectral types to previous determinations. The types listed in GJ91 are taken from a variety of sources including Joy & Abt (1974), Veeder (1974), Boeshaar (1976), and Bidelman (1985), and therefore are not on a uniform system. These various systems generally become more discrepant for very red spectra. When putting the catalogue together, the authors were well aware of this, and have provided in many cases the source of the type. Because of the different systems, however, comparisons of objects based upon those spectral types were approximate and could lead to inaccurate target characterization. In eight cases, in fact, only Luyten (1979) color classes of "*m*" or "*k*−*m*" were known. Furthermore, large disparities were sometimes seen when comparing the catalogue types to the tabulated absolute magnitudes. This is illustrated in panels (a) and (b) of Fig. 2, which show $M_V$ as a function of spectral class for the GJ91 types and for the types presented here. In Fig. 2, the K types are plotted at negative M dwarf class values (K2=−3.0, K5=−2.0, K7=−1.0), and the M types begin at zero (M0=0.0, M1=1.0, etc.). Open points represent targets without known close companions that might contaminate the photometry or spectral types, and solid points represent composite types for close multiples. Due to the additional flux of the secondary, the points representing close multiples generally fall above the mean relation defined by the presumably single objects. The binary which lies furthest below the fit [the solid point at class −1.0 in panel (b)] is the GL 185 AB system, which has one of the largest parallax errors for any target in the survey (6%) and falls near the 8 pc limit.

A third-order polynomial fit has been made to the 77 single objects in panel (b) (the two extreme points, GL 884 and 752B have been omitted), yielding the following equation:

$$M_V = 0.101(\mathrm{ST})^2 + 0.596(\mathrm{ST}) + 8.96. \qquad (1)$$

This relation can be used to estimate $M_V$ given a spectral type, ST (where K5 V corresponds to ST=−2.0, M3.5 V to ST=3.5, etc.), and is valid for types K5 V–M7 V. Comparison of the two panels of Fig. 2 clearly shows that the scatter is significantly reduced with the new types. The rms of the residual to the fit in panel (b) is only ±0.5 subclasses (the same as our estimated accuracy in assigning spectral types on this system), whereas the rms for a similar fit to the 69 available points from GJ91 is ±0.9 subclasses. Higher order fits did not significantly improve the rms, which is due not only to errors in assigning spectral types, but to true differences in the stars because of metallicity and age effects. These factors will affect both the absolute magnitudes and the spectral types. Representative errors on the points in panel (b) are shown in the upper right. The adopted ±0.5 subclass error is shown for the types, and we illustrate a 0.1 mag error in $M_V$, which is greater than or equal to the $M_V$ errors for 90% of the survey targets. The scatter in $M_V$ for the fit in panel (b) is ±0.6 mag, and we conclude that the relation described by Eq. (1) can be used to estimate $M_V$ to this accuracy. A comparable fit to the GJ91 data results in a poorer ability to estimate $M_V$ because of a larger rms (±1.1 mag).

As an extreme example of the improvement in spectral typing, we examine the two outlying points in the lower right of panel (a). GL 83.1 with $M_V$=14.04 is noted as a dM8e in GJ91, whereas GL 752B with $M_V$=18.74 is noted as a dM5e. The improved types are M4.5 V and M8 V, respectively, which now fall along the mean relation.

Two of the objects in the 8 pc sample, GL 445 and 643, are listed as subdwarfs in GJ91, but at our spectral resolution neither these, nor any of the sample members, show subdwarf spectral characteristics, and therefore all are classified as normal dwarfs. Two examples of stars classified as subdwarfs are illustrated in Fig. 3 for comparison, as well as the spectral standard GL 725B (M3.5 V). LHS 2238 is a mild subdwarf and LHS 515 an extreme subdwarf. The subdwarf types of GL 445 and 643 were assigned nearly 50 yr ago by Joy (1947), and although both were retyped in Joy & Abt (1974) as dM4, the older types are listed in GJ91. Obvious differences between the spectra of the LHS objects and those of GL 445 and 643 can be seen in CaH from 6750 to 7050 Å

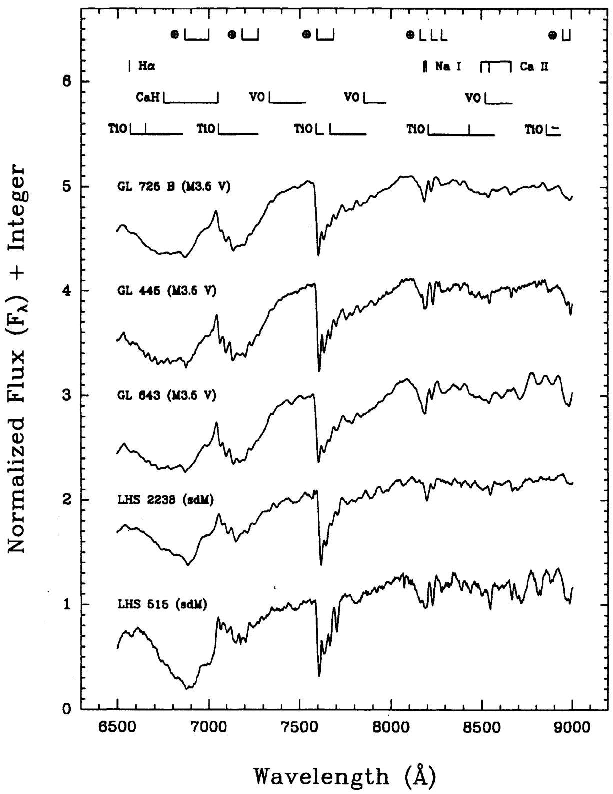


FIG. 3. Spectra of the subdwarfs LHS 2238 and LHS 515, and the survey objects GL 445 and GL 643, which we do *not* classify as subdwarfs. An M3.5 V standard, GL 725B, is also shown for comparison. Normalization, offsets, and clipping are the same as in Fig. 1. Spectra of GL 725B, GL 643, LHS 2238, and LHS 515 were taken at the MMT at a resolution of 18 Å, and GL 445 was taken at McDonald at a resolution of 12 Å. Also indicated are the TiO and VO bands, several atomic features, and the CaH absorption feature indicative of subdwarfs. Atmospheric absorption has not been removed—these telluric features are shown at the top of the figure.

and in the strength of the TiO bands at 7050–7250 and 7650–7850 Å, and we therefore adopt dwarf, rather than subdwarf, classes for these stars.

### *3.3 Emission*

The final three columns of Table 1 list emission data for stars examined in the studies of Boeshaar (1976, hereafter referred to as Boe), Stauffer & Hartmann (1986, hereafter referred to as SH), and Herbst & Miller (1989, hereafter referred to as HM). We have chosen these surveys to evaluate chromospheric activity in the red dwarfs because they utilize the relatively strong hydrogen lines found in these stars. Due to the weak flux of the red dwarfs in the blue, it is difficult to measure emission through the Ca II H and K emission at 3934 and 3968 Å, which is often used for earlier type stars.

The fundamental Boe work is that used to establish the spectral sequence for red dwarfs to type M6.5, and includes an evaluation of stellar emission properties based upon the hydrogen Balmer lines present on photographic spectra taken at dispersions of 110 and 250 Å/mm. In column (10) the letter "*e*" denotes that emission was listed as part of the spectral type, and "*n*" that it was not. The SH work includes high resolution (<0.2 Å) Hα measurements for the targets, and in column (11) *e* again indicates emission (Hα equivalent width greater than zero), *n* indicates no feature seen, and "*a*" is given when Hα was observed in absorption. The HM work involved measuring the Hα equivalent width photometrically, using three filters centered at 6563 Å. The codes for the measurements listed in column (12) are the same as for SH. Our resolution of 12–18 Å is insufficient to measure accurately the emission properties of the survey targets.

The match of the emission status for stars common to the three studies is excellent. For objects common to the Boe and SH work, every star listed as *e* by Boe has positive Hα in SH; likewise, the nonemission objects in Boe have no Hα feature or Hα in absorption in SH. The correlation between the SH and HM studies is similarly strong—all stars match in emission category except GL 447, which Boe and SH found to have no feature, whereas HM found a very weak absorption feature (−0.11 Å). On the other hand, the agreement between the Boe/SH/HM work and the emission status listed in GJ91 is poor. Because of the homogeneity and the strong correlation of the Boe, SH, and HM studies, we favor their emission determinations to those given in GJ91. We must await a systematic study of activity for the nearby M dwarfs (Hawley 1994) before deciding upon the emission status of stars not included in the three studies discussed here.

## 4. DISCUSSION

### *4.1 Completeness*

The solar neighborhood sample is arguably the best available representation of the disk population because the faintest members *can* be detected and studied. However, our knowledge of even the nearest stars is limited, and the sample discussed here is clearly incomplete, as is demonstrated in Fig. 4. Each *system* in the northern 8 pc sample (all

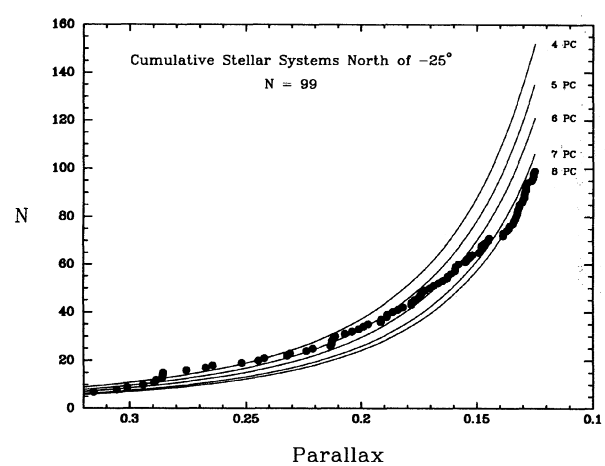


FIG. 4. Space density of nearby stellar systems north of −25°. Solid curves represent constant space densities using the measured densities at 4, 5, 6, 7, and 8 pc. The best fit is the 5 pc curve, which predicts ~35 undiscovered systems.

TABLE 2. Spectral types for northern red dwarfs possibly within 8 pc.

| Name | RA 1950.0 | DEC 1950.0 | V | Ref | Obs. (UT) | Tel | GJ91 SpT | GJ91 $\pi_{phot} \pm \sigma$ | GJ91 dist | this work SpT | this work $M_V$ | this work $\pi_{phot}$ | this work dist |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
| LP 476-207 | 04 59 14 | +09 54.8 | 11.47 | GJ | 1993 Mar 17 | McD | dM3 | .142 .032 | 7.0 pc | M3.5 V | 12.28 | .145 | 6.9 pc |
| LHS 1723 | 04 59 33 | −07 00.6 | 12.1 | GJ | 1993 Mar 17 | McD | m | .163 .026 | 6.1 | M3.5 V | 12.28 | .109 | 9.2 |
| LHS 1885 | 06 53 17 | +62 23.7 | 13.65 | GJ | 1993 Mar 17 | McD | m | .129 .020 | 7.8 | M4.5 V | 13.68 | .101 | 9.9 |
| GL 268.3[a] | 07 13 14 | +27 14.0 | 10.85 | GJ | 1993 Mar 17 | McD | dM0 | .126 .025 | 7.9 | M2.5 V | 11.08 | .111 | 9.0 |
| G 89-32 | 07 33 43 | +07 11.7 | 13.22 | GJ | 1993 Mar 16 | McD | m | .162 .026 | 6.2 | M4.5 V | 13.68 | .124 | 8.1 |
| GL 283 B[b] | 07 38 02 | −17 17.4 | 16.42 | GJ | 1990 Nov 23 | MMT | m | .112 .005 | 8.9 | M6 V | 16.16 | .089 | 11.2 |
| G 41-14 | 08 56 14 | +08 40.4 | 10.89 | GJ | 1993 Mar 16 | McD | k | .224 .036 | 4.5 | M3.5 V | 12.28 | .190 | 5.3 |
| GJ 2097 | 13 04 36 | +21 05.0 | 12.58 | GJ | 1993 Mar 16 | McD | m | .156 .023 | 6.4 | M2 V | 10.55 | .039 | 25.5 |
| G 165-8 | 13 29 28 | +29 32.0 | 11.95 | GJ | 1993 Mar 16 | McD | M4 e | .126 .022 | 7.9 | M4 V | 12.95 | .158 | 6.3 |

[a] $\pi_{trig} = 0.0694 \pm 0.0188$
[b] $\pi$ listed in column (9) is $\pi_{trig}$

stars included, not just red dwarfs) is denoted by a point corresponding to its measured trigonometric parallax. We have chosen to evaluate the density of systems rather than distinct objects in order to prevent overemphasizing multiples. The vertical axis represents the cumulative number of known systems, steadily increasing for larger distances. Overplotted on this empirical trend are curves of constant space density matching the observed density at the distances labeled. The empirical curve is shallower than the curves of constant density, indicating that members of the nearby star sample have been missed. The curves at 4 and 5 pc predict densities which agree relatively well with the observed values at smaller distances, whereas the 6, 7 and 8 pc curves call for too few systems at small distances compared to the number actually known. The 5 pc curve provides a slightly better fit than the 4, and predicts that ~35 systems remain undiscovered in the northern 8 pc sample. This estimate, of course, assumes that the Sun does not lie in a localized region of enhanced stellar density a few parsecs in size. Any incompleteness in the observed density to 5 pc only increases the number of undetected systems at larger distances. At declinations south of −25°, the list of nearby stars is likely to be even more incomplete because historically, all-sky proper motion surveys to faint magnitudes and the necessary follow-up parallax work to confirm nearby stars have not been done.

### *4.2 Possible New 8 pc Members*

The obvious dearth of known stars between 5 and 8 pc has led us to search for "hidden" nearby stars. As part of this effort, we have observed several red dwarfs which may be within the boundary of the present survey. Table 2 includes stars that were selected from GJ91 that are promising nearby candidates (many of the columns are the same as in Table 1). Only GL 268.3 and GL 283B have trigonometric parallaxes, while the others have $\pi_{\rm phot}$ placing them within 8 pc. From our spectral types listed in column (11), we estimate $M_V$ [column (12)] using Eq. (1). Using this value of $M_V$ and the measured $V$ listed in column (4), we estimate the photometric parallaxes and distances in columns (13) and (14).

Based upon the data presented here, three objects should be tentatively placed within the 8 pc survey, although they will not be "officially" included in further 8 pc analyses until trigonometric parallaxes are available. Nonetheless, it appears that they are among the Sun's 200 nearest neighbors. We point out that because of the faintness of these stars, the Hipparcos mission will not provide parallaxes, and they should prove to be good targets for ground-based determinations of $\pi_{\rm trig}$.

## 5. FUTURE

Hartmut Jahreiss has kindly provided an updated list of potential nearby red dwarfs, several of which will lie within 8 pc, and, in a few cases, within 5 pc. These are obvious targets for future work. Continuing efforts to reveal nearby stars also include searches for companions to known survey members, searches for single objects with measured proper motions but no trigonometric parallaxes, and a new proper motion survey utilizing reject plates from the second generation Palomar Observatory Sky Survey (POSS II). As the sample becomes more complete, robust estimates can be made of the true luminosity and mass functions of low mass stars in the disk and their contribution to the total disk mass. The list of potential nearby targets continues to grow, and the reader is encouraged to alert the authors to any new nearby candidates. We are planning to extend the survey to the southern hemisphere in order to place those stars on the standard spectroscopic system, and eventually to continue the effort by including stars to 10 pc.

We wish to express our appreciation for the efforts of Dr. Gliese and Dr. Jahreiss, who have helped establish the fundamentals of stellar astronomy through their hard work in compiling data for the nearby stars. T.J.H. acknowledges support from NASA's High Resolution Microwave Survey, and J.D.K. acknowledges support from the W. J. McDonald Fellowship.

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