ABSTRACT

Broadband optical spectra are presented for 34 known and candidate nearby stars in the southern sky. Spectral types are determined using a new method that compares the entire spectrum with spectra of more than 100 standard stars. We estimate distances to 13 candidate nearby stars using our spectra and new or published photometry. Six of these stars are probably within 25 pc, and two are likely to be within the RECONS horizon of 10 pc.

Subject headings: stars: distances — stars: low mass, brown dwarfs — white dwarfs — surveys

1. Introduction

The nearest stars have received renewed scrutiny because of their importance to fundamental astrophysics (e.g., stellar atmospheres, the mass content of the Galaxy) and because of their potential for harboring planetary systems and life (e.g., the NASA Origins and Astrobiology initiatives).
The smallest stars, the M dwarfs, account for at least 70% of all stars in the solar neighborhood and make up nearly half of the Galaxy’s total stellar mass (Henry et al. 1997; hereafter H97). Their slightly lesser cousins, the brown dwarfs, may lurk in comparable numbers. Yet, many of the nearest red, brown, and white dwarfs remain unrecognized because of their low luminosities. H97 estimate that more than 30% of stellar systems within 10 pc of the Sun are currently missing from compendia of nearby stars.

The number of “missing” stars within 25 pc of the Sun is estimated to be twice the fraction missing within 10 pc. The NASA/NSF NStars Project is a new effort to foster research on all stars within 25 pc, with special emphasis on the development of a comprehensive NStars Database. All systems with trigonometric parallaxes greater than or equal to 0\(^{\prime\prime}\)04000 from *The Yale Catalog of Stellar Parallaxes* (YPC, van Altena et al. 1995) and *The Hipparcos Catalogue* (HIP, ESA 1997) have been included in the Database. The weighted means of the YPC and HIP parallaxes have been determined, including the combination of all trigonometric parallax values for stellar systems in which widely separated components have had separate parallax measurements. Table 1 lists the numbers of known and predicted stellar systems within 25 pc, and their distributions within equal regions of the sky, obtained from the NStars Database as of 01 July 2001. The predicted number of 1375 systems in each region is based on the assumptions that (1) the density of stellar systems within 5 pc (0.084 systems pc\(^{-3}\)) extends to 25 pc, and (2) the distribution of the systems is isotropic. Table 1 clearly shows that more stars are missing in the southern sky than in the northern sky — we predict that more than two-thirds of the systems are undiscovered in the south. Furthermore, new systems within 5 pc are still being found (H97), so the total number predicted within 25 pc is a lower limit.

In a concerted effort to discover and characterize the nearest stars, the RECONS (Research Consortium on Nearby Stars) team has been conducting astrometric, photometric, spectroscopic, and multiplicity surveys of known and candidate stars within 10 pc (for more information about RECONS, see H97). In this paper, the sixth in *The Solar Neighborhood* series, we present optical spectra of 34 known or suspected nearby southern red and white dwarfs, including 10 known members of the RECONS sample and 16 stars for which no spectral types have been previously published. We report spectral types for all the stars in our sample using a method that will define the spectral types used in the NStars Database. We supplement the spectral data with VRI photometry for five stars. Our analysis has revealed two new stars that are probably closer than the 10 pc RECONS horizon, and four others that are probably closer than the 25 pc NStars horizon.

2. Sample

The 34 stars for which we obtained optical spectra are grouped into four categories:

1. 12 stars that lie within, or close to, the 10 pc RECONS horizon for which no broadband spectra are published. These stars have well known distances, so they are good standards for
calibrating spectroscopic parallaxes.

2. 14 recently discovered stars having high proper motions. Because nearer stars appear to move faster than more distant ones, high proper motion is a good indicator of stars in the solar neighborhood. Between 1989 and 1997, Wroblewski and collaborators identified 2055 new stars lying south of $-5^\circ$ declination with proper motions, $\mu \geq 0''.15 \text{ yr}^{-1}$ (Wroblewski & Torres 1997, and references therein). In February 1998, we observed 12 of the 52 stars from this collection that have $\mu \geq 0''.50 \text{ yr}^{-1}$. We also observed two high-proper-motion stars selected from the Calan-ESO survey of Ruiz and collaborators (Ruiz et al. 1993). Between our observing run and the end of 2000, Wroblewski and collaborators identified an additional 293 new stars with $\mu \geq 0''.15 \text{ yr}^{-1}$, only one of which has $\mu \geq 0''.50 \text{ yr}^{-1}$ (Wroblewski & Costa 1999).

3. 4 stars whose Hipparcos parallaxes have suspiciously high errors. Nine targets in eight systems were reported by the Hipparcos mission to have parallaxes larger than 0''100 with errors larger than 0''020 (i.e., 14–56% errors – enormous for Hipparcos). In every case, the targets are near bright stars that corrupted the parallax measurements. In two cases, HIP 114110 and HIP 114176, there is no star at all. In February 1998, we observed two of the remaining seven targets, HIP 15689 and HIP 20698, as well as two of the neighboring bright stars.

4. 4 stars for which available photometry implies a distance less than 25 pc. These stars come from an extensive list of possible nearby stars maintained by the first author.

3. Observations

A total of 34 targets were observed during nights of UT 08 and 09 February 1998 using the Blanco 4m telescope at Cerro Tololo Interamerican Observatory (CTIO). The R-C Spectrograph with a Loral 3K $\times$ 1K CCD was used with grating #181 at tilt 58.77°, order blocking filter OG-515, and a gain setting of 4 (2.07 $e^- \text{ ADU}^{-1}$). The wavelength coverage was 5500–10000 Å, with a resolution of 6 Å. This broad spectral range includes the TiO absorption bands characteristic of red dwarfs, the Hα emission line used to measure activity, and the K I, Na I, and Ca II absorption features used to discriminate dwarfs from giants.

Bias frames and dome flats were taken at the beginning of each night. A HeAr arc lamp spectrum was recorded after each target spectrum to permit accurate dispersion correction throughout the night. Observations were conducted through clouds for four hours on 08 February 1998, and for eight hours through increasing clouds on 09 February 1998. Several of the program stars were observed on both nights, thereby allowing confirmation of the spectral types.

Photometric observations were carried out in the $V_J$, $R_C$, $I_C$ bands for five stars at the CTIO 0.9m telescope during our NOAO Surveys Program, CTIOPI (CTIO Parallax Investigation), on the nights of UT 27 November to 01 December 1999. Standards from Landolt (1992) and Bessell (1990)
were observed for the purpose of deriving extinction coefficients and transformation equations for each night.

4. Data Reduction

4.1. Photometry Reduction

Reduction of the photometric data was done using the Image Reduction and Analysis Facility (IRAF). Bias subtraction and flatfielding of the VRI frames were accomplished using the ccdred package, and instrumental magnitudes were obtained using the apphot package. The photcal package was then used to perform fits to the extinction and transformation equations, and to transform the magnitudes to the standard Cousins system. An aperture of 3\" was used to extract counts for the program stars, and aperture corrections used to match the methodology of Landolt (1992). Errors in the final photometry are estimated to be 0.03 mag.

4.2. Extraction of Spectra

The long-slit spectra were reduced and extracted using IRAF. Bias levels were removed by subtracting a median bias frame scaled to match the overscan signal of each image. The images were flattened by dividing by a normalized, median dome flat from which the spectral response of the illuminating quartz lamp had been removed. After the removal of night-sky emission lines, the target spectra were distortion-corrected and wavelength-calibrated using the consecutively recorded HeAr arc spectra. One dimensional spectra were extracted from summed apertures of 10 to 14 pixels width centered on the spectra. Correction for atmospheric extinction was performed using the default IRAF extinction tables for CTIO, but telluric features (which can be seen in the white dwarf spectra of Figure 2) were not removed. Finally, the extracted spectra were flux calibrated using a recorded spectrum of the spectrophotometric standard star GJ 440 and the appropriate IRAF flux table.

4.3. Assignment of Spectral Types

We have developed a software program, called ALLSTAR, that matches a target spectrum to one from a database of 106 standard spectra of K and M dwarfs previously published by RECONS (see Table 2). When expanded to include the complete range of spectral types, ALLSTAR will likely become the standard algorithm for assigning spectral types in the NStars Database.

For each target and standard spectrum, ALLSTAR interpolates flux values at 1 Å intervals between 6500 and 9000 Å, regardless of the original spectral resolution. The spectra are normalized at 7500 Å, a wavelength which lies in a region that is relatively free of opacity sources in red dwarfs.
(and most stars). To account for possible spurious normalization of the target spectrum caused by noisy data, an array of 21 spectra is created by multiplying the normalized spectrum by integral percentages between 90% and 110%. These 21 spectra are subtracted from each of the standard spectra over the entire 6500–9000 Å range, and the rms deviation of each difference spectrum is then computed. Pixels offset by more than $2\sigma$ from the rms deviation are set to zero. Trial and error has shown that this threshold effectively rejects unwanted pixels associated with variable telluric absorption features or detector defects. If more than 20% of the difference spectrum is rejected, then the standard spectrum from which it was derived is removed from further consideration. After rejecting the deviant pixels, ALLSTAR sums the elements of each difference spectrum and sorts the sums for all matches in ascending order. These ordered sums provide a rating system in which the standard spectrum generating the smallest sum is the best match to the target spectrum.

The technique embodied in ALLSTAR differs from that used in previous RECONS efforts (Kirkpatrick, Henry, & McCarthy 1991) in four ways: (1) ALLSTAR interpolates fluxes every 1 Å rather than every 3 Å, (2) the target spectra are compared with the standard spectra over the entire 6500–9000 Å range, rather than over pre-assigned chunks of the spectra, (3) rejection of varying telluric features and detector defects is carried out in a rigorous, well-defined fashion, and (4) spectral typing is based on a single, best match to a standard spectrum rather than a relative ranking of all spectra from bluest to reddest. For 100 of our 106 standard stars, ALLSTAR returns the same spectral types previously reported by RECONS and listed in Table 2. For the remaining six, ALLSTAR produces spectral types within 0.5 subtype (the published uncertainty) of those previously reported. These 0.5 subtype discrepancies are attributable to subtle differences in the reduction techniques, and are not significant. Therefore, we have not altered the previously published types.

In Table 2, “J” has been appended to some of the previously published spectral types to denote those stars whose spectra represent the combined light of multiple components. The “J” (for joint) designation was not previously used for GJ 22 AC, GJ 352 AB, GJ 570 BC, G 203-047 AB, GJ 791.2 AB, GJ 829 AB, GJ 896 AC, and GJ 896 BD because, for many of these systems, close companions have been discovered since their spectral types were first published. We anticipate that other changes in spectral type will occur once spectra obtained at infrared wavelengths are combined with existing optical spectra.

5. Results and Discussion

Table 3 contains astrometric, photometric, and spectroscopic information for the 34 stars in our sample. The photometry is given on the Johnson ($UBV$) and Cousins ($RI$) systems. The photometry from Weis (1996) has been converted to the Cousins system using the relations of Bessell & Weis (1987). Previously reported spectral types for many of the stars come from Reid et al. (1995) and Hawley et al. (1996), who used narrower-band spectra ($\approx 6200–7400$ Å) than ours to determine the spectral types of over 2000 known and candidate nearby stars. Our observations
differ from theirs in that ours cover more than three times the spectral range and result in somewhat more robust spectral types. Also listed are distances to stars with trigonometric parallaxes from Hipparcos (denoted by H) or from a weighted mean of YPC and Hipparcos measurements (denoted YH).

Using the $M_V$–spectral type relation of Henry et al. (1994) for red dwarfs (ST is spectral type),

$$M_V = 0.101 \text{(ST)}^2 + 0.596 \text{(ST)} + 8.96$$  \hspace{1cm} (1)

we have estimated distances (last column of Table 3) to stars for which we have obtained new spectra and that have $V_J$ photometry. Comparison of the true and predicted distances for the stars with known trigonometric parallaxes shows that the errors on the distance estimates are substantial, which is typical of distances estimated spectroscopically. However, only for GJ 190 and GJ 433 do the trigonometric and spectroscopic distances differ by more than a factor of two. GJ 433 is a known close binary system (Bernstein 1997; confirmed by C. Leinert, personal communication), and we are suspicious that GJ 190 may also be a close binary system.

We find that eleven of the candidate nearby stars identified by Wroblewski and Torres (WT stars) are red dwarfs of types M0.0V to M5.5V. The twelfth WT star is a newly identified nearby white dwarf. The two Calan-ESO stars are also red dwarfs. As expected, the Hipparcos stars with large parallax errors are giants and, therefore, not members of the solar neighborhood. The four stars in the photometrically selected sample yield the highest proportion of nearby stars – GJ 1123 and GJ 1128 are likely to be within 10 pc, while GJ 1129 lies just beyond 10 pc. (We lack the accurate $V_J$ photometry required to estimate the distance to LHS 1957.) Many of the targets with estimated distances within 25 pc are being observed in our southern parallax program, CTIOPI. Those stars likely to be within the 10 pc RECONS horizon receive the highest priority.

The spectra of the most interesting stars in our sample are shown in Figures 1 and 2. Several noteworthy stars are discussed here, in alphabetical order.

**ESO 440-064** (spectral type M5.5V) is one of the two latest stars observed. It exhibits a prominent Hα emission feature. This star and **ESO 440-139**, which is estimated to lie at 20 pc, were revealed during the Calan-ESO effort of Ruiz and collaborators (Ruiz et al. 1993) to reveal new proper motion stars in the southern sky.

**GJ 432 B** is a 15th magnitude companion 17″ from a 6th magnitude K0 dwarf. Observing difficulty precludes much information for this star. Its spectrum is similar to our white dwarf spectrophotometric standard, GJ 440. We cannot determine with our spectral coverage whether the star has type DC or DQ, but it is not type “m” as reported by Gliese & Jahreiss (1991).

**GJ 1123, GJ 1128, GJ 1129** and **WT 84** are four stars with estimated distances within 15 pc. All are being observed as high-priority CTIOPI targets because they may lie within the RECONS horizon of 10 pc. WT 84 (spectral type M5.5V) is one of the two latest stars observed
and exhibits a prominent $\text{H}\alpha$ emission feature.

**GJ 2036 A and B** have enormous $\text{H}\alpha$ emission features.

**HIP 14555** (= LTT 1479 = GJ 1054A) was observed instead of the intended target, HIP 14559, which lies 28$''$ to the east. The Hipparcos parallax of HIP 14559 ($V_J = 11.72$), $0''.11473 \pm 0''.03398$, has a large error because of the proximity of HIP 14555 ($V_J = 10.21$). HIP 14555 has spectral type M1.0V and a prominent $\text{H}\alpha$ emission feature. Using our new spectral type and the $V_J$ magnitude from Hipparcos, we estimate a distance to HIP 14555 of 12.9 pc, which is 5$\sigma$ less than the distance obtained from the Hipparcos parallax of $0''.05238 \pm 0''.00503$. The fainter star found 64$''$ to the southwest is LTT 1477 (= GJ 1054B), which has common proper motion with HIP 14555.

**HIP 15689** ($V_J = 12.16$) lies 24$''$ southwest of HIP 15690 ($V_J = 8.83$). The Hipparcos parallax of $0''.22745 \pm 0''.06179$ for HIP 15689 has a large error because of the proximity of HIP 15690. Our spectrum of HIP 15689 lacks a K I feature, has a weak Na I feature, and has a strong Ca II triplet. These features clearly indicate that the star is a giant or supergiant. It is therefore not a nearby star.

**HIP 20968** ($V_J = 11.42$) lies 21$''$ northeast of **HIP 20965** ($V_J = 7.73$). The Hipparcos parallax of $0''.12070 \pm 0''.05647$ for HIP 20968 has a large error because of the proximity of HIP 20965 (parallax $0''.00218 \pm 0''.00189$). Our spectra indicate that both stars are giants or supergiants. HIP 20968 is therefore not a nearby star. HIP 20965’s spectrum shows the CN band at 7900 Å.

**WT 248** (M3.0V) is estimated to lie at a distance of 37 pc, despite its large proper motion (1$''.197$ yr$^{-1}$). Its spectrum does not show the obvious CaH band around 6900 Å that is characteristic of subdwarfs, as might be expected for such a high velocity star.

**WT 1759** is a newly identified nearby white dwarf. Its spectrum is virtually identical to that of our spectroscopic standard, GJ 440, which is a DQ6 white dwarf with a temperature of ∼8500 K (Bergeron et al. 2001). With our spectral coverage, we cannot determine if the star has type DC or DQ. Assuming that WT 1759 has the same absolute magnitude as GJ 440, we estimate that the distance to WT 1759 is 28 pc.

### 6. Concluding Remarks

The recent identifications of candidate nearby stars from the proper motion studies of Wrobleski et al., Ruiz et al., and others, and from photometric sky surveys such as DENIS, 2MASS and SDSS, suggest that many nearby stars remain undiscovered. In essence, this paper represents a small step in fingerprinting some suspected nearby stars via spectroscopy. We have established a method for consistent spectral typing that will provide definitive types both for the RECONS effort (horizon 10 pc) and the more extensive NASA/NSF NStars Project (horizon 25 pc). Using this method, we report the first spectral types on a standard system for 16 nearby star candidates. We also provide updated spectral types for 18 other stars using broader spectral coverage than was
previously available.

This work will allow us to improve the luminosities, colors, and temperatures for the ubiquitous red dwarfs, as well as broaden the database used to investigate the luminosity function, mass function, kinematics, and multiplicity of stars in the solar neighborhood. The nearest objects, such as GJ 1123 and GJ 1128 from this study, will be prime targets of upcoming NASA missions like SIRTF, SIM, and TPF, as well as being additions to the target lists of SETI efforts like Project Phoenix.

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Fig. 1.— Spectra of some of the nearest suspects in our sample of candidate nearby stars. The spectra and photometry of GJ 1129, GJ 1123, GJ 1128, and WT 84 suggest that these stars lie within 15 pc (see Table 3). The spectra of GJ 2036 A and B exhibit enormous H\(\alpha\) emission features. Important spectral features are labelled at the top. The absorption complex at 9300 Å and redward is due primarily to H\(_2\)O in the Earth’s atmosphere.

Fig. 2.— Spectra of the three white dwarfs and the three giants. WT 1759 is a newly identified white dwarf with an estimated distance of 28 pc. GJ 432 B is a nearby white dwarf companion to a K0 dwarf. The spectra of both white dwarfs are similar to that of the DQ6 spectrophotometric standard, GJ 440. HIP 15689, HIP 20968, and HIP 20965 are giants or supergiants, as indicated by the lack of K I absorption near 7700 Å, the weak NaI absorption near 8200 Å, and the strong CaII triplet in the 8500–8700 Å window. Note also the CN absorption feature near 7900 Å in the spectrum of HIP 20965. Important spectral features are labelled at the top. The absorption complex at 9300 Å and redward is due primarily to H\(_2\)O in the Earth’s atmosphere.
Table 1. Number of Stellar Systems within 25 Parsecs$^a$

| Region of Sky | # Systems Known | Total Predicted | Fraction Missing |
|---------------|-----------------|-----------------|-----------------|
| +90 to +30    | 575             | 1375            | 58%             |
| +30 to +00    | 578             | 1375            | 58%             |
| −00 to −30    | 463             | 1375            | 66%             |
| −30 to −90    | 395             | 1375            | 71%             |
| TOTAL         | 2011            | 5500            | 63%             |

$^a$in NStars Database as of 01 July 2001
Table 2. List of Spectral Standards.

| Name   | Comp. | RA       | Dec       | Spectral type | Ref. |
|--------|-------|----------|-----------|---------------|------|
| GJ 1002 | ·     | 00 06 43.8 | −07 32 22 | M5.5V        | Hen94|
| GJ 1005 AB | 00 15 28.1 | −16 08 02 | M4.0V      | Hen94|
| GJ 15| A    | 00 18 22.9 | +44 01 23 | M1.5V        | Hen94|
| GJ 15 B | 00 18 22.9 | +44 01 23 | M3.5V      | Hen94|
| GJ 2005 ABCD | 00 24 42.0 | −27 08 52 | M5.5V      | Hen99|
| GJ 22 AC | 00 32 26.0 | +67 14 00 | M2.0V      | McC91|
| GJ 22 B | 00 32 26.0 | +67 14 00 | M3.0V      | McC91|
| GJ 34 B | 00 49 06.3 | +57 48 55 | K7.0V      | Hen94|
| GJ 51 | ·     | 01 03 18.0 | +62 22 00 | M5.0V        | Kir91|
| GJ 54.1 | ·     | 01 12 30.6 | −16 59 57 | M4.5V        | Hen94|
| GJ 65 A | 01 39 01.3 | −17 57 01 | M5.5V      | Kir91|
| GJ 65 B | 01 39 01.3 | −17 57 01 | M6.0V      | Kir91|
| GJ 83.1 | ·     | 02 00 13.2 | +13 03 08 | M4.5V        | Kir91|
| GJ 106 | ·     | 02 44 15.5 | +25 31 24 | M3.0V        | Hen94|
| GJ 1061 | ·     | 03 36 00.0 | −44 30 46 | M5.5V        | Hen97|
| LP 944-020 | ·     | 03 39 35.2 | −35 25 41 | >M9.0V       | Kir97|
| GJ 185 AB | 05 02 28.4 | −21 15 24 | K7.0V      | Hen94|
| GJ 205 | ·     | 05 31 27.4 | −03 40 38 | M1.5V        | Kir91|
| GJ 213 | ·     | 05 42 09.3 | +12 29 22 | M4.0V        | Kir91|
| G 099-049 | ·     | 06 00 03.6 | +02 42 20 | M3.5V        | Hen94|
| LHS 1805 | ·     | 06 01 09.7 | +59 35 54 | M3.5V        | Hen94|
| GJ 226 | ·     | 06 10 19.8 | +82 06 24 | M2.5V        | Kir91|
| GJ 229 A | 06 10 34.6 | −21 51 53 | M1.0V      | Kir91|
| GJ 232 | ·     | 06 24 41.6 | +23 25 59 | M4.0V        | Kir91|
| GJ 234 AB | 06 29 23.4 | −02 48 50 | M4.5V      | Kir91|
| GJ 250 B | 06 52 18.1 | −05 11 25 | M2.5V      | Kir91|
| GJ 251 | ·     | 06 54 49.0 | +33 16 05 | M3.0V        | Kir91|
| GJ 1093 | ·     | 06 59 28.4 | +19 20 52 | M5.0V        | Hen94|
| GJ 268 AB | 07 10 01.8 | +38 31 46 | M4.5V      | Kir91|
| GJ 273 | ·     | 07 27 24.5 | +05 13 33 | M3.5V        | Kir91|
| GJ 283 B | 07 40 20.7 | −17 24 52 | M6.0V      | Hen94|
| GJ 285 | ·     | 07 44 40.2 | +03 33 09 | M4.0V        | Hen94|
| GJ 299 | ·     | 08 11 57.5 | +08 46 28 | M4.0V        | Hen94|
| GJ 300 | ·     | 08 12 40.8 | −23 33 10 | M3.5V        | Hen94|
| GJ 1111 | ·     | 08 29 49.5 | +26 46 37 | M6.5V        | Hen94|
| LHS 2065 | ·     | 08 53 36.0 | −03 29 28 | M9.0V        | Kir91|
| GJ 1116 AB | 08 58 14.9 | +19 45 43 | M5.5V      | Hen94|
| GJ 338 A | 09 14 22.8 | +52 41 12 | M0.0V      | Kir91|
| GJ 338 B | 09 14 24.7 | +52 41 11 | K7.0V      | Kir91|
| GJ 352 AB | 09 31 19.4 | −13 29 19 | M3.0V      | Kir91|
| GJ 380 | ·     | 10 11 22.1 | +49 27 15 | K7.0V        | Kir91|
| GJ 391 | ·     | 10 12 05.0 | −02 41 12 | M2.5V        | Kir91|
| GJ 392 | ·     | 10 12 17.7 | −03 44 44 | M2.0V        | Kir91|
| GJ 393 | ·     | 10 28 55.5 | +00 50 28 | M2.0V        | Hen94|
| LHS 292 | ·     | 10 48 12.6 | −11 20 14 | M6.5V        | Hen94|
| GJ 402 | ·     | 10 50 52.1 | +06 48 29 | M4.0V        | Kir91|
| Name         | Comp. | RA (J2000) | Dec (J2000) | Spectral type | Ref. |
|--------------|-------|------------|-------------|---------------|------|
| GJ 406       |       | 10 56 29.2 | +07 00 53   | M6.0V         | Kir91|
| GJ 411       |       | 11 03 20.2 | +35 58 12   | M2.0V         | Kir91|
| GJ 412       | A     | 11 05 28.6 | +43 31 36   | M1.0V         | Hen94|
| GJ 412       | B     | 11 05 30.4 | +43 31 18   | M5.5V         | Hen94|
| GJ 436       |       | 11 47 41.4 | +26 42 24   | M3.0V         | Kir91|
| GJ 445       |       | 11 47 44.4 | +00 48 16   | M4.0V         | Hen94|
| GJ 1156      |       | 12 19 00.3 | +11 07 31   | M5.0V         | Hen94|
| GJ 436       |       | 11 42 09.0 | +26 42 24   | M3.0V         | Hen94|
| GJ 445       |       | 11 42 09.0 | +26 42 24   | M3.0V         | Hen94|
| GJ 447       |       | 11 47 41.4 | +26 42 24   | M3.0V         | Hen94|
| GJ 1156      |       | 12 19 00.3 | +11 07 31   | M5.0V         | Hen94|
| GJ 473       | AB    | 12 33 17.2 | +09 01 15   | M5.5V         | Hen94|
| GJ 514       |       | 11 47 41.4 | +26 42 24   | M3.0V         | Hen94|
| GJ 526       |       | 11 47 41.4 | +26 42 24   | M3.0V         | Hen94|
| GJ 551       |       | 11 47 41.4 | +26 42 24   | M3.0V         | Hen94|
| GJ 555       |       | 11 47 41.4 | +26 42 24   | M3.0V         | Hen94|
| TVLM 513-46546 |   | 15 01 07.9 | +22 50 02   | M8.5V         | Kir95|
| GJ 570       | BC    | 14 57 26.5 | +22 50 02   | M8.5V         | Kir95|
| GJ 623       | AB    | 16 24 09.3 | +48 21 10   | M2.5V         | Hen94|
| GJ 625       |       | 16 25 24.6 | +54 18 15   | M1.5V         | Hen94|
| GJ 628       |       | 16 30 18.1 | +12 39 45   | M3.0V         | Hen94|
| GJ 644       | ABD   | 16 55 28.8 | +08 20 11   | M2.5V         | Hen94|
| GJ 644       | C     | 16 55 28.8 | +08 20 11   | M2.5V         | Hen94|
| GJ 623       | AB    | 16 24 09.3 | +48 21 10   | M2.5V         | Hen94|
| GJ 625       |       | 16 25 24.6 | +54 18 15   | M1.5V         | Hen94|
| GJ 628       |       | 16 30 18.1 | +12 39 45   | M3.0V         | Hen94|
| GJ 644       | ABD   | 16 55 28.8 | +08 20 11   | M2.5V         | Hen94|
| GJ 644       | C     | 16 55 28.8 | +08 20 11   | M2.5V         | Hen94|
| GJ 623       | AB    | 16 24 09.3 | +48 21 10   | M2.5V         | Hen94|
| GJ 625       |       | 16 25 24.6 | +54 18 15   | M1.5V         | Hen94|
| GJ 628       |       | 16 30 18.1 | +12 39 45   | M3.0V         | Hen94|
| GJ 644       | ABD   | 16 55 28.8 | +08 20 11   | M2.5V         | Hen94|
| GJ 644       | C     | 16 55 28.8 | +08 20 11   | M2.5V         | Hen94|
| GJ 661       | AB    | 17 12 07.9 | +45 39 57   | M3.0V         | Hen94|
| GJ 673       |       | 17 25 45.2 | +02 06 41   | K7.0V         | Hen94|
| GJ 686       |       | 17 37 53.4 | +18 35 30   | M0.0V         | Hen94|
| GJ 687       |       | 17 36 25.9 | +68 20 21   | M3.0V         | Hen94|
| GJ 699       |       | 17 57 48.5 | +04 41 36   | M4.0V         | Kir91|
| GJ 701       |       | 18 05 07.6 | +03 01 53   | M0.0V         | Hen94|
| GJ 725       | A     | 18 42 46.7 | +59 37 49   | M3.0V         | Kir91|
| GJ 725       | B     | 18 42 46.9 | +59 37 37   | M3.5V         | Kir91|
| GJ 729       |       | 18 49 49.4 | +23 50 10   | M3.5V         | Hen94|
| GJ 752       | A     | 19 16 55.3 | +05 10 08   | M3.0V         | Kir91|
| GJ 752       | B     | 19 16 58.3 | +05 09 11   | M8.0V         | Kir91|
| GJ 725       | AC    | 19 53 54.2 | +44 24 15   | M5.5V         | Kir91|
| GJ 725       | B     | 19 53 55.2 | +44 24 56   | M6.0V         | Kir91|
| GJ 791.2     | AB    | 20 29 48.0 | +09 41 23   | M4.5V         | Kir91|
| GJ 809       |       | 20 53 19.8 | +62 09 16   | M0.0V         | Hen94|
| GJ 820       | A     | 21 06 53.9 | +38 44 58   | K5.0V         | Kir91|
| GJ 820       | B     | 21 06 55.3 | +38 44 31   | K7.0V         | Kir91|
| GJ 829       | AB    | 21 29 36.8 | +17 38 36   | M3.5V         | Hen94|
| GJ 831       | ABC   | 21 31 18.9 | +09 47 22   | M4.5V         | Hen94|
| Name      | Comp. | RA (J2000) | Dec (J2000) | Spectral type | Ref.   |
|-----------|-------|------------|-------------|---------------|--------|
| GJ 846    | ·     | 22 02 09.0 | +01 23 54   | M0.5V         | Kir91  |
| GJ 860 A  | 22 27 59.5 | +57 41 45 | M3.0V       | Hen94         |
| GJ 860 B  | 22 27 59.5 | +57 41 45 | M4.0V       | Hen94         |
| GJ 866    | ABC   | 22 38 33.4 | −15 19 07   | M5.0VJ        | Kir91  |
| GJ 873    | ·     | 22 46 49.7 | +44 20 02   | M3.5V         | Hen94  |
| GJ 876    | Ap*   | 22 53 16.7 | −14 15 49   | M3.5VJ        | Hen94  |
| GJ 880    | ·     | 22 56 34.8 | +16 33 12   | M1.5V         | Hen94  |
| GJ 896 AC | 23 31 52.2 | +19 56 14 | M3.5VJ      | Hen94         |
| GJ 896 BD | 23 31 52.2 | +19 56 14 | M4.5VJ      | Hen94         |
| GJ 1286   | ·     | 23 35 10.7 | −02 23 25   | M5.5V         | Hen94  |
| GJ 905    | ·     | 23 41 54.7 | +44 10 30   | M5.5V         | Hen94  |
| GJ 908    | ·     | 23 49 12.5 | +02 24 04   | M1.0V         | Hen94  |

*p indicates probable planetary companion(s)

references: Hen92, Hen94, Hen97, Hen99 = Henry et al. 1992, 1994, 1997, 1999; Kir91, Kir95, Kir97 = Kirkpatrick et al. 1991, 1995, 1997, McC91 = McCarthy et al. 1991
Table 3. Sample stars

| Name    | RA (J2000) | Dec (J2000) | $\mu$ | $\theta$ | $U_J$ | $B_J$ | $V_J$ | $R_C$ | $I_C$ | Ref.                  | Previous Ref. | Adopted Spec Type | Exposure (sec) | Known dist (pc) | Estimated dist (pc) |
|---------|------------|-------------|-------|----------|-------|-------|-------|-------|-------|----------------------|----------------|--------------------|-----------------|------------------|-------------------|
| HIP 14555 | 03 07 55.7 | −28 13 11   | 0.360 | 250.6    | ⋯     | ⋯     | 10.21 | ⋯     | ⋯     | HIP97                 | ⋯              | M1.0V              | 90              | 19.1 H           | 12.9              |
| HIP 20965 | 04 29 43.4 | −29 01 47   | 0.045 | 223.8    | ⋯     | ⋯     | 7.73  | ⋯     | ⋯     | HIP97                 | KIII/IV SIMBAD | giant+             | 10              | >100 H           | ⋯                 |
| GJ 2036 A | 04 53 31.2 | −55 51 37   | 0.130 | 059.0    | 13.78 | 12.70 | 11.13 | ⋯     | ⋯     | GJ79                  | M2.0V          | M2.0V              | 60              | 11.2 H           | 7.8               |
| GJ 2036 B | 04 53 31.2 | −55 51 37   | 0.130 | 059.0    | 15.03 | 13.75 | 12.15 | ⋯     | ⋯     | GJ79                  | M3.5V          | Haw96              | 60              | 11.2 H           | 6.9               |
| LHS 1731 | 05 03 20.1 | −17 22 25   | 0.512 | 209.0    | ⋯     | 13.32 | 11.69 | 10.56 | 9.15  | We96                  | M3.0V          | M3.0V              | 1560            | 9.3 H            | 10.1              |
| GJ 190   | 05 08 35.0 | −18 10 19   | 1.376 | 156.6    | 12.86 | 11.84 | 10.32 | 9.17  | 7.67  | Bes90,Leg92           | M3.5V          | Rei95              | 420             | 9.3 YH           | 10.8              |
| GJ 203   | 05 28 00.2 | +09 38 38   | 0.783 | 195.1    | 15.33 | 14.12 | 12.49 | 11.29 | 9.80  | Bes90,GJ91            | M3.5V          | Rei95              | 1200,135        | 9.7 YH           | 10.8              |
| GJ 239   | 06 37 10.8 | +17 33 53   | 0.885 | 293.4    | 12.27 | 11.14 | 9.64  | 8.72  | 7.75  | We96,Leg92            | K7.0V          | Rei95              | 300,35          | 9.5 YH           | 13.7              |
| GJ 1125 | 09 30 44.6 | +00 19 22   | 0.760 | 229.0    | 14.52 | 13.27 | 11.72 | 10.58 | 9.13  | We96,GJ91             | M3.5V          | Rei95              | 30              | 9.9 YH           | 10.3              |
| GJ 358   | 09 39 46.4 | −41 04 03   | 0.663 | 305.0    | 13.32 | 12.21 | 10.72 | 9.64  | 8.29  | Leg92                 | M2.0V          | Haw96              | 600,22          | 9.5 YH           | 6.5                |
| GJ 432 A | 11 34 30.5 | −32 50 01   | 1.063 | 320.3    | ⋯     | ⋯     | ⋯     | ⋯     | ⋯     | DC SIMBAD             | DC/DQ          | SIMBAD             | 600             | 9.5 YH           | ⋯                 |
| GJ 433 AB| 11 35 26.9 | −32 32 24   | 0.780 | 186.0    | 12.51 | 11.36 | 9.84  | 8.84  | 7.69  | Bes90,GJ91            | M1.5V          | Haw96              | 420,20          | 9.1 YH           | 4.1                |
| GJ 442 B | 11 46 32.5 | −40 29 47   | 1.592 | 284.4    | ⋯     | ⋯     | ⋯     | ⋯     | ⋯     | M4.0V                 | M4.0V          | Haw96              | 480             | 9.2 YH           | ⋯                 |
| GJ 480.1 | 12 40 46.3 | −43 33 59   | 1.047 | 311.7    | 15.36 | 13.97 | 12.24 | 11.07 | 9.63  | Bes90,GJ91            | M3.0V          | Haw96              | 120             | 7.8 YH           | 13.1              |

Stars with trigonometric parallaxes

| Name    | RA (J2000) | Dec (J2000) | $\mu$ | $\theta$ | $U_J$ | $B_J$ | $V_J$ | $R_C$ | $I_C$ | Ref.                  | Previous Ref. | Adopted Spec Type | Exposure (sec) | Known dist (pc) | Estimated dist (pc) |
|---------|------------|-------------|-------|----------|-------|-------|-------|-------|-------|----------------------|----------------|--------------------|-----------------|------------------|-------------------|
| WT 60   | 01 51 59.7 | −57 47 58   | 0.652 | 212.2    | ⋯     | ⋯     | ⋯     | ⋯     | ⋯     | ⋯                    | ⋯              | M4.0V              | 600             | ⋯                | ⋯                 |
| WT 84   | 02 17 27.9 | −59 22 43   | 0.559 | 212.6    | ⋯     | ⋯     | 15.88 | 14.29 | 12.28 | Pat98                | ⋯              | M5.5V              | 600             | ⋯                | 13.1              |
| WT 1356 | 03 13 19.7 | −16 38 47   | 0.682 | 235.4    | ⋯     | ⋯     | ⋯     | ⋯     | ⋯     | ⋯                    | ⋯              | M4.5V              | 600             | ⋯                | ⋯                 |
Table 3—Continued

| Name        | RA (J2000) | Dec (J2000) | \(\mu\) | \(\theta\) | \(U_J\) | \(B_J\) | \(V_J\) | \(R_C\) | \(I_C\) | Ref. Previous Spec Type | Adopted Spec Type | Exposure (sec) | Known dist (pc) | Estimated dist (pc) |
|-------------|------------|-------------|--------|---------|--------|--------|--------|--------|--------|----------------------|------------------|-----------------|-----------------|-------------------|
| HIP 15689   | 03 22 05.5 | −13 16 44   | unknown\(^a\) | 12.08   | 12.04  | 11.54  | ·      | ·      | ·      | ·       | Sin96             | ·                | 140             | ·               | ·                 |
| WT 133      | 04 02 13.9 | −43 25 26   | 0.561 175.5 | ·        | 16.09  | 14.71  | 13.00  | ·      | ·      | this paper          | ·                | 600             | ·               | 30.2              |
| WT 135      | 04 11 27.1 | −44 18 09   | 0.689 066.7 | ·        | ·      | ·      | ·      | ·      | ·      | ·                   | ·                | 420             | ·               | ·                 |
| HIP 20968   | 04 29 44.9 | −29 01 37   | unknown\(^a\) | ·        | 11.42  | ·      | ·      | ·      | ·      | HIP97              | ·                | ·               | ·               | ·                 |
| WT 207      | 07 02 36.6 | −40 06 29   | 0.624 105.3 | ·        | 15.08  | 13.91  | 12.31  | ·      | ·      | Pat98               | ·                | 600             | ·               | 26.5              |
| WT 214      | 07 28 40.1 | −61 20 41   | 0.626 319.5 | ·        | 16.06  | 14.80  | 13.17  | ·      | ·      | Pat98               | ·                | 600             | ·               | 41.7              |
| WT 233      | 07 56 13.7 | −67 05 19   | 0.792 325.2 | ·        | 16.23  | 15.34  | 14.44  | ·      | ·      | this paper          | ·                | 600             | ·               | 284.4             |
| LHS 1957    | 07 57 00.2 | −45 37 23   | 0.666 341.6 | ·        | ·      | ·      | ·      | ·      | ·      | ·                   | ·                | ·               | ·               | ·                 |
| GJ 1123     | 09 16 45.0 | −77 49 42   | 1.023 139.3 | 15.89   | 14.74  | 13.10  | ·      | ·      | ·      | GJ91                | M4.5V            | ·               | 7.6             | ·                 |
| GJ 1128     | 09 42 53.0 | −68 54 06   | 1.057 348.0 | 15.73   | 14.51  | 12.78  | ·      | ·      | ·      | GJ91                | M4.5V            | ·               | 6.6             | ·                 |
| WT 244      | 09 44 28.6 | −73 58 39   | 0.524 256.9 | ·        | 15.24  | 13.85  | 12.07  | ·      | ·      | Pat98               | ·                | 600             | 20.4            | ·                 |
| GJ 1129     | 09 44 48.0 | −18 12 48   | 1.633 264.0 | 15.47   | 14.19  | 12.60  | ·      | ·      | ·      | GJ91                | M4.0V            | ·               | 11.6            | ·                 |
| WT 248      | 10 05 54.9 | −67 21 31   | 1.197 264.5 | 14.51   | 13.43  | 12.02  | ·      | ·      | ·      | Pat98               | ·                | ·               | 37.2            | ·                 |
| WT 1759     | 10 12 01.9 | −18 43 34   | 0.508 264.8 | ·        | 15.44  | 15.20  | 14.97  | ·      | ·      | this paper          | ·                | 600             | 28.3\(^b\)      | ·                 |
| WT 1760     | 10 12 06.2 | −28 51 38   | 0.505 144.8 | ·        | 16.19  | 14.84  | 13.14  | ·      | ·      | this paper          | ·                | 600             | 44.3            | ·                 |
| ESO 440-064 | 11 48 48.5 | −28 33 27   | 0.710 260.0 | ·        | 14.88  | 12.97  | ·      | ·      | ·      | this paper          | M6.4V            | ·               | ·               | ·                 |
| ESO 440-139 | 12 03 27.5 | −29 22 49   | 0.310 316.0 | ·        | 15.19  | ·      | ·      | ·      | ·      | Rui95               | M5.5V            | ·               | 20.0            | ·                 |

\(^a\)The Hipparcos proper motions have enormous errors, probably caused by the effects of nearby bright stars.

\(^b\)Distance derived by comparison to the white dwarf standard, GJ 440.

References: Bes90 = Bessell 1990; GJ79, GJ91 = Gliese & Jahreiß 1979, 1991; Haw96 = Hawley et al. 1996; HIP97 = ESA 1997; Leg92 = Leggett 1992; Pat98 = Patterson et al. 1998; Rei95 = Reid et al. 1995; Rui95 = Ruiz et al. 1995; SIMBAD = SIMBAD database, operated at CDS, Strasbourg, France; Sin96 = Sinachopoulos & van Dessel 1996; Wei96 = Weis 1996.
Normalized Flux ($F_\lambda$) vs. Wavelength (Å)

- GJ 440 (DQ)
- WT 1759 (DC/DQ)
- GJ 432B (DC/DQ)
- HIP 15689 (giant+)
- HIP 20968 (giant+)
- HIP 20965 (giant+)

Wavelength (Å)